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Assessment of Eastern Georges Bank Atlantic Cod for 2011

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ABSTRACT

Combined Canada/USA catches averaged 17,208 mt between 1978 and 1993, declined to 1,683 mt in 1995, then fluctuated around 3,000 mt until 2004 and subsequently declined again. Catches in 2010 were 1,326 mt, including 221 mt of discards. Canadian and USA catches were 840 mt and 486 mt in 2010, respectively.

Two alternative VPA model formulations, “split M 0.2” and “split M 0.5”, were used in the assessment.

Adult population biomass (ages 3+) declined from about 50,000 mt in 1990 to below 10,000 mt in 1995. Since 1995, adult population biomass from the “split M 0.2” model has fluctuated between 3,100 mt and 10,100 mt; from the “split M 0.5” model it has fluctuated between 4,200 mt and 12,600 mt. Biomass at the beginning of 2011 was 3,288 mt from the “split M 0.2” model and 5,088 mt from the “split M 0.5” model, the second lowest in the time series from both models.

The 2003 year class was the highest recruitment observed since 2000, but was less than half of the average (about 10 million) during 1978-1990, when productivity was considered to be higher. The 2002 and 2004 year classes were the two lowest on record. Initial indications were that the 2007, 2008, and 2009 year classes were less than 2 million. Recruitment indices from the bottom trawl surveys for the 2010 year class were higher than those for recent year classes.

Fishing mortality (F_{4-9}) was high prior to 1994. F declined in 1995 to 0.36 for the “split M 0.2” model and to 0.24 for the “split M 0.5” model due to restrictive management measures. F in 2010 was estimated to be 0.41 from the “split M 0.2” model and 0.25 from the “split M 0.5” model. F has been consistently above F_{ref} = 0.18 for both model formulations since the beginning of the time series (1978).

Assuming a 2011 catch equal to the 1,050 mt total quota, a combined 2012 Canada/USA catch of about 600 mt (“split M 0.2” model) and 925 mt (“split M 0.5” model) will result in a neutral risk (50%) that the fishing mortality rate in 2012 will exceed F_{ref}. A catch of 1,350 mt (“split M 0.2” model) and 900 mt (“split M 0.5” model) will result in a neutral risk (50%) that the 2013 adult biomass (ages 4+) will be lower than 2012. A catch of about 1,000 mt (“split M 0.2” model) and 300 mt (“split M 0.5” model) will result in a neutral risk (50%) that 2013 adult biomass will not increase by 10% from 2012. A catch of 650 mt will result in a neutral risk (50%) that 2013 adult biomass will not increase by 20% from the “split M 0.2” model, but even with no catch, there is more than a 50% probability that biomass will not increase by 20% from the “split M 0.5” model.

RÉSUMÉ

Les captures combinées du Canada et des États-Unis, qui étaient en moyenne d'environ 17 208 tm entre 1978 et 1993, sont tombées à 1 683 tm en 1995, puis ont fluctué alentour de 3 000 tm jusqu'en 2004, avant de décliner à nouveau. Les captures totales de 2010 se chiffraient à 1 326 tm, dont 211 tm de rejets, soit 840 tm pour le Canada et 486 tm pour les États-Unis

Deux formes d'APV ont été utilisées dans l'évaluation : un « modèle fractionné M = 0,2 » et un « modèle fractionné M = 0,5 ».

La biomasse de la population adulte (âges 3 +) a diminué, passant d'environ 50 000 tm en 1990 à moins de 10 000 tm en 1995. Depuis 1995, la biomasse de la population adulte a fluctué entre 3 100 tm et 10 100 tm selon le « modèle fractionné M = 0,2 » et entre 4 200 tm et 12 600 tm selon le « modèle fractionné M = 0,5 ». Elle se chiffrait au début de 2011 à 3 288 tm selon le « modèle fractionné M = 0,2 » et à 5 088 tm selon le selon le « modèle fractionné M = 0,5 », ce qui la situait à l'avant-dernier rang de ses valeurs les plus basses selon les deux modèles.

La classe d'âge 2003 a représenté le plus fort recrutement observé depuis 2000, mais elle n'atteignait pas la moitié de la moyenne (environ 10 millions de poissons) de 1978-1990, période où la productivité était considérée comme plus élevée. Les classes d'âge 2002 et 2004 étaient les plus faibles observées à ce jour. D'après les indications initiales, l'effectif des classes d'âge 2007, 2008 et 2009 était inférieur à 2 millions de poissons. Pour ce qui est de la classe d'âge 2010, les indices de recrutement provenant des relevés au chalut de fond étaient supérieurs à ceux des récentes classes d'âge.

La mortalité par pêche (F_{4-9}) était élevée avant 1994. F a diminué en 1995 à 0,36 selon le « modèle fractionné M = 0,2 » et à 0,24 selon le « modèle fractionné M = 0,5 », en raison de mesures de gestion strictes. En 2010, F a été estimée à 0,41 d'après le « modèle M = 0,2 » et à 0,25 d'après le « modèle fractionné M = 0,5 ». F a été constamment supérieure à $F_{réf.}$ = 0,18, selon les deux modèles, depuis le début de la série chronologique (1978).

Si les captures sont égales au quota total de 1 050 tm en 2011, des captures combinées du Canada et des États-Unis qui seraient en 2012 de 600 tm (« modèle fractionné M = 0,2 ») et de 925 tm (« modèle fractionné M = 0,5 ») se traduiraient par un risque neutre (50 %) que le taux de mortalité par pêche dépasse $F_{réf.}$ cette année-là. Des captures de 1 350 tm (« modèle fractionné M = 0,2 ») et de 900 tm (« modèle fractionné M = 0,5 ») se solderaient par un risque neutre (50 %) que la biomasse des adultes (âges 4 +) en 2013 soit inférieure à celle de 2012. Des captures d'environ 1 000 tm (« modèle fractionné M = 0,2 ») et 300 tm (« modèle fractionné M = 0,5 ») se traduiraient par un risque neutre (50 %) que la biomasse des adultes en 2013 n'augmente pas de 10 % par rapport à 2012. Des captures de 650 tm correspondraient à un risque neutre (50 %) que la biomasse des adultes en 2013 n'augmente pas de 20 %, selon le « modèle fractionné M = 0,2 », mais même en l'absence de captures, il y a plus de 50 % de probabilité que la biomasse des poissons n'augmente pas de 20 %, selon le « modèle fractionné M = 0,5 ».

INTRODUCTION

The basis and background for the delineation of management units of cod on Georges Bank and the vicinity were reviewed and summarized at the 2009 Eastern Georges Bank cod benchmark assessment meeting (O'Brien and Worcester, 2009). For the purpose of a sharing agreement and consistent management by Canada and the USA, agreement was reached that the transboundary management unit for Atlantic cod would be limited to the eastern portion of Georges Bank (DFO Statistical Unit Areas 5Zej and 5Zem; USA Statistical Areas 551, 552, 561 and 562)) (DFO, 2002). The management area is shown in Figure 1. The USA has a requirement for management advice for the Georges Bank cod stock (5Z + SubArea 6). The status quo has been to use an assessment of cod in 5Zjm for transboundary management advice and an assessment of cod in 5Z+6 for USA domestic management advice. While other options could be followed, this option is less disruptive to the existing processes. This approach requires concurrent assessment reviews of 5Zjm and of 5Z+6 to harmonize results.

The model formulation established by the 2002 Eastern Georges Bank cod benchmark assessment (O'Boyle and Overholtz, 2002) was used for the eastern Georges Bank cod assessment from 2002 to 2008. In recent assessments the results exhibited a domed catchability pattern by age in both the DFO and NMFS spring surveys, and the descending limb of the fishery partial recruitment became increasingly steep for older ages. The resulting assessment generated appreciable 'cryptic' biomass that could not be observed by either the fishery or the surveys. An examination of the implications of eliminating the first quarter fishery indicated that the magnitude of those removals was not large enough to appreciably alter the annual size composition. Therefore, a marked change in fishery partial recruitment after the mid 1990s, a key feature of the 2002 benchmark model formulation, was not supported. An Eastern Georges Bank cod benchmark assessment was conducted in 2009 to address these concerns and the details of the model formulations that were agreed upon were documented in Wang et al. (2009a).

The current assessment applied the 2009 benchmark formulations using Canadian and USA fishery information updated to 2010 including commercial landings and discards, the Fisheries and Oceans Canada (DFO) survey updated to 2011, the National Marine Fisheries Services (NMFS) spring survey updated to 2011 and the NMFS fall survey updated to 2010.

FISHERY

Commercial Fishery Catches

Historical catch data were updated at the 2009 benchmark meeting (Wang et al., 2009a). For the 2010 assessment, the USA landings for 2007-2009 were re-estimated due to auditing of the commercial landings database that included changes in area designation of landings. The effect on the total eastern Georges Bank cod landings was minimal: a 9% increase in 2007, a 3% decrease in 2008 and less than a 1% increase in 2009. Combined Canada/USA catches averaged 17,208 mt between 1978 and 1993, peaking at 26,464 mt in 1982, and then declined to 1,683 mt in 1995. They fluctuated around 3,000 mt until 2004 and subsequently declined again. Catches in 2010 were 1,326 mt, including 221 mt of discards (Table 1, Figure 2). Catches include USA and Canadian discards in all years where discard estimates were available.

Canadian catches peaked at 17,898 mt in 1982 and declined to 1,140 mt in 1995 (Table 1, Figure 3). Since 1995, with lower cod quotas, the fishery has reduced targeting for cod through changes in fishing practices, including the introduction of the cod separator panel for bottom

trawls in 1999 (Table 2). From 1995-2009, Canadian catches fluctuated between 859 mt and 3,405 mt (Table 1). In 2010, total catch including discards were 840 mt against a quota of 1,012 mt, taken primarily between June and December by otter trawl and longline (Table 3, Figure 4 and 5). All 2010 landings were subject to dockside monitoring and at sea observers monitored close to 18% by weight of the mobile gear fleet landings (16% of trips), 6% by weight of the fixed gear landings (8% of trips) and 10% of the gillnet fleet landings (11% of trips).

Canadian regulations prohibit the discarding of undersized fish from the groundfish fishery. The ratio of sums method, which uses the difference in ratio of cod to haddock from observed and unobserved trips, was applied to estimate discards of cod. Discards from the Canadian groundfish fishery were estimated for 1997 to 1999 (Van Eeckhaute and Gavaris, 2004) and for 2005 and 2006 (Gavaris et al., 2006, 2007b) (Table 1). In 2007, no discards were attributed to the mobile gear fleet because of the high observer coverage (99%) and discards for the fixed gear fleet could not be calculated because of the low observer coverage but were assumed to be negligible as discards had not been detected in previous years (Clark et al., 2008). Discards were calculated for both fleets in the 2009 and 2010 assessments (Wang et al., 2009b, Clark et al., 2010). Cod discards from the 2010 Canadian groundfish fishery were estimated at 48 mt from the mobile gear fleet (Table 1, Appendix A).

Since 1996, the Canadian scallop fishery has not been permitted to land cod. Landings until 1995 included those landings reported by the scallop fishery. Estimated discards of cod by the Canadian scallop fishery ranged up to 200 mt annually since 1978 (Van Eeckhaute et al., 2005). The 3-month moving average observed discards rate has been applied to scallop effort to estimate discards from scallop fishery since 2005 (Gavaris et al., 2007a). In 2010, estimated discards of cod by the Canadian scallop fishery were 44 mt (Van Eeckhuate et al., 2011, Table 1).

USA catches increased from 5,502 mt in 1978 to 10,550 mt in 1984, then declined and fluctuated around 6,000 mt between 1985 and 1993 (Table 1, Figure 3). Since December 1994, a year-round closure of Area II (Figure 1) has been in effect, with the exception of a Special Access Program in 2004 and 2010. Minimum mesh size limits were increased in 1994, 1999 and in 2002. Quotas were introduced in May 2004. Limits on sea days, as well as trip limits, have also been implemented (Table 2). With the implementation of a catch share system in 2010, most of the fleets are now managed by quotas. USA catches during 1994-2000 ranged between 544 mt and 1,207 mt and increased to 1,955 mt in 2003. In 2009, USA landings increased to 433 mt, the highest landings since 2004. Landings then declined to 357 mt in 2010. The majority of USA landings are usually taken in the second calendar quarter with the least amount landed during the third quarter (Figure 5). Otter trawl accounted for 76% and longline gear about 23% of the landings, with the remainder taken by gillnet and other unknown gears during 2010. Total USA catch (landings and discards combined) was 486 mt for calendar year 2010.

Discards by USA groundfish fleets occur because of trip limits and minimum size restrictions. In September 2008, the 'Ruhle trawl', which reduces by-catch of cod, was authorized for use on eastern Georges Bank. Cod discarded in the eastern Georges Bank area by otter trawl and scallop fisheries were estimated using the NEFSC observer data from 1989-2010. A ratio of discarded cod to total kept weight of all species (d:k) was estimated on a trip basis. Total discards (mt) were estimated from the product of d:k and total commercial landings. The estimated discards of cod in the groundfish fishery were 129 mt in 2010, a decrease from 194 mt discarded in 2009 (Table 1, Figure 3). Otter trawl gear accounted for almost all of the 2010 discarded fish (128.8 mt) with scallop gear accounting for the remainder. Observers noted that the majority of fish (60%) were discarded because of minimum size restrictions, culling for a

better price when a trip quota was in effect (20%) and because there was no market for small fish (11%).

Size and Age Composition

The size and age compositions of the 2010 landings by the Canadian groundfish fishery were derived from port and at-sea samples from all principal gears and seasons (Table 4, Figure 6). There were representative samples from the mobile gear fishery over all the fishing months. For the fixed gear fleet, except in the second quarter when landings were low, the samples spread representatively over the fishing months. Comparison of port and at-sea length frequencies did not indicate any discrepancies for otter trawlers. Fixed gear observer samples tended to have more small fish than the port samples, especially in September, indicating that discarding might have occurred (Figure 7). However, discarding could not be inferred using the ratio of sums method, perhaps because of the low observer coverage. At-sea samples were pooled with port samples to derive catch at length and age. Landings peaked at 58 cm (23 in) for bottom trawlers and 58 to 64 cm (23 to 25 in) for longliners. Gillnetters caught fewer cod but these fish were larger, peaking at 70 cm (28 in) (Figure 8). The gear-combined landings peaked at 58 cm (23 in) (Figure 9).The size composition of cod discards from the 2010 Canadian scallop fishery was derived from at-sea sampling. Cod discards from the scallop fishery peaked at 55 cm (22 in) (Figure 8). The discards from otter trawlers were assumed to have the same size composition as the landings from the otter trawl fishery. The Canadian combined cod discards in 2010 from otter trawl and scallop fishery peaked at 58 cm (23 in) (Figure 9).

The size and age compositions of the 2010 USA fishery landings on eastern Georges Bank were estimated using port samples of length frequencies and age structures collected from all principal gears and seasons by market category (Table 4). The size frequencies and age composition of discarded fish were estimated using at-sea observer samples of length frequency and commercial and NEFSC survey age-length keys from the same area and season. Landings in 2010 peaked at 65 cm (25.6 in) and discards peaked at 53 cm (21 in) (Figure 10).

The catch composition, combined landings and discards for Canada and the USA, is shown in Figure 11. Canadian and USA catches peaked at similar lengths (Canada: 58 cm (22 in); USA: 56-65 cm (22 to 26 in)), but USA catches contained proportionally more small fish than Canadian catches.

Otoliths taken from port and at-sea observer samples were used for age determinations. Comparisons have indicated good agreement between DFO and NMFS age readers (Table 5).

Canadian catch-at-age composition was obtained by applying quarterly fishery age-length keys to the size composition. The age-length key from the 2010 DFO survey was used to augment the first quarter key.

The age composition of the re-estimated 2007-2009 and the 2010 USA landings was estimated by market category by applying age-length keys to the size composition pooled by calendar quarter, semi-annually, or annually depending on the number of available length samples. Based on the USA sampling protocol, 1 sample per 100 mt of landings (i.e. where 1 length sample=100 fish and 1 age sample=20-25 fish), the age sampling of eastern Georges Bank cod landings was sufficient during 2007-2010 so there was no need to supplement the NEFSC age data with DFO age data as had been done in previous years. Discards at age from the USA groundfish and scallop fisheries (1989-2010), the Canadian groundfish fishery (1997-2010) and the Canadian scallop fishery (1978-2010) were included in the assessment.

The combined Canada/USA 2010 fishery age composition by number was dominated by the 2006 year class at age 4 (44%), followed by the 2007 year class at age 3 (23%) and the 2005 year class at age 5 (15%) (Table 6, Figure 12). The 2003 year class at age 7 continued to make some contribution to the 2010 catch (7%). By weight, the 2006 year class still dominated the 2010 fishery (41%) followed by the 2005 (19%) and 2007 year classes (17%) (Figure 12). The contribution to the catch of ages 7 and older continued to be small in recent years (Table 6, Figure 12), 8% by number (1% from 8+) and 17% by weight in 2010, even with the inclusion of age 7 fish from the stronger 2003 year class (Table 6, Figure 12 and 13).

Fishery weights at age showed a declining trend starting in the early 1990s (Table 7, Figure 14). In 2010, the weight at age decreased for all ages except for age 3 from 2009.

ABUNDANCE INDICES

Research Surveys

Surveys of Georges Bank have been conducted by DFO each year (February/March) since 1986 and by NMFS each fall (October) since 1963 and each spring (April) since 1968. All surveys use a stratified random design (Figures 15 and 16). Most of the DFO surveys have been conducted by the *CCGS Alfred Needler*. A sister ship, the *CCGS Wilfred Templeman*, conducted the survey in 1993, 2004, 2007 and 2008, and another vessel, the *CCGS Teleost*, conducted 6 of the sets in 2006. No conversion factors were applied. For the NMFS surveys, two vessels have been employed and there was a change in the trawl door in 1985. Vessel and door type conversion factors derived experimentally from comparative fishing (Table 8) 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 from 1973-81 and a Yankee 36 in other years, but no net conversion factors were available for cod. A new net and vessel (*FSV Henry B. Bigelow*), with revised station protocols have been used to conduct the NMFS spring and fall surveys since 2009. Calibration factors by length were calculated for Atlantic cod for the data collected by the *FSV Henry B Bigelow* to make the data equivalent to previous surveys conducted by *FRV Albatross IV*. The new research vessel/net combination tended to catch more cod at all lengths, but also proportionally more small cod. The calibration factors at length applied to the 2009, 2010 and 2011 NMFS spring survey and 2009 and 2010 NMFS fall survey are shown in Table 9 (Brooks et al. 2010).

The spatial distribution of ages 3 and older cod caught during the 2011 DFO survey was similar to those observed from surveys over the previous decade, with most fish concentrated on the northeastern part of Georges Bank (Figure 17). Total catch in numbers in the 2011 DFO survey was low, less than half of the 2010 survey (Table 10). The 2003 year class at age 8 accounted for 3% by number from this survey. The 2006 year class was still prominent in the 2011 survey (33% by number), consistent with the previous years' survey results (30% and 43% by number in 2009 and 2010, respectively). The 2007 year class at age 4 looked moderate from this survey (24% by number). Initial indication of the 2010 year class at age 1 was promising in the 2011 DFO survey (5% by number), the strongest since the 2003 year class (Table 10, Figure 20).

With the calculation of the calibration factors for cod (Table 9), the 2011 NMFS spring survey distribution of age 3+ cod showed a similar distribution pattern relative to the previous decade (Figure 18). The 2011 spring survey total catch in numbers, however, was the second lowest in the time series (Table 11). The 2003 year class at age 8 was only 3% by number from this survey. The 2006 year class did not appear particularly strong in the 2011 NMFS spring survey

(16% by number) although it was dominant in the 2009 and 2010 NMFS spring survey (41% and 43% by number). The 2007 year class at age 4 was moderate (29% by number) and the 2010 year class at age 1 accounted for 10% by number in the 2011 survey (Table 11, Figure 20).

The distribution of age 3+ cod from the 2010 NMFS fall survey was similar to the average distribution in the last decade of surveys (Table 12, Figure 19). There was a large tow on the northeastern part of Georges Bank, in which the 2010 year class at age 0 was dominant (41 age 0 fish out of a total of 52 fish caught in the tow). Compared to the 2009 survey, the total catch in numbers of ages 1+ was low in 2010. The 2006 year class at age 4 accounted for the largest catch by number at 38% (Table 12, Figure 20).

With the exception of the 2003 and 2006 year classes and potentially 2010 year class, the survey abundance at age (Tables 10-12, Figure 20) shows poor recruitment since the 1990 year class in all 3 surveys. The 2003 year class appears strong in the spring surveys until age 7 and in the fall surveys until age 3. The 2006 year class appears prominent in the surveys, but not as strong as the 2003 year class. Initial indications for the 2010 year class are promising from the 2011 DFO and 2010 NMFS fall surveys. Compared with pre-1990 surveys, representation at older ages and younger ages in recent years continues to be poor (Figure 20).

Biomass indices at age were calculated by applying weight at age to the abundance indices at age. The survey biomasses in 2011 for all 3 surveys are lower than 2010, and the NMFS spring survey is the second lowest in the time series (Figure 21). Survey biomass indices have been lower since the mid-1990s, and continue to decline for all ages (Figure 22).

The average weights at age derived from the DFO survey and NMFS spring survey were used to represent the population weight at age for the beginning of the year. All weights at age display a declining trend since the early 1990s (Table 13, Figure 23). Except for age 6, the weights at age for all other ages in 2011 were lower than 2010 surveys. Fulton's K, an indicator which uses weight-length relationship to measure fish condition, was calculated from the DFO survey data. It showed notable downward trends for all the ages in recent years (Figure 24).

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, $F_{ref} = 0.18$ (TMGC meeting in December, 2002). When stock conditions are poor, fishing mortality rates should be further reduced to promote rebuilding.

ESTIMATION AND DIAGNOSTICS

Calibration of Virtural Population Analysis (VPA)

Evaluation of the state of the resource was based on results from an age structured analytical assessment (Virtual Population Analysis, VPA), which used fishery catch statistics and sampling for size and age composition of the catch from 1978 to 2010 (including discards). The VPA was calibrated to trends in abundance from three research bottom trawl survey series: NMFS spring, NMFS fall and DFO.

Two consensus VPA model formulations were established during the benchmark assessment review in 2009 (O'Brien and Worcester, 2009; Wang et al., 2009a). The survey abundance indices were split in 1993-1994 for both model formulations. Natural mortality (M) was fixed at 0.2 for all the ages in all years for the "split M 0.2" model and was fixed at 0.5 for ages 6+ in years after 1994 for the "split M 0.5" model. These model formulations will be referred to as "split M 0.2" and "split M 0.5" model in this document. The adaptive framework, ADAPT, (Gavaris 1988) was used for calibrating the virtual population analysis with the research survey data for both the "split M 0.2" and "split M 0.5" formulations. Computational formulae used in ADAPT are described by Rivard and Gavaris (2003a). The data used in the model were:

$C_{a,t}$ = catch at age for ages a = 1 to 10+ and time t = 1978 to 2010, where t represents the year during which the catch was taken

$I_{1,a,t}$ = DFO survey for ages a = 1 to 8 and time t = 1986.17, 1987.17… 1992.17, 1993.17

$I_{2,a,t}$ = DFO survey for ages a = 1 to 8 and time t = 1994.17, 1995.17… 2010.17, 2011.00

$I_{3,a,t}$ = NMFS spring survey (Yankee 41) for ages a = 1 to 8 and time t = 1978.28, 1979.28, 1980.28, 1981.28

$I_{4,,a,t}$ = NMFS spring survey (Yankee 36), for ages a = 1 to 8 and time t = 1982.28, 1983.28… 1992.28, 1993.28

$I_{5,a,t}$ = NMFS spring survey (Yankee 36), for ages a = 1 to 8 and time t = 1994.28, 1995.28… 2010.28, 2011.00

$I_{6,a,t}$ = NMFS fall survey, ages a = 1 to 5 and time t = 1978.79, 1979.79… 1992.79, 1993.79

$I_{7,a,t}$ = NMFS fall survey, ages a = 1 to 5 and time t = 1994.79, 1995.79… 2009.79, 2010.79.

The population was calculated to the beginning of 2011; therefore the DFO and NMFS spring survey indices for 2011 were designated as occurring at the beginning of the year, i.e. 2011.00. The benchmark formulations assumed that observation errors for the catch at age data were negligible. Observation errors for the abundance indices at age were assumed to be independent and identically distributed after taking natural logarithms of the values. Zero observations for abundance indices were treated as missing data as the logarithm of zero is not defined. Fishing mortality on age 9 for 1978 to 2010 was assumed to be equal to the population weighted average fishing mortality on ages 7 and 8.

Estimation was based on minimization of the objective function:

$\sum_{s,a,t}\left(lnI_{s,a,t} - \left(\hat{\kappa}_{s,a} + v_{a,t}\right)\right)^2$, where s indexes survey.

The estimated model parameters were:

$v_{a,t} = lnN_{a,t} = ln$ population abundance for a = 2 to 9 at time t = 2011

$K_{1,a} = ln$ DFO survey catchability for a = 1 to 8 at time t=1986 to 1993

$K_{2,a} = ln$ DFO survey catchability for a = 1 to 8 at time t =1994 to 2010 and a=2 to 8 at time t=2011

$K_{3,a}$ = *ln* NMFS spring survey (Yankee 41) catchability for ages *a* = 1 to 8 at time t=1978 to 1981

$K_{4,a}$ = *ln* NMFS spring survey (Yankee 36) catchability for ages *a* = 1 to 8 at time t=1982 to 1993

$K_{5,a}$ = *ln* NMFS spring survey (Yankee 36) catchability for ages *a* = 1 to 8 at time t=1993 to 2010 and a=2 to 8 at time t=2011

$K_{6,a}$ = *ln* NMFS fall survey catchability for ages *a* = 1 to 5 at time t= 1978-1993

$K_{7,a}$ = *ln* NMFS fall survey catchability for ages *a* = 1 to 5 at time t=1994-2010.

Statistical properties of the estimators were determined using conditional non-parametric bootstrapping of model residuals (Efron and Tibshirani 1993, Rivard and Gavaris 2003a).

A. "split M 0.2" model

For population abundance estimates at the beginning of 2011, age 2 exhibited the largest relative bias of 9% followed by the estimate at age 9 which showed a relative bias of 8%. The relative bias for other ages ranged between 4% and 7%. The relative error ranged between 34% and 60% (Table 14). Survey catchability (q) at age progressively increased until about age 6 for DFO 1994-2011 and age 5 for NMFS spring Y36 1994-2011 survey (Figure 25). Compared with the survey catchability prior to 1994, both DFO and NMFS spring survey catchability has abruptly increased starting at about age 3. Survey catchability at age for the NMFS fall survey was very low (Figure 25).

B. "split M 0.5" model

For population abundance estimate at the beginning of 2011, age 2 exhibited the largest relative bias of about 9%, whilst for other ages/times it ranged between 2% and 5%. The relative error ranged between 31% and 45% (Table 15). This model tended to have a smaller relative error and bias than the "split M 0.2" model. Survey catchability (q) at age progressively increased until about age 5 for the DFO 1994-2011 survey and the NMFS spring Y36 1994-2011 survey, remaining flat at older ages (Figure 25). Compared with the survey catchability prior to 1994, both DFO and NMFS spring survey catchability after 1994 has increased starting at about age 3. Survey catchability at age for the NMFS fall survey was very low (Figure 25).

Comparisons

The overall fit of model estimated biomass to the DFO, NMFS spring and NMFS fall surveys was generally consistent with the survey trends after 1994. VPA estimates at older ages were higher than survey observations for 2009 and 2011 (Figure 26). There were still residual patterns for both models, which suggested some strong year effects (Figure 27).

Retrospective analyses were used to detect any patterns of consistently overestimating or underestimating fishing mortality, biomass and recruitment relative to the terminal year estimates. Both model formulations exhibited similar patterns, with the "split M 0.2" model exhibiting a slightly stronger retrospective pattern than the "split M 0.5" model. The 2003 and 2005 year classes were initially overestimated at age 1, whilst the 2002, 2006, 2007 and 2008 year classes were initially underestimated at age1. There was a tendency to initially overestimate 3+ biomass and underestimate fishing mortality in recent years, and the patterns appear stronger in the 2011 assessment compared to the 2009 and 2010 assessment

(Figures 28 and 29). The average Mohn's rho from seven year peels (Mohn 1999) calculations showed an overestimate of 3+ biomass of approximately 0.88 for the "split M 0.2" model and approximately 0.62 for the "split M 0.5" model, and the F rho was -0.39 for the "split M 0.2" model and -0.31 for the "split M 0.5"model (Table 16). If the 3+ biomass in 2011 was adjusted to account for the retrospective pattern, it would be about 53% for the "split 0.2'" model and 62% for the '"split 0.5" model by applying the multiplier 1/(1+rho) to the model estimate.

Fishing mortality calculated from the "split M 0.5" model was more consistent with the perception about changes in effort associated with more restrictive management measures (Figure 30). The model output was more in line with recent management measures and observed catch. Both models indicated flat fishing partial recruitment except for the 10+ group (Figure 31).

STATE OF RESOURCE

Adult population biomass (ages 3+) declined substantially from about 50,000 mt in 1990 to below 10,000 mt in 1995, the lowest year observed at that time (Table 19 and 22, Figure 32), regardless of model formulation. In the "split M 0.2" model, biomass subsequently fluctuated between 5,100 mt and 10,100 mt before decreasing to 3,100 mt in 2005, then slightly increased until 2011, when the biomass decreased again to 3,288 mt (80% confidence interval: 2,769 mt – 4,217 mt). In the "split M 0.5" model, biomass since 1995 fluctuated between 6,700 mt and 12,600 mt before decreasing to 4,200 mt in 2005. The estimated biomass was 5,088 mt (80% confidence interval: 4,274 mt – 6,291 mt) at the beginning of 2011. Production in 2005 was largely due to the recruitment of the 2003 year class, and the increases in 2006-2010 were due to growth of this year class (Figure 33). Lower weights-at-age in the population in recent years and generally poor recruitment have contributed to the lack of sustained rebuilding.

Recruitment at age 1 has been low in recent years (Table 17 and 20, Figure 32). Since 2000, the 2003 year class (2.8 million fish from the "split M 0.2" model and 4.1 million fish from the "split M 0.5" model) has shown the highest recruitment observed by either model, but it was less than half of the average (about 10 million) during 1978-1990, when the productivity was considered to be higher (Figure 33). Recruitment for the 2002 and 2004 year classes was the lowest on record in both models. The 2006 year class at age 1 (1.6 million from the "split M 0.2" model and 1.9 million from the "split M 0.5" model) was close to half the strength of the 2003 year class. Initial indications were that the 2007, 2008, and 2009 year classes were similar in strength to the 2000 year class, which was only about 10% of the 1978-1990 average recruitment in both models. The current biomass is well below 30,000 mt where recruitment has historically been poor (Figure 34). Recruitment indices from the bottom trawl surveys for the 2010 year class were higher than those for recent year classes although they were not estimated in the VPA.

Fishing mortality (population number weighted average) for ages 4-9 was higher prior to 1994 (Table 18 and 21, Figure 35). F declined in 1995 to F=0.36 for the "split M 0.2" model and to 0.24 for the "split M 0.5" model due to restrictive management measures. F then fluctuated between 0.38 and 0.85 for the "split M0.2" model and 0.26 and 0.59 for the "split M 0.5" model. F in 2010 was estimated to be 0.41 from the "split M 0.2" model and 0.25 from the "split M 0.5" model. Both models show recent reductions in F, but fishing mortality is consistently above the reference level F_{ref} of 0.18.

Yield exceeded surplus production during the early 1990s (Figure 36). Surplus production since the mid 1990s has remained considerably lower than that prior to 1990. Growth of ages 2 to 10

has typically accounted for the greatest percentage of the production (Figure 33). Occasionally, a strong incoming year-class at age 2 makes a greater contribution to production. The 2003 year class made such a contribution in 2005. In 2009 and 2010, yield exceeded surplus production (Figure 36).

PRODUCTIVITY

Recruitment, age structure, fish growth and spatial distribution reflect changes in the productive potential. Recruitment, while highly variable, has generally been higher when ages 3+ biomass exceeded 30,000 mt (Figure 34). The current biomass is well below 30,000 mt. The number of recruits per spawner has not increased when the biomass has been low (Figure 37). This lack of compensation hampers stock rebuilding. In both absolute numbers and percent composition, the population age structure since 1995 displays a very low proportion of older 7+ age groups compared to the 1980s (Figure 38). Average weight at length, used to reflect condition, has been stable in the past, but has started to decline in recent years. The declines in length and weight at age from the early 1990s have hampered biomass rebuilding. Weights at age in the 2010 fishery continued to decline for all ages except for age 3 (Figure 14). The spatial distribution patterns observed during the most recent bottom trawl surveys showed that adult cod were distributed in a similar manner to the average over the past decade (Figures 17 to 19). Resource productivity is currently very poor due to low recent recruitment and low weights at age compared to the 1980s.

OUTLOOK

This outlook is provided in terms of consequences with respect to the harvest reference points for alternative catch quotas in 2012 (Gavaris and Sinclair 1998, Rivard and Gavaris 2003b). Uncertainty about standing stock generates uncertainty in forecast results which is expressed here as the risk of exceeding F_{ref} = 0.18. 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.

For projections, the 2008-2010 average values were assumed for the fishery weight at age in 2011-2012. The 2009-2011 survey average values were assumed for the beginning of year population weights at age in 2012-2013. However, for the slower growing 2003 year class, fishery weights at age 8 in 2011 and age 9 in 2012 and beginning of year weights at age 9 in 2012 and at age 10 in 2013 were obtained from cohort regressed values under the assumption of a linear regression relationship between age and weight at age. The 2006-2010 average values were assumed for the partial recruitment pattern in 2011-2012 (Table 23). The 2006-2010 average value of recruitment at age 1 from each model was used for 2011-2013 projections. Catch in 2011 was assumed to be equal to the 1,050 mt quota, and F=0.18 in 2012. Deterministic projection (Table 24) and stochastic projections (Figures 39-40) are provided from each of the model results.

A. “split M 0.2” model

A combined Canada/USA catch of 525 mt in 2012 corresponds to a low (25%) probability that F will exceed F_{ref}=0.18, whereas catches of 600 mt correspond to a neutral (50%) probability and

catches of 700 mt correspond to a high (75%) probability that F will exceed F_{ref} (Figure 39). Catches of 1,350 mt will result in a neutral risk (50%) that the 2013 adult biomass (4+) will be lower than the 2012 adult biomass, a catch of 1,000 mt will result in a neutral risk (50%) that 2013 adult biomass will not increase by 10% and a catch of 650 mt will result in a neutral risk (50%) that 2013 adult biomass will not increase by 20% (Figure 40).

B. "split M 0.5" model

A combined Canada/USA catch of 825 mt in 2012 corresponds to a low (25%) probability that F will exceed F_{ref}=0.18, whereas catches of 925 mt correspond to a neutral (50%) probability and catches of 1,025 mt correspond to a high (75%) probability that F will exceed F_{ref} (Figure 39). Catches of 900 mt will result in a neutral risk (50%) that the 2013 adult biomass (4+) will be lower than the 2012 adult biomass and a catch of about 300 mt will result in a neutral risk (50%) that the 2013 adult biomass will not increase by 10%. Even at 0 catch there is a more than 50% probability that 4+ biomass will not increase by 20% (Figure 40).

The benchmark methods do not account for the retrospective pattern in projections. If the magnitude of the retrospective pattern was accounted for, short term projections for catch would be decreased for both models.

While management measures have resulted in decreased exploitation rates since 1995, fishing mortality has remained above F_{ref} and adult biomass has fluctuated at a low level without any appreciable rebuilding. The continuing poor recruitment since the early 1990s is an important factor for this lower productivity. The 2003 year class made a substantial contribution to the fishery and population biomass. It is projected to be only a small component in the fishery catch in 2011-2012 and population biomass in 2012-2013 (Figures 41-42, Table 24). With the passing of the 2003 year class through the population, rebuilding will not occur without improved recruitment.

SPECIAL CONSIDERATIONS

The management advice and performance since 1999 are summarized in Table 25, which was kindly provided by Tom Nies (staff member of the New England Fishery Management Council, NEFMC). The Transboundary Resource Assessment Committee (TRAC) advice, TMGC quota decision, actual catch, and realized stock conditions for eastern Georges Bank cod are compared. The inconsistency of TRAC advice in the past with the realized stock conditions from the recent assessment was mainly due to the assessment model changes after the 2009 benchmark assessment, and the retrospective pattern in the assessment also accounted for part of this inconsistency.

Cod and haddock are often caught together in groundfish fisheries, although they are not necessarily caught in proportion to their relative abundance because their catchabilities to the fisheries differ. Due to the higher haddock quota, discarding of cod may be high and should be monitored; at-sea observers are an essential component of this monitoring. Modifications to fishing gear and practices, with enhanced monitoring, may mitigate these concerns.

Mechanisms that explain changes in either survey catchability or natural mortality could not be established. Changes in natural mortality could be aliasing "missing" catch, particularly during the regulatory and reporting changes of the mid 1990s. It could also be aliasing emigration or imperfect designation of the boundaries for this component, though an excess of larger/older fish is not apparent in adjacent cod components.

There is no strong evidence to determine which of the two benchmark methods provides a better scientific basis for fishery management; both models should be considered when setting catch levels. The range of stock perceptions and outlooks from the two models reflect the substantial uncertainty in the assessment. Despite these uncertainties, all assessment results indicate that low catches are needed to promote rebuilding and/or prevent further decline.

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Table 1. Catches (mt) of cod from eastern Georges Bank, 1978-2010.

	Canada				USA			Total
Year	Landings	Discards Scallop	Discards Grnfish	Total	Landings	Discards	Total	
1978	8,777	98		8,875	5,502		5,502	14,377
1979	5,979	103		6,082	6,408		6,408	12,490
1980	8,066	83		8,149	6,418		6,418	14,567
1981	8,508	98		8,606	8,091		8,091	16,697
1982	17,827	71		17,898	8,566		8,566	26,464
1983	12,131	65		12,196	8,572		8,572	20,768
1984	5,761	68		5,829	10,550		10,550	16,379
1985	10,442	103		10,545	6,641		6,641	17,186
1986	8,504	51		8,555	5,696		5,696	14,251
1987	11,844	76		11,920	4,794		4,794	16,714
1988	12,741	83		12,824	7,646		7,646	20,470
1989	7,895	76		7,971	6,183	100	6,283	14,254
1990	14,364	70		14,434	6,415	92	6,507	20,941
1991	13,467	65		13,532	6,353	149	6,502	20,034
1992	11,667	71		11,738	5,080	235	5,315	17,053
1993	8,526	63		8,589	4,027	69	4,096	12,684
1994	5,277	63		5,340	998	6	1,005	6,344
1995	1,102	38		1,140	544	<1	544	1,683
1996	1,924	56		1,980	676	1	677	2,658
1997	2,919	58	428	3,405	549	6	556	3,960
1998	1,907	92	273	2,272	679	7	687	2,959
1999	1,818	85	253	2,156	1,195	13	1,207	3,364
2000	1,572	69		1,641	772	22	793	2,434
2001	2,143	143		2,286	1,488	195	1,682	3,968
2002	1,278	94		1,372	1,688	12	1,700	3,072
2003	1,328	200		1,528	1,851	105	1,955	3,483
2004	1,112	145		1,257	1,006	69	1,075	2,332
2005	630	84	144	859	175	253	428	1,287
2006	1,096	112	237	1,445	135	126	260	1,705
2007	1,108	114		1,222	234	355	589	1,811
2008	1,390	36	103	1,529	224	27	251	1,780
2009	1,003	69	137	1,209	433	194	628	1,837
2010	748	44	48	840	357	129	486	1,326
Minimum	630	36	48	840	135	<1	251	1,287
Maximum	17,827	200	428	17,898	10,550	355	10,550	26,464
Average	5,905	83	203	6,037	3,635	98	3,700	9,737

Table 2. Canadian and USA fishery management history of cod on eastern Georges Bank, 1978-2010.

2a. Canadian Management History

1978 Foreign fleets were excluded from the 200 mile exclusive economic zones of Canada and USA;
1984 Oct. Implementation of the maritime boundary between the USA and Canada in the Gulf of Maine Area;
1985 5Z cod assessment started in Canada Set TAC; TAC=25,000mt
1986 TAC=11,000mt
1987 TAC=12,500mt
1988 TAC=12,500mt
1989 TAC=8,000mt 5Zjm cod assessment
1990 Changes to larger and square mesh size; Changes from TAC to individual and equal boat quotas of 280,000lb with bycatch restrictions; Temporary Vessel Replacement Program was introduced
1991 TAC=15,000mt Dockside monitoring Maximum individual quota holdings increased to 2% or 600t(whichever was less)
1992 TAC=15,000mt Introduction of ITQs for the OTB fleet
1993 TAC=15,000mt, ITQ for the OTB fleet not based on recommended catch quotas; OTB <65 fleet was allowed to fish during the spawning season (Mar.–May. 31).
1994 TAC=6,000mt, Spawning closures January to May 31; Mesh size was 130mm square for cod, haddock an Pollock for ITQ fleet; Minimum mesh size of 6" was required for gillnets; Minimum fish size is 43cm (small fish protocols) for cod, haddock an Pollock for ITQ fleet; OT> 65' could not begin fishing until July 1; Fixed gear must choose to fish either 5Z or 4X during June 1 to September 30.
1995 TAC=1,000mt as a bycatch fishery; January 1 to June 18 was closed to all groundfish fishery; 130mm square mesh size for all mobile fleets; Small fish protocols continued; 100% dock side monitoring; 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.
1996 TAC=2,000mt; Prohibition of the landing of groundfish (except monkfish) by the scallop fishery; ITQ vessel require minimum 130mm square mesh for directed cod, haddock and Pollock trips; Small fish protocols continued; For community management, quota allocation of each fixed gear based on catch history using the years 1986-1993; 100% mandatory dockside monitoring and weighout.
1997 TAC=3,000mt
1998 TAC=1,900mt
1999 TAC=1,800mt; Mandatory cod separator panel when no observer on board; Jan. and Feb. mobile gear winter Pollock fishery.
2000 TAC=1,600mt Jan. and Feb. mobile gear winter Pollock fishery
2001 TAC=2,100mt
2002 TAC=1,192mt
2003 TAC=1,301mt;

2004	TAC=1,000mt; Canada-USA resource sharing agreement on Georges Bank.
2005	TAC=740mt; Exploratory winter fishery Jan. to Feb. 18, 2005; Spawning protocol: 25% of maturity stages at 5 and 6.
2006	TAC=1,326mt; Exploratory winter fishery Jan. to Feb.6, 2006; Spawning protocol: 30% of maturity stages at 5 to 7.
2007	TAC=1,406mt; Exploratory winter fishery Jan. to Feb. 15, 2007; High mobile gear observer coverage (99%); Spawning protocol: 30% of maturity stages at 5 to 7.
2008	TAC=1,633mt; Winter fishery from Jan.1 to Feb. 8, 2009; At sea observer coverage 38% by weight of the mobile gear fleet landings and 21% by weight of the fixed gear landings; Spawning protocol: 30% of maturity stages at 5 to 7.
2009	TAC=1,173mt; Winter fishery from Jan. 1 to Feb. 21, 2009; At sea observer coverage 23% by weight of the mobile gear fleet landings and 15% by weight of the fixed gear landings; Spawning protocol: 30% of maturity stages at 5 to 7.
2010	TAC=1,350mt; Winter fishery from Jan. 1 to Feb. 8, 2010; At sea observer coverage 18% by weight of the mobile gear fleet landings and 6% by weight of the fixed gear landings; Spawning protocol: 30% of maturity stages at 5 to 7.

2b. USA Management History

2001	November 6: Daily haddock possession limit removed(maximum 50,000lbs.-trip).
2002	May: Interim rule as a result of FW 33 lawsuit settlement agreement. Continuation of most measures from previous frameworks. DAS: 15 hour minimum charged for all trips over 3 hours,Vessels limited to 25% of allocation May 1 through July 31, 2002 (only). Prohibition on front-loading DAS. Minimum size: Cod 22". Gear: GOM Regulated Mesh Area (RMA): 6.5 in. diamond or square codend minimum, 6.5" mesh for trip gillnets, 6.5 inch mesh standup (roundfish) or 7" mesh tiedown (flatfish) for day gillnets. All areas:day gillnets limited to 50 standup/100 tiedown nets. *Hook gear*: de-hooking devices with spacing of less than 6" prohibited. Recreational: Cod minimum size 23". All areas- private recreational limited to 10 cod. Possession limits: Remain the same. June: Revised interim rule:Minimum size: Cod 19", Gear: *Hook*: Requirement for 6" spacing for de-hooking gear removed. Aug: Emergency rule implementing FW 33 lawsuit settlement agreement: DAS: DAS allocation for each permit reduced 20 percent from maximum used \ FY 1996-2000 (est 71,218 allocated, including carry-over). DAS counted by the minute, except for day gillnet vessels (15 hour minimum). (This change reverted to DAS counting in effect in FY 2001). Prohibition on front-loading DAS clock. Minimum size: Cod 22". Gear: *Trawl:* GOM/GB RMAs: 6.5" diamond or square codend minimum; *Hook*: GB: 3,600 rigged hooks Closures: Add GB seasonal closure areas, May – Blocks 80, 81, 118, 119, 120 (south of 42-20N). Recreational: Cod/haddock: 23" minimum size. Party/charter: GOM RMA: April-November, 10 cod/haddock combined per person, Dec-Mar – 10 cod/haddock combined, no more than 5 cod per person per trip. Private: GOM RMA: December-March – 10 cod/haddock combined, no more than 5 cod. Commercial minimum size increased to 22" (55.9 cm)
2003	July: Final emergency rule implementing FW 33 lawsuit settlement agreement. Recreational: Other areas (including GB):10 cod/haddock combined.
2004	May: Implementation of Amendment 13. Measures based on emergency rule and measures in effect prior to interim rule. Special Management Programs: *US/Canada Area*: hard TAC on cod, Cod possession limit: 500 lbs-DAS/5,000 lbs-trip, not more than 5 percent of catch. No DAS charged to/from SAs 561, 562. VMS required in U.S/Canada Management Area ; only Category A DAS Daily catch report via VMS (catch&discard) ;Haddock separator trawl; flatfish net. October: Closure of SAs 561 and 562 to all fishing on a multispecies DAS. November: Framework Adjustment 40A. *Eastern US/CA Area Haddock SAP Pilot Program* Access to northern corner of CAII and adjacent area to target haddock using separator trawl. Season: May 1 through December 31. Authorized use of Category B DAS.
2005	January: Eastern US/CA reopened, Cod trip limit of 5,000 lbs./trip in Eastern US/CA area. Vessels fishing in Eastern US/CA area must use haddock separator trawl. April: Eastern US/CA area closed until April 30, 2005. May: Eastern US/CA Area reopens at beginning of fishing year. Measures revert to those implemented May 1, 2004. July: NE multispecies DAS vessels are limited to one trip per month in the Eastern US/CA area. Multispecies DAS vessels are prohibited from fishing in the Category B (regular) DAS program in the GB cod stock area through July 31. NE multispecies trawl vessels are required to use haddock separator trawl when fishing in the Eastern US/CA area. August : Eastern US/CA area is closed to all limited access multispecies DAS vessels because 90 percent of the GB cod TAC for the area is projected to be harvested.
2006	Implementation of an emergency rule to reduce fishing mortality on groundfish stocks while FW 42 is reviewed. Special Management Programs: *Eastern US/Canada haddock SAP*: Opening delayed until August 1. Category B (regular) DAS Program: Renewed, with vessels restricted to the US/CA Area, required to use a haddock separator trawl, limited to 500 days May-June, 1,000 days in other quarters, low trip limits on stocks of concern. Other: Vessels allowed to fish inside and outside the eastern US/CA area on the same trip. June: All trawl vessels fishing in the eastern US/CA area required to use a haddock separator trawl. November: Implementation of FW 42 - Major regulatory changes: Special Management Programs: *US/Canada Area*: Opening delayed until August 1. Prohibition on discarding legal sized fish. Category B (regular) DAS Program: Renewed for all areas. Trawl vessels required to use a haddock separator trawl, limited to 500 days May-June, 1,000 days in other quarters, low trip limits on stocks of concern. Prohibition on discarding legal sized fish. Other: (same as emergency rule) Vessels allowed to fish inside and outside the eastern US/CA area on the same trip.
2007	March: Trawl vessels fishing in the eastern US/CA area allowed to use either a haddock separator trawl or a flounder net. April: Eastern U.S./Canada area closed to limited access multispecies vessels (through April 30, 2007). May: Eastern U.S./Canada area reopens. June: Eastern US/CA area is closed to limited access multispecies DAS vessels due to cod catch.. October: The Eastern US/CA area is opened to limited access multispecies DAS vessels. The GB cod possession limit is 1,000 lb/trip for all vessels declared into the Eastern US/CA Area or the Eastern US/CA Area SAP.
2008	May: Eastern U.S./Canada area opening delayed until August 1, 2008 for vessels fishing with trawl gear. Eastern U.S./Canada area opened to longline gear but with a cod cap of 33.4 mt. August: Eastern U.S./Canada management area opens to all vessels. U.S./Canada Haddock SAP opens. Haddock rope trawl (later called the Ruhle trawl, previously called the eliminator trawl) approved for use in the Category B (regular) DAS program and the U.S./Canada Haddock SAP. September: Ruhle trawl authorized for use in the Eastern U.S./Canada management area. November: Landing limit for Eastern GB cod increased to 1,000 lbs./DAS up to a maximum of 10,000 lbs./trip (applies to cod caught in the Eastern U.S./Canada management area).
2009	January 26: NE Multispecies regulations adopted by FW 42 suspended as a result of a court order. No clear explanation of what measures are affected. February 13: NMFS identifies following measures as NOT impacted by the court order to suspend measures adopted by FW 42: • Recordkeeping and reporting requirements • Gear restrictions • DAS allocations

	• Time and area closures • Minimum fish sizes • SAPs • Recreational measures • Cape Cod Hook Sector • Some possession limits (GOM cod 800 lbs DAS-4,000 lbs/trip,, GB cod 1,000 lbs./DAS – 10,000 lbs./trip, US/CA area trip limits Confusion continues on what regulations are not in effect. February 17: Federal court rescinds decision to suspend FW 42 measures and limits suspension to differential DAS counting areas in the GOM and SNE/MA areas, and authorizes submission of DAS leasing requests through March 31, 2009 (vice normal March 1 deadline for such requests). March 9: Eastern GB cod landing limit reduced to 500 lbs./DAS – 5,000 lbs./trip. April 16: **Eastern US/CA area** closed until May 1. May 1: Interim rules in effect to reduce overfishing on multispecies stocks until Amendment 16 implemented. Major changes: DAS: DAS allocations reduced according to Amendment 13 schedule. Category A DAS are reduced to 45 percent of the permit's DAS baseline, an 18 percent reduction from the previous year's allocations. Differential DAS area increased in SNE/MA. Possession limits: *GB cod*: 1,000 lbs./DAS-10,000 lbs./trip (eastern US/CA area 500 lbs./DAS-5,000 lbs./trip). Special Management Programs: *US/Canada Area*: Opening delayed until August 1 for trawl vessels. *SNE/MA winter flounder SAP* suspended. State waters winter flounder exemption eliminated. *CAI Hook Gear Haddock SAP* expanded to May 1 to January 31, area increased, no separation between common pool and sector participants. Recreational Measures: GB cod bag limit of n10 cod per person per day for party/charter vessels; Other: Conservation tax removed from DAS transfers. May 6: Limited access general category scallop fishery closed to IFQ vessels until June 1. June 26: **eastern US/CA Area closed** to all vessels until August 1 (including fixed gear vessels) to prevent exceeding first quarter GB cod TAC. June 29: CAII Scallop Access Area closed to prevent exceeding GB yellowtail flounder cap. July 19: Limited access general category scallop fishery closed to IFQ vessels until September 1. September 15: Limited access general category scallop fishery closed to IFQ vessels until December 1. September 17: Use of flounder trawl net prohibited when fishing in the Eastern US/CA area. November 20: In the **US/CA management area**, trawl vessels required to use a haddock separator trawl or Ruhle trawl south of 41-40N latitude. Any vessel fishing in this area and other areas cannot use any other gear on the same trip. Vessels fishing north of 41-40N for the entire trip can use any legal gear.
2010	January 12: Limited access general category scallop fishery closed to IFQ scallop vessels March 1: Limited access general category scallop IFQ program opens. Scallop fishery Elephant Trunk and DELMARVA Access Areas open. March 11: All multispecies vessels fishing on a Category A DAS allowed to use any legal trawl gear in the Western US/CA Area (statistical areas 522, 525) (lifts restrictions adopted November 20, 2009). April 13: All multispecies vessels fishing on a Category A DAS allowed to use a flounder trawl net in the Eastern US/CA area. April 20: Eastern US/CA area (statistical areas 561, 562) closed to multispecies vessels and harvest, possession, and landing of GB yellowtail flounder from entire US/CA area (statistical areas 522, 525, 561, 562) prohibited. May 1: Implementation of Amendment 16 and Framework 44. Expansion of sector management program to majority of the fishery. Major revisions to common pool measures for permitted vessels not in sectors. Adoption of additional at-sea and dockside monitoring requirements for sector vessels, and new reporting requirements for other vessels. Adoption of new US/CA area TACs. Adoption of annual catch limit (ACL) and accountability measures (AM) for most stocks. Key elements: *Sector Management:* Vessels in sectors subject to hard TACs for most stocks, increased at-sea monitoring (targeting 38 percent of trips), dockside monitoring; not subject to trip limits, groundfish DAS limits. Permits committed to sectors account for 94 percent or more of available catch except for GOM WFL (84 pct) and SNE/MA YTF (76 pct), and SNE/MA WFL (0%). Total permits committed to sectors: 762. Sector vessels required to retain all legal-sized fish (except limited to one Atlantic halibut, and the five species prohibited). Sectors required to stop fishing in a stock area when a quota (Annual Catch Entitlement, or ACE) for a stock in the area is caught. *Common pool*: Only a small portion of the ACL available to common pool vessels. Major elements of common pool regulations: DAS: Category A DAS allocations reduced to 27.5 percent of the Amendment 13 baseline allocation. All DAS charged in 24 hour increments. Possession limits: *GB cod*: 2,000 lbs./DAS-20,000 lbs./trip (eastern US/CA area 500 lbs./DAS-5,000 lbs./trip). Restricted Gear Areas: Areas near CAI and off SNE created to reduce flatfish catches; limited to separator/Ruhle trawls, rope trawl, certain gillnets in these areas. Special Management Programs: *US/Canada Area*: Opening delayed until August 1 for trawl vessels. Prohibition on discarding legal sized fish. *SNE/MA winter flounder SAP* suspended. State waters winter flounder exemption eliminated. *CAI Hook Gear Haddock SAP* expanded to January 31, area increased, no separation between common pool and sector participants. *CAII yellowtail flounder –haddock SAP*: SAP opening authorized to target haddock (not GB yellowtail flounder_ subject to specific gear requirements. Opening date August 1. *Adjustments*: RA authorized to make in-season adjustments to trip limits and DAS counting rates. *DAS Leasing and Transfers*: Permits in CPH category allowed to participate in these programs. No conservation tax on transfers. May 27: Changes to common pool trip limits: GOM haddock: 1,000 lbs./trip

GB haddock: 10,000 lbs./trip
GOM winter flounder: 250 lbs./trip
GB winter flounder: 1,000 lbs./trip (offshore)
GB yellowtail flounder: 1,000 lbs./trip (offshore)
July 15: Pollock ACL revised; increased to 16,553 mt.
July 30: Changes to common pool measures:
GB yellowtail flounder: Selective trawl gear required in Eastern US/CA area and Western US/CA area south of 41-40N.
August 6: Changes to common pool measures:
Pollock trip limit removed
Witch flounder: 130 lbs./trip
August 31: Common pool DAS counting rate set to 2:1 for GOM and GB differential DAS areas.
September 22: Changes to common pool measures:
GB yellowtail flounder: 100 lbs./trip
White hake: 100 lbs./DAS – 500 lbs./trip
US/CA area: Selective trawl gear required to entire US/CA management area
October 18: Handgear A cod trip limit reduced to 50 lbs/trip.

Table 3. Nominal landings (mt) of cod from eastern Georges Bank by gear and month for Canada 2001-2010.

Year	Gear	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2001	Mobile						160	84	58	104	133	111	72	722
	Gillnet						37	75	48	60	43	21		284
	Longline						62	212	273	282	229	62	16	1,137
	Total						259	371	379	446	406	193	88	2,143
2002	Mobile						38	87	33	83	62	55	86	445
	Gillnet						3	45	51	23	1	9	7	140
	Longline						2	150	199	156	127	31	29	693
	Total						43	282	283	263	190	95	122	1,278
2003	Mobile						87	81	55	65	67	74	45	474
	Gillnet						6	31	31	27	3	14	1	112
	Longline						20	166	252	136	124	30	14	742
	Total						114	277	338	228	194	117	59	1,328
2004	Mobile						78	82	50	47	56	42	16	371
	Gillnet						4	2	14	21		11		52
	Longline						6	85	231	168	89	97	14	689
	Total						88	169	294	236	145	150	30	1,112
2005	Mobile	12	22			3	50	49	31	27	28	31	30	283
	Gillnet						11	18		6				36
	Longline	1					9	44	101	71	52	29	4	311
	Total	13	22			3	70	111	133	105	80	60	34	630
2006	Mobile	41	16				88	73	74	63	39	24	39	458
	Gillnet							27	15					43
	Longline	3					7	126	173	147	91	34	14	595
	Total	44	16				96	226	262	211	130	58	53	1,096
2007	Mobile	68	18				44	84	55	31	49	14	28	393
	Gillnet							4	41	13				58
	Longline						7	116	173	219	102	39		657
	Total	68	18				51	205	268	263	152	53	28	1,108
2008	Mobile	40	21				69	100	55	67	46	43	28	468
	Gillnet						1	22	50	22				94
	Longline						7	190	280	177	136	38		827
	Total	40	21				77	312	384	265	182	81	28	1,390
2009	Mobile	23	7				51	32	17	10	59	46	25	271
	Gillnet						4	29	61	36	12			142
	Longline							68	135	198	124	53	13	590
	Total	23	7				55	129	213	244	195	99	38	1,003
2010	Mobile	26	8				56	56	26	31	51	54	36	345
	Gillnet						5	17	13	19				54
	Longline						1	21	100	107	72	47		349
	Total	23	7				62	95	139	158	123	102	36	748

Table 4. Length and age samples from the USA and Canadian fisheries on eastern Georges Bank. For Canadian fisheries, at-sea observer samples are included since 1990. The first quarter age samples are supplemented with USA fishery age samples from 5Zjm for 1978 to 1986 and DFO survey age samples for 1987-2011; the numbers are shown in brackets.

Year	USA		Canada	
	Lengths	Ages	Lengths	Ages
1978	2,294[1]	384	7,684	1,364
1979	2,384	402	3,103	796(205)
1980	2,080[1]	286	2,784	728(192)
1981	1,498	455	3,906	842
1982	4,466[1]	778	4,948	1,054(268)
1983	3,906[1]	903	3,822	754(150)
1984	3,891	1,130	1,889	1,241(858)
1985	2,076	597	7,031	1,309(351)
1986	2,145	643	5,890	987(103)
1987	1,865	524	9,133	1,429(193)
1988	3,229	797	11,350	1,892(510)
1989	1,572	347	8,726	1,499
1990	2,395	552	31,951	2,825(1153)
1991	1,969	442	27,739	1,782
1992	2,048	489	28,825	2,215(359)
1993	2,215	569	31,473	2,146
1994	898	180	27,659	1,268
1995	2645[1]	14	6,633	548
1996	4,895[1]	1,163	25,818	828
1997	1,761[1]	82	31,420	1,216
1998	1,301[1]	338	25,743	1,643
1999	726	228	25,871	1,290(410)
2000	500	121	20,127	1,374
2001	1,434	397	18,627	1,505
2002	1,424	429	15,616	1,252
2003	1,367	416	19,185	1,070
2004	1,547	517	17,856	1,370
2005	297[1]	65	21,942	1,483(697)
2006	446	151	43,259	1,455(648)
2007	589	183	139,816	1,672(456)
2008	972	295	63,213	1,729(495)
2009	1,286	326	47,206	1,518(246)
2010	1,446	333	30,159	1,022(433)

[1] Includes length samples from western Georges Bank.

Table 5. Results of intra- and inter-reader ageing comparisons.

Sample Source	Stock	Test Type	Date Completed	[1]Age Reader	Sample Size	Agreement (%)
2010 CAN Intra Aging Tests Qtr 1-4	GB	Precision	April 2011	BH	214	94
Mar., Aug., Dec. NMFS Comm.	GB	Exchange	May 2011	NS vs. BH	64	94
2008 NMFS Comm. 200025	GB	Exchange	May 2011	NS vs. BH	19	100
2007 NMFS Comm. O01013	GB	Exchange	May 2011	NS vs. BH	19	95
2008 DFO Spring Survey TEM2008775	GB	Exchange	May 2011	BH vs NS	20	85
2008 DFO Comm. Sample 20080122	GB	Exchange	May 2011	BH vs NS	19	79
2008 DFO Comm. Sample 20080279	GB	Exchange	May 2011	BH vs NS	19	95
2007 DFO Comm. Sample 20070485	GB	Exchange	May 2011	BH vs NS	20	95

[1]BH: Bette Hatt from DFO; NS: Nina Shepherd from NMFS.

Table 6. Annual catch at age numbers (thousands) for eastern Georges Bank cod for 1978-2010.

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1978	1	8	108	3643	1167	394	163	127	22	23	6	2	1	0	0	0	0	5667
1979	1	15	890	734	1520	543	182	74	61	11	3	2	1	0	1	0	0	4037
1980	2	6	973	1650	301	968	354	97	26	46	16	4	1	0	0	0	0	4445
1981	3	35	860	1866	1337	279	475	181	96	59	21	3	1	0	0	0	0	5216
1982	0	15	3516	1971	1269	1087	195	399	155	49	14	22	6	3	4	1	0	8707
1983	10	22	783	2510	1297	562	398	118	182	102	25	28	12	1	3	1	0	6055
1984	0	17	230	805	1353	546	376	279	39	90	38	17	7	2	3	0	1	3804
1985	33	9	2861	1409	661	987	271	110	110	21	27	3	4	1	1	0	0	6509
1986	1	41	451	2266	588	343	456	68	48	29	4	8	1	0	0	0	0	4303
1987	2	22	4116	846	1148	163	132	174	41	24	8	3	1	0	0	0	0	6680
1988	1	23	289	4190	680	855	130	116	182	52	21	13	4	1	0	0	0	6556
1989	1	34	680	812	1980	228	373	56	40	59	15	7	5	0	0	0	0	4290
1990	1	20	733	3116	1038	1374	145	153	12	12	24	3	2	1	0	0	0	6633
1991	0	65	1022	1010	1923	904	746	105	69	21	11	8	4	2	0	1	0	5892
1992	0	70	2600	1379	460	890	314	316	45	34	3	5	2	1	0	0	0	6119
1993	0	10	499	1898	909	299	359	133	97	25	17	2	0	0	0	0	0	4249
1994	1	5	184	483	788	270	45	61	30	21	2	1	0	0	0	0	0	1890
1995	3	1	57	237	94	105	18	7	4	4	0	0	0	0	0	0	0	531
1996	0	7	40	234	397	79	60	13	4	3	0	0	0	0	0	0	0	839
1997	1	7	145	205	358	359	83	37	13	4	1	1	0	0	0	0	0	1214
1998	0	4	100	315	161	158	134	23	13	4	1	0	1	0	0	0	0	914
1999	0	7	77	486	337	109	61	57	14	2	1	0	0	0	0	0	0	1150
2000	1	7	71	111	378	151	37	22	12	3	0	0	0	0	0	0	0	795
2001	1	3	98	541	212	398	105	32	17	7	1	0	0	0	0	0	0	1416
2002	1	1	12	127	445	108	156	30	9	6	2	1	0	0	0	0	0	897
2003	13	0	38	159	241	406	81	89	19	4	1	0	0	0	0	0	0	1052
2004	0	21	13	145	151	147	139	35	30	7	1	1	0	0	0	0	0	690
2005	0	2	86	55	191	56	31	39	11	5	1	0	0	0	0	0	0	478
2006	0	3	21	242	76	188	48	18	17	2	1	0	0	0	0	0	0	617
2007	0	2	80	89	409	31	77	11	7	6	0	0	0	0	0	0	0	712
2008	0	1	49	158	59	235	15	32	4	2	1	0	0	0	0	0	0	557
2009	1	7	66	224	142	40	124	9	10	1	1	0	0	0	0	0	0	626
2010	0	1	30	123	216	68	14	29	3	2	0	0	0	0	0	0	0	485

Table 7. Average fishery weights at age (kg) of cod from eastern Georges Bank.

Year/Age	1	2	3	4	5	6	7	8	9
1978	0.44	1.26	2.07	2.72	3.72	5.41	5.61	8.28	7.50
1979	0.73	1.45	1.52	3.28	4.45	6.59	9.41	9.62	9.86
1980	0.38	1.24	2.21	3.07	4.96	6.29	7.22	11.46	10.41
1981	0.52	1.28	1.99	3.06	4.54	6.50	8.02	9.25	11.62
1982	0.56	1.30	2.13	3.61	5.01	6.76	8.51	9.86	11.86
1983	0.90	1.49	2.21	3.10	4.60	6.10	7.81	10.15	11.47
1984	0.68	1.60	2.31	3.42	4.76	6.09	8.30	9.35	11.16
1985	0.54	1.32	1.81	3.19	4.55	5.95	7.91	9.60	10.75
1986	0.54	1.36	2.43	3.30	4.83	6.70	8.08	9.20	11.38
1987	0.58	1.46	2.38	3.93	5.38	7.23	8.76	9.46	11.27
1988	0.62	1.17	2.19	3.07	4.91	6.10	8.27	9.89	11.14
1989	0.65	1.28	1.96	3.35	4.89	6.02	6.79	9.80	10.70
1990	0.69	1.55	2.38	3.22	4.60	6.04	7.80	9.81	11.19
1991	0.73	1.51	2.41	3.14	4.24	5.53	7.45	9.46	9.18
1992	0.86	1.41	2.28	3.32	4.25	5.67	6.80	8.66	11.21
1993	0.60	1.40	2.11	2.84	4.29	5.40	6.76	8.29	9.14
1994	0.59	1.33	2.14	3.44	4.39	6.42	7.19	8.15	7.96
1995	0.29	1.32	2.12	3.35	4.94	6.38	10.09	10.01	10.43
1996	0.49	1.42	2.17	3.05	4.70	5.83	6.42	8.96	10.35
1997	0.72	1.44	2.07	2.93	3.86	5.36	7.26	8.31	11.49
1998	0.78	1.36	2.15	2.98	3.97	5.33	6.59	7.82	10.23
1999	0.56	1.33	1.97	3.10	3.91	5.48	6.27	7.54	9.38
2000	0.65	1.26	1.96	2.91	4.02	4.70	5.72	6.78	8.38
2001	0.21	1.07	1.82	2.73	3.58	4.87	5.22	7.28	8.65
2002	0.32	1.17	1.96	2.85	4.01	4.89	6.41	8.23	7.98
2003		1.22	2.09	2.73	3.54	4.27	5.47	6.84	7.63
2004	0.24	1.24	1.84	2.78	3.47	4.56	5.24	7.25	8.54
2005	0.17	0.91	1.55	2.43	3.50	4.51	4.87	6.79	8.10
2006	0.20	0.66	1.77	2.38	3.36	4.32	6.08	5.81	6.91
2007	0.48	1.14	1.64	2.45	3.15	4.04	6.17	6.87	6.92
2008	0.22	1.35	2.29	2.78	3.68	5.05	5.89	7.92	7.94
2009	0.55	1.32	1.94	3.20	3.67	4.56	5.72	6.79	10.08
2010	0.43	1.29	2.05	2.64	3.44	3.53	5.15	5.95	8.74
Min	0.17	0.66	1.52	2.38	3.15	4.04	4.87	5.81	6.91
Max	0.90	1.60	2.43	3.93	5.38	7.23	10.09	11.46	11.86
Avg[1]	0.38	1.15	1.94	2.69	3.46	4.30	5.80	6.67	8.12

[1]for 2006-2010

Table 8. Conversion factors used to adjust for changes in door type and survey vessel for the NMFS surveys, 1978 to 2008.

Year Door	Spring		Fall	
	Vessel	Conversion	Vessel	Conversion
1978 BMV	Albatross IV	1.56	Delaware II	1.2324
1979 BMV	Albatross IV	1.56	Delaware II	1.2324
1980 BMV	Albatross IV	1.56	Delaware II	1.2324
1981 BMV	Delaware II	1.2324	Delaware II	1.2324
1982 BMV	Delaware II	1.2324	Albatross IV	1.56
1983 BMV	Albatross IV	1.56	Albatross IV	1.56
1984 BMV	Albatross IV	1.56	Albatross IV	1.56
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	0.79	Delaware II	0.79
1990 Polyvalent	Delaware II	0.79	Delaware II	0.79
1991 Polyvalent	Delaware II	0.79	Delaware II	0.79
1992 Polyvalent	Albatross IV	1	Albatross IV	1
1993 Polyvalent	Albatross IV	1	Delaware II	0.79
1994 Polyvalent	Delaware II	0.79	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	0.79	Delaware II	0.79
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

Table 9. Calibration factors at length used to adjust for differences between the catches of cod by the NMFS research vessels FSV Henry B. Bigelow and FRV Albatross IV. The factors are applied to the H.B. Bigelow numbers at length for the 2009 to 2011 NMFS spring and fall surveys.

Length (cm)	Calibration Factor
1 to 20	5.723743
21	5.600243012
22	5.476743024
23	5.353243035
24	5.229743047
25	5.106243059
26	4.982743071
27	4.859243082
28	4.735743094
29	4.612243106
30	4.488743118
31	4.365243129
32	4.241743141
33	4.118243153
34	3.994743165
35	3.871243176
36	3.747743188
37	3.6242432
38	3.500743212
39	3.377243223
40	3.253743235
41	3.130243247
42	3.006743259
43	2.88324327
44	2.759743282
45	2.636243294
46	2.512743306
47	2.389243318
48	2.265743329
49	2.142243341
50	2.018743353
51	1.895243365
52	1.771743376
53	1.648243388
54+	1.601603

Table 10. Indices of swept area abundance (thousands) for eastern Georges Bank cod from the DFO survey.

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1986		770	3538	3204	331	692	445	219	35	66	0	10	0	0	0	0	0	9311
1987		48	1791	642	753	162	89	181	89	13	13	0	13	16	0	0	0	3812
1988		148	450	5337	565	838	95	79	179	18	12	4	0	16	0	0	0	7741
1989		350	2169	764	1706	258	332	42	85	112	5	32	8	5	0	0	0	5868
1990	20	106	795	3471	1953	4402	535	1094	144	157	289	65	52	37	0	0	5	13125
1991		1198	1019	1408	1639	882	1195	148	249	38	45	30	12	5	8	0	0	7876
1992		48	2049	1221	409	643	451	300	93	38	0	3	3	18	0	0	0	5276
1993		31	355	1723	622	370	754	274	268	51	31	0	20	6	0	0	0	4504
1994		13	629	691	1289	477	182	363	84	119	12	0	0	0	8	5	0	3871
1995		32	187	1240	757	520	186	44	67	28	18	8	6	0	0	0	0	3093
1996		90	203	1744	4337	1432	1034	445	107	149	39	4	0	0	5	0	0	9590
1997		30	376	568	1325	1262	216	50	35	23	17	0	3	0	0	0	0	3905
1998		6	582	831	322	317	238	56	29	7	8	3	4	0	0	0	0	2402
1999		3	156	1298	1090	449	317	190	10	28	5	9	0	3	0	0	0	3561
2000		0	423	1294	4967	2157	1031	510	317	20	23	12	0	0	0	0	0	10754
2001		3	37	802	519	1391	645	334	224	225	36	24	7	0	0	0	0	4248
2002		0	118	477	2097	694	1283	458	188	63	76	7	0	0	0	0	0	5462
2003		0	8	200	510	867	194	219	69	12	0	0	0	0	0	0	0	2078
2004		427	40	246	381	422	353	59	108	25	5	0	3	0	0	0	0	2069
2005		25	1025	1398	7149	1766	816	743	60	87	8	4	0	0	0	0	0	13082
2006		0	41	1500	673	1779	757	217	216	83	34	10	15	0	0	0	0	5325
2007		18	130	549	2606	379	653	119	81	53	0	4	0	0	0	0	0	4591
2008		12	147	1027	755	2978	194	392	41	4	20	0	0	0	0	0	0	5569
2009		11	51	2487	2261	519	2955	0	82	0	0	0	18	0	0	0	0	8384
2010		5	92	956	4105	1781	703	1828	65	84	5	0	0	0	0	0	0	9623
2011		193	271	766	952	1324	256	67	112	14	8	2	0	0	0	0	0	3965

Table 11. Indices of swept area abundance (thousands) for eastern Georges Bank cod from the NMFS spring survey. Conversion factors to account for vessel and trawl door changes have been applied. During 1973-1981 a Yankee 41 net was used rather than the standard Yankee 36 net.

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1970	0	354	1115	302	610	73	263	48	0	71	24	0	48	0	0	0	0	2907
1971	0	185	716	503	119	326	124	257	227	40	40	79	0	0	0	0	0	2615
1972	56	1578	1856	2480	393	114	136	60	88	73	18	14	0	0	14	0	0	6879
1973	0	665	37880	5474	6109	567	467	413	0	163	231	0	0	0	95	0	0	52064
1974	0	461	5877	4030	759	2001	360	91	267	45	48	54	0	0	0	0	0	13991
1975	0	0	467	3061	4348	446	960	79	0	122	0	0	0	0	0	0	0	9483
1976	84	1733	1111	620	444	759	0	167	35	0	0	0	0	48	0	0	0	5001
1977	0	0	2358	736	354	307	334	22	35	0	0	0	0	0	0	0	0	4145
1978	373	187	0	2825	615	916	153	787	62	43	40	0	0	0	0	0	0	6001
1979	71	339	1332	122	1430	543	176	91	130	0	0	0	0	0	0	0	0	4234
1980	0	11	2251	2168	169	1984	410	78	48	31	0	47	0	0	0	0	0	7197
1981	283	1956	1311	2006	1093	43	453	197	59	0	0	0	0	0	0	0	0	7399
1982	44	455	6642	13614	12667	9406	0	3088	992	120	0	0	0	0	0	0	0	47027
1983	0	389	2017	3781	779	608	315	106	98	0	70	0	0	0	0	0	35	8197
1984	0	103	117	344	483	92	182	74	18	105	0	0	0	0	0	0	0	1518
1985	58	36	2032	633	1061	1518	328	217	213	83	116	34	23	0	0	0	0	6352
1986	97	619	339	1132	298	427	536	20	109	142	0	0	0	0	0	0	0	3719
1987	0	0	1194	247	568	0	152	148	30	54	0	0	0	0	0	0	0	2394
1988	138	320	243	2795	274	461	51	5	67	0	0	10	0	0	0	0	0	4364
1989	0	174	1238	338	1685	234	396	99	12	36	48	24	0	0	0	0	0	4284
1990	24	45	360	1687	586	634	152	164	19	0	0	24	0	0	0	0	0	3696
1991	217	725	620	514	903	460	382	44	17	0	24	53	0	0	0	0	0	3957
1992	0	81	666	349	103	261	152	159	27	52	0	0	0	0	0	0	0	1850
1993	0	0	462	1284	262	46	182	46	43	46	12	0	0	0	0	0	0	2382
1994	38	54	194	152	185	44	11	33	0	8	0	0	0	0	0	0	0	720
1995	384	70	294	927	495	932	191	253	0	68	0	0	0	0	0	0	0	3614
1996	0	139	300	990	1343	121	94	28	0	0	0	0	0	0	0	0	0	3016
1997	271	54	218	48	402	519	53	126	57	0	0	0	0	0	0	0	0	1747
1998	54	0	1040	1985	995	983	609	30	31	0	0	0	0	0	0	0	0	5729
1999	22	22	145	673	624	370	172	107	34	8	0	0	0	0	0	0	0	2176
2000	36	0	304	643	1348	492	138	52	20	0	0	0	0	0	0	0	0	3032
2001	0	0	64	889	96	350	109	0	12	10	0	0	0	0	0	0	0	1530
2002	36	0	121	470	1081	175	214	61	0	0	0	0	0	0	0	0	0	2158
2003	0	0	125	287	812	1154	135	78	9	0	0	0	0	0	0	0	0	2599
2004	0	549	10	838	2091	2105	1351	239	382	29	0	0	0	0	0	0	0	7595
2005	36	15	345	70	747	287	190	131	34	0	0	0	0	0	0	0	0	1855
2006	0	37	73	952	411	1007	340	151	79	0	0	0	0	0	0	0	0	3050
2007	0	0	369	308	2258	239	291	47	28	0	0	0	0	0	0	0	0	3540
2008	43	37	112	675	372	1385	51	66	0	0	0	0	0	0	0	0	0	2741
2009	0	61	86	875	408	219	377	24	12	15	0	0	0	0	0	0	0	2078
2010	0	25	126	367	667	168	44	147	0	12	0	0	0	0	0	0	0	1556
2011	0	88	164	164	266	144	56	9	24	0	0	0	0	0	0	0	0	914

Table 12. Indices of swept area abundance (thousands) for eastern Georges Bank cod from the NMFS fall survey. Conversion factors to account for vessel and trawl door changes have been applied.

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1970	348	1416	836	208	412	11	0	0	5	25	0	0	0	0	0	0	0	3261
1971	203	1148	900	181	232	130	142	14	0	0	0	0	0	0	0	0	0	2951
1972	1110	3299	614	667	24	40	0	0	0	0	0	0	0	0	0	0	0	5753
1973	46	2435	2947	997	979	93	0	25	63	0	0	0	0	0	0	0	0	7584
1974	77	196	399	622	54	31	15	0	0	0	0	0	0	0	0	0	0	1394
1975	414	660	177	414	764	27	46	0	0	0	0	0	0	0	0	0	0	2501
1976	0	8260	362	144	0	91	0	48	0	0	0	0	0	0	0	0	0	8904
1977	51	0	3475	714	184	156	178	3	0	0	0	0	0	0	0	0	0	4760
1978	113	1519	58	3027	417	58	63	77	0	0	0	0	0	0	0	0	0	5330
1979	182	1704	1695	116	1522	243	48	20	11	18	0	0	0	0	0	0	0	5557
1980	315	782	409	649	22	184	14	17	20	0	0	0	0	0	0	0	0	2412
1981	360	2352	1208	933	269	15	29	0	0	0	53	0	0	0	0	0	0	5220
1982	0	549	718	54	59	0	0	27	0	0	0	0	0	0	0	0	0	1406
1983	948	73	267	567	24	8	8	0	23	0	0	0	0	0	0	0	0	1917
1984	29	1805	120	690	1025	23	32	0	0	9	0	0	0	0	0	0	0	3734
1985	1245	209	993	161	18	5	9	0	0	0	4	0	0	0	0	0	0	2645
1986	119	3018	56	198	0	0	6	0	0	0	0	0	0	0	0	0	0	3396
1987	156	129	845	121	100	0	0	0	0	0	0	0	7	0	0	0	0	1357
1988	95	561	177	1182	163	206	0	30	41	10	0	0	0	0	0	0	0	2464
1989	318	570	1335	222	607	78	24	0	0	0	0	0	0	0	0	0	0	3154
1990	198	403	442	831	120	204	20	0	15	0	0	0	0	0	0	0	0	2232
1991	0	158	60	71	10	24	0	0	0	0	0	0	0	0	0	0	0	322
1992	0	205	726	154	0	37	12	0	0	0	0	0	0	0	0	0	0	1134
1993	0	81	104	158	19	0	0	0	0	0	0	0	0	0	0	0	0	362
1994	10	78	282	220	143	13	26	0	0	0	0	0	0	0	0	0	0	771
1995	223	28	122	304	66	29	7	0	0	0	0	0	0	0	0	0	0	779
1996	10	291	76	293	211	53	28	0	0	0	0	0	0	0	0	0	0	961
1997	0	161	394	181	58	84	29	0	0	0	0	0	0	0	0	0	0	907
1998	0	171	684	480	65	109	0	0	29	0	0	0	0	0	0	0	0	1538
1999	0	15	14	249	124	32	0	0	0	0	0	0	0	0	0	0	0	434
2000	30	55	204	68	89	46	0	0	0	0	0	0	0	0	0	0	0	493
2001	25	74	106	257	38	75	12	12	0	0	0	0	0	0	0	0	0	598
2002	122	110	635	712	2499	170	211	17	0	0	0	0	0	0	0	0	0	4476
2003	76	0	24	100	70	17	0	6	0	0	0	0	0	0	0	0	0	293
2004	108	422	68	840	385	545	436	103	30	0	30	0	0	0	0	0	0	2969
2005	21	29	508	114	251	43	0	10	0	0	0	0	0	0	0	0	0	976
2006	0	146	123	530	37	263	16	16	16	16	0	0	0	0	0	0	0	1162
2007	60	22	136	7	69	0	7	0	0	0	0	0	0	0	0	0	0	302
2008	0	74	170	55	15	98	15	15	0	0	0	0	0	0	0	0	0	442
2009	54	37	194	280	39	18	11	0	0	0	0	0	0	0	0	0	0	633
2010	434	27	79	74	121	20	0	0	0	0	0	0	0	0	0	0	0	755

Table 13. Beginning of year population weights at age (kg) derived from DFO and NMFS spring surveys. The weight at age for age group 10+ was derived from catch number weighted fishery weight at age.

Year/Age	1	2	3	4	5	6	7	8	9	10+
1970	0.09	0.84	1.74	2.60	4.80	5.64	8.15	7.99	11.43	14.64
1971	0.12	0.81	1.80	2.35	4.37	5.38	6.45	7.99	7.38	14.64
1972	0.08	0.87	1.98	2.96	3.48	5.21	5.61	6.54	13.81	14.64
1973	0.09	0.80	1.89	2.96	3.25	3.43	7.72	7.13	10.00	14.64
1974	0.15	0.61	1.70	2.64	4.17	5.81	7.45	7.75	8.15	14.64
1975	0.11	1.13	2.35	2.75	3.73	5.18	7.71	7.57	9.15	14.64
1976	0.14	0.95	2.16	3.00	3.75	5.34	8.01	7.38	9.15	14.64
1977	0.12	0.91	2.13	3.36	6.18	5.50	6.67	5.66	9.15	14.64
1978	0.11	0.89	1.62	3.56	5.41	6.25	8.63	8.97	10.23	14.64
1979	0.11	0.87	1.74	3.00	4.56	5.19	9.63	10.88	10.98	14.64
1980	0.28	0.71	1.89	2.79	5.24	6.28	5.92	8.97	11.76	14.64
1981	0.09	0.85	1.83	3.34	4.97	6.86	8.18	12.71	11.26	14.64
1982	0.09	0.87	2.22	3.05	4.11	6.43	8.06	8.83	10.78	14.64
1983	0.22	1.13	1.87	2.26	3.13	6.01	8.15	8.65	10.53	14.64
1984	0.05	0.58	1.95	2.44	2.70	4.12	5.89	8.97	10.28	14.64
1985	0.09	0.65	1.93	3.20	3.78	5.83	8.77	9.87	14.11	14.64
1986	0.13	0.77	1.74	3.22	4.92	5.70	7.44	8.99	10.68	14.64
1987	0.15	0.85	1.70	2.69	5.67	7.49	7.48	6.66	10.10	14.64
1988	0.15	0.93	1.79	3.02	4.17	6.27	8.44	8.72	12.33	14.64
1989	0.14	0.83	1.70	2.76	4.31	6.43	7.62	7.81	11.32	14.64
1990	0.21	0.79	1.84	2.90	4.36	6.00	8.59	9.52	13.49	14.64
1991	0.09	0.90	1.95	3.17	4.24	4.90	7.54	10.06	9.97	14.64
1992	0.13	0.85	2.05	2.79	4.16	6.13	6.98	8.55	10.45	14.64
1993	0.07	0.95	1.84	2.91	4.51	5.89	7.00	7.38	9.34	14.64
1994	0.14	0.66	1.43	2.63	3.95	7.46	7.33	8.66	9.21	14.64
1995	0.18	0.79	1.59	2.25	3.47	4.70	6.69	7.92	11.83	14.64
1996	0.09	0.84	1.55	2.60	3.91	6.11	5.46	12.03	11.92	14.64
1997	0.19	0.72	1.69	2.18	3.22	6.20	6.20	9.80	10.17	14.64
1998	0.08	0.65	1.38	2.26	3.03	4.52	5.83	7.79	8.21	14.64
1999	0.11	1.00	1.35	2.24	2.97	4.63	6.51	8.25	8.57	14.64
2000	0.06	0.90	1.59	2.33	3.23	4.46	6.50	8.21	11.52	14.64
2001	0.01	0.77	1.42	2.58	3.60	5.09	6.91	7.55	10.09	11.65
2002	0.02	0.49	1.21	2.27	3.54	4.38	5.86	8.44	10.00	11.65
2003	0.02	0.44	1.14	1.88	3.05	3.36	5.12	6.70	7.66	11.65
2004	0.02	0.29	1.45	2.45	3.45	4.09	4.31	6.32	9.92	11.65
2005	0.06	0.59	1.17	1.77	2.97	3.30	3.94	7.66	6.45	11.65
2006	0.03	0.31	1.15	1.57	2.62	3.18	4.62	4.68	5.73	11.65
2007	0.05	0.63	1.07	1.76	2.62	4.10	5.79	6.81	7.98	11.65
2008	0.05	0.58	1.45	2.04	2.50	3.47	4.16	7.93	10.05	11.65
2009	0.11	0.72	1.47	2.48	2.70	3.53	4.48	5.59	8.28	11.65
2010	0.08	0.66	1.58	2.21	3.19	3.50	3.96	5.38	6.52	11.65
2011	0.04	0.48	1.19	2.04	2.71	3.58	3.67	4.48	5.08	11.65
Average	0.10	0.76	1.67	2.60	3.83	5.16	6.65	8.04	9.88	13.83
Minimum	0.01	0.29	1.07	1.57	2.50	3.18	3.67	4.48	5.08	11.65
Maximum	0.28	1.13	2.35	3.56	6.18	7.49	9.63	12.71	14.11	14.64

Table 14. Statistical properties of estimates for population abundance (numbers in thousands) at beginning of year 2011 and survey calibration constants (unitless, survey:population) from the "split M 0.2" benchmark model formulation for eastern Georges Bank cod obtained from a bootstrap with 1000 replications.

Parameter	Estimate	Standard Error	Relative Error	Bias	Relative Bias
N[2011 2]	742	353	47%	69	9%
N[2011 3]	606	207	34%	32	5%
N[2011 4]	395	139	35%	19	5%
N[2011 5]	345	130	38%	13	4%
N[2011 6]	90	40	44%	6	7%
N[2011 7]	24	11	47%	2	7%
N[2011 8]	82	38	46%	6	7%
N[2011 9]	16	10	60%	1	8%
DFO 1986-1993 age 1	0.024	0.008	32%	0.001	6%
DFO 1986-1993 age 2	0.217	0.072	33%	0.010	5%
DFO 1986-1993 age 3	0.413	0.142	34%	0.024	6%
DFO 1986-1993 age 4	0.398	0.133	33%	0.018	5%
DFO 1986-1993 age 5	0.642	0.209	33%	0.036	6%
DFO 1986-1993 age 6	0.663	0.228	34%	0.038	6%
DFO 1986-1993 age 7	0.770	0.257	33%	0.045	6%
DFO 1986-1993 age 8	1.029	0.349	34%	0.050	5%
DFO 1994-2011 age 1	0.012	0.003	25%	0.000	3%
DFO 1994-2011 age 2	0.125	0.026	21%	0.002	2%
DFO 1994-2011 age 3	0.969	0.208	21%	0.018	2%
DFO 1994-2011 age 4	2.377	0.523	22%	0.059	2%
DFO 1994-2011 age 5	3.280	0.722	22%	0.085	3%
DFO 1994-2011 age 6	4.153	0.924	22%	0.147	4%
DFO 1994-2011 age 7	4.273	0.979	23%	0.114	3%
DFO 1994-2011 age 8	3.903	0.838	21%	0.077	2%
NMFS Spring Y41 1978-1981 age 1	0.017	0.009	53%	0.002	13%
NMFS Spring Y41 1978-1981 age 2	0.193	0.122	63%	0.025	13%
NMFS Spring Y41 1978-1981 age 3	0.216	0.118	55%	0.023	11%
NMFS Spring Y41 1978-1981 age 4	0.209	0.114	54%	0.024	11%
NMFS Spring Y41 1978-1981 age 5	0.309	0.164	53%	0.040	13%
NMFS Spring Y41 1978-1981 age 6	0.296	0.144	49%	0.028	9%
NMFS Spring Y41 1978-1981 age 7	0.380	0.196	52%	0.041	11%
NMFS Spring Y41 1978-1981 age 8	0.332	0.169	51%	0.037	11%
NMFS Spring Y36 1982-1993 age 1	0.028	0.008	30%	0.001	3%
NMFS Spring Y36 1982-1993 age 2	0.131	0.035	26%	0.005	4%
NMFS Spring Y36 1982-1993 age 3	0.259	0.068	26%	0.005	2%
NMFS Spring Y36 1982-1993 age 4	0.315	0.084	27%	0.008	3%
NMFS Spring Y36 1982-1993 age 5	0.385	0.109	28%	0.014	4%
NMFS Spring Y36 1982-1993 age 6	0.407	0.111	27%	0.007	2%
NMFS Spring Y36 1982-1993 age 7	0.348	0.095	27%	0.009	3%
NMFS Spring Y36 1982-1993 age 8	0.382	0.103	27%	0.010	3%
NMFS Spring Y36 1994-2011 age 1	0.037	0.011	29%	0.001	3%
NMFS Spring Y36 1994-2011 age 2	0.142	0.030	21%	0.003	2%
NMFS Spring Y36 1994-2011 age 3	0.533	0.115	22%	0.013	2%
NMFS Spring Y36 1994-2011 age 4	1.172	0.255	22%	0.025	2%
NMFS Spring Y36 1994-2011 age 5	1.506	0.325	22%	0.038	3%
NMFS Spring Y36 1994-2011 age 6	1.374	0.289	21%	0.034	2%
NMFS Spring Y36 1994-2011 age 7	1.517	0.340	22%	0.037	2%
NMFS Spring Y36 1994-2011 age 8	1.538	0.429	28%	0.061	4%
NMFS Fall 1978-1993 age 1	0.071	0.016	23%	0.001	2%
NMFS Fall 1978-1993 age 2	0.068	0.015	22%	0.001	2%
NMFS Fall 1978-1993 age 3	0.097	0.022	23%	0.004	4%
NMFS Fall 1978-1993 age 4	0.055	0.013	24%	0.001	3%
NMFS Fall 1978-1993 age 5	0.045	0.012	26%	0.001	2%
NMFS Fall 1994-2010 age 1	0.055	0.013	23%	0.001	2%
NMFS Fall 1994-2010 age 2	0.143	0.031	22%	0.002	2%
NMFS Fall 1994-2010 age 3	0.259	0.057	22%	0.005	2%
NMFS Fall 1994-2010 age 4	0.252	0.054	21%	0.002	1%
NMFS Fall 1994-2010 age 5	0.306	0.070	23%	0.005	2%

Table 15. Statistical properties of estimates for population abundance (numbers in thousands) at beginning of year 2011 and survey calibration constants (unitless, survey:population) from the "split M 0.5" benchmark model formulation for eastern Georges Bank cod obtained from a bootstrap with 1000 replications.

Parameter	Estimate	Standard Error	Relative Error	Bias	Relative Bias
N[2011 2]	894	405	45%	81	9%
N[2011 3]	738	264	36%	30	4%
N[2011 4]	509	173	34%	18	3%
N[2011 5]	504	182	36%	23	5%
N[2011 6]	177	65	37%	7	4%
N[2011 7]	44	16	36%	2	5%
N[2011 8]	210	66	31%	5	2%
N[2011 9]	20	9	44%	1	5%
DFO 1986-1993 age 1	0.023	0.008	35%	0.001	5%
DFO 1986-1993 age 2	0.210	0.071	34%	0.013	6%
DFO 1986-1993 age 3	0.403	0.136	34%	0.027	7%
DFO 1986-1993 age 4	0.385	0.125	32%	0.016	4%
DFO 1986-1993 age 5	0.616	0.202	33%	0.041	7%
DFO 1986-1993 age 6	0.637	0.214	34%	0.033	5%
DFO 1986-1993 age 7	0.735	0.243	33%	0.028	4%
DFO 1986-1993 age 8	0.984	0.324	33%	0.045	5%
DFO 1994-2011 age 1	0.010	0.003	26%	0.000	4%
DFO 1994-2011 age 2	0.104	0.023	22%	0.002	2%
DFO 1994-2011 age 3	0.793	0.171	22%	0.018	2%
DFO 1994-2011 age 4	1.842	0.395	21%	0.053	3%
DFO 1994-2011 age 5	2.232	0.469	21%	0.017	1%
DFO 1994-2011 age 6	2.356	0.533	23%	0.095	4%
DFO 1994-2011 age 7	2.511	0.546	22%	0.055	2%
DFO 1994-2011 age 8	2.300	0.535	23%	0.072	3%
NMFS Spring Y41 1978-1981 age 1	0.017	0.009	52%	0.002	9%
NMFS Spring Y41 1978-1981 age 2	0.193	0.121	63%	0.030	15%
NMFS Spring Y41 1978-1981 age 3	0.216	0.108	50%	0.023	11%
NMFS Spring Y41 1978-1981 age 4	0.209	0.103	49%	0.018	9%
NMFS Spring Y41 1978-1981 age 5	0.309	0.152	49%	0.030	10%
NMFS Spring Y41 1978-1981 age 6	0.296	0.159	54%	0.035	12%
NMFS Spring Y41 1978-1981 age 7	0.380	0.189	50%	0.037	10%
NMFS Spring Y41 1978-1981 age 8	0.332	0.171	51%	0.033	10%
NMFS Spring Y36 1982-1993 age 1	0.027	0.008	29%	0.001	3%
NMFS Spring Y36 1982-1993 age 2	0.128	0.034	26%	0.003	2%
NMFS Spring Y36 1982-1993 age 3	0.254	0.066	26%	0.006	2%
NMFS Spring Y36 1982-1993 age 4	0.308	0.081	26%	0.014	5%
NMFS Spring Y36 1982-1993 age 5	0.371	0.108	29%	0.018	5%
NMFS Spring Y36 1982-1993 age 6	0.393	0.112	29%	0.016	4%
NMFS Spring Y36 1982-1993 age 7	0.336	0.090	27%	0.011	3%
NMFS Spring Y36 1982-1993 age 8	0.369	0.100	27%	0.013	4%
NMFS Spring Y36 1994-2011 age 1	0.031	0.008	26%	0.001	2%
NMFS Spring Y36 1994-2011 age 2	0.118	0.027	23%	0.002	2%
NMFS Spring Y36 1994-2011 age 3	0.433	0.096	22%	0.009	2%
NMFS Spring Y36 1994-2011 age 4	0.897	0.199	22%	0.023	3%
NMFS Spring Y36 1994-2011 age 5	1.001	0.212	21%	0.014	1%
NMFS Spring Y36 1994-2011 age 6	0.781	0.176	23%	0.021	3%
NMFS Spring Y36 1994-2011 age 7	0.880	0.200	23%	0.035	4%
NMFS Spring Y36 1994-2011 age 8	0.906	0.248	27%	0.039	4%
NMFS Fall 1978-1993 age 1	0.070	0.015	22%	0.001	1%
NMFS Fall 1978-1993 age 2	0.066	0.015	23%	0.002	2%
NMFS Fall 1978-1993 age 3	0.095	0.022	23%	0.003	3%
NMFS Fall 1978-1993 age 4	0.054	0.013	25%	0.002	3%
NMFS Fall 1978-1993 age 5	0.044	0.011	25%	0.002	4%
NMFS Fall 1994-2010 age 1	0.046	0.010	23%	0.001	3%
NMFS Fall 1994-2010 age 2	0.118	0.025	21%	0.003	3%
NMFS Fall 1994-2010 age 3	0.206	0.044	22%	0.006	3%
NMFS Fall 1994-2010 age 4	0.184	0.042	23%	0.005	3%
NMFS Fall 1994-2010 age 5	0.188	0.040	21%	0.003	2%

Table 16. Mohn's rho calculations for the "split M 0.2" and the "split M 0.5" models.

	"Split M 0.2"			"Split M 0.5"		
Peel	**Age 1**	**3+ Biomass**	**F**	**Age 1**	**3+ Biomass**	**F**
1	0.152	0.547	-0.442	0.168	0.419	-0.321
2	-0.045	0.748	-0.470	-0.031	0.486	-0.315
3	-0.359	1.411	-0.533	-0.354	0.912	-0.409
4	1.116	1.526	-0.442	1.074	1.059	-0.393
5	0.600	1.532	-0.399	0.521	1.156	-0.388
6	3.807	0.489	-0.458	2.826	0.457	-0.435
7	-0.629	-0.097	0.036	-0.769	-0.140	0.056
Mohn's Rho	**0.663**	**0.879**	**-0.387**	**0.491**	**0.621**	**-0.315**

Table 17. Beginning of year population abundance (numbers in thousands) for eastern Georges Bank cod using the "split M 0.2" benchmark model formulation.

Year/Age	1	2	3	4	5	6	7	8	9	10+	1+
1978	12451	3341	10749	3987	1312	714	618	105	111	50	33437
1979	10440	10186	2637	5535	2217	721	438	392	66	102	32734
1980	10038	8534	7537	1500	3167	1327	426	292	266	123	33210
1981	17435	8213	6111	4687	957	1724	768	262	216	258	40630
1982	5680	14243	5949	3329	2637	533	985	466	128	312	34262
1983	5065	4637	8502	3103	1589	1187	262	449	243	272	25308
1984	14178	4127	3091	4707	1381	797	615	109	205	267	29478
1985	5108	11593	3171	1808	2639	642	317	254	54	244	25832
1986	23619	4174	6921	1337	888	1277	284	160	110	193	38963
1987	7602	19300	3011	3635	569	420	637	171	89	211	35645
1988	13332	6204	12100	1706	1946	319	225	365	104	213	36514
1989	4501	10895	4819	6151	788	829	145	81	137	179	28524
1990	6284	3654	8306	3215	3261	441	345	68	30	182	25786
1991	8828	5127	2333	4011	1701	1441	231	146	45	135	23998
1992	2341	7170	3278	1007	1567	588	515	95	58	105	16724
1993	3030	1854	3541	1451	414	491	202	141	38	92	11254
1994	1965	2471	1070	1209	382	75	85	47	30	67	7402
1995	1278	1604	1857	444	292	74	22	16	12	58	5658
1996	2312	1045	1261	1307	279	145	44	12	9	55	6470
1997	3630	1887	819	822	714	158	64	24	6	49	8174
1998	1412	2966	1414	486	353	265	55	20	8	41	7019
1999	3552	1153	2338	875	253	148	97	25	4	35	8479
2000	1391	2902	875	1477	414	110	67	29	8	29	7302
2001	932	1132	2312	616	870	204	57	35	13	27	6197
2002	1580	760	838	1406	315	356	74	18	13	25	5386
2003	499	1293	612	572	752	161	152	34	7	24	4105
2004	2784	409	1024	358	253	254	60	45	11	20	5217
2005	501	2260	323	708	158	77	85	17	10	17	4156
2006	1023	409	1772	215	408	80	35	34	5	17	3997
2007	1584	835	316	1233	107	166	23	13	13	14	4303
2008	970	1295	615	183	646	60	59	9	4	15	3856
2009	903	793	1020	371	96	307	36	19	3	13	3560
2010	824	733	585	639	184	43	132	21	6	12	3178
2011		673	574	376	332	84	22	77	14	13	2166

Table 18. Annual fishing mortality rate for eastern Georges Bank cod using the "split M 0.2" benchmark model formulation.

Year/Age	1	2	3	4	5	6	7	8	9	10+	F4-9
1978	0.00	0.04	0.46	0.39	0.40	0.29	0.26	0.26	0.26	0.24	0.36
1979	0.00	0.10	0.36	0.36	0.31	0.33	0.21	0.19	0.20	0.07	0.33
1980	0.00	0.13	0.27	0.25	0.41	0.35	0.29	0.10	0.21	0.20	0.33
1981	0.00	0.12	0.41	0.38	0.38	0.36	0.30	0.52	0.35	0.11	0.37
1982	0.00	0.32	0.45	0.54	0.60	0.51	0.59	0.45	0.54	0.19	0.56
1983	0.00	0.21	0.39	0.61	0.49	0.46	0.68	0.58	0.62	0.33	0.56
1984	0.00	0.06	0.34	0.38	0.57	0.72	0.68	0.49	0.65	0.33	0.48
1985	0.00	0.32	0.66	0.51	0.53	0.62	0.48	0.64	0.55	0.18	0.53
1986	0.00	0.13	0.44	0.65	0.55	0.50	0.31	0.39	0.34	0.07	0.54
1987	0.00	0.27	0.37	0.42	0.38	0.42	0.36	0.30	0.34	0.06	0.41
1988	0.00	0.05	0.48	0.57	0.65	0.59	0.83	0.78	0.80	0.22	0.64
1989	0.01	0.07	0.20	0.43	0.38	0.68	0.55	0.78	0.63	0.18	0.46
1990	0.00	0.25	0.53	0.44	0.62	0.45	0.66	0.22	0.59	0.20	0.53
1991	0.01	0.25	0.64	0.74	0.86	0.83	0.69	0.73	0.70	0.25	0.78
1992	0.03	0.51	0.61	0.69	0.96	0.87	1.09	0.73	1.04	0.13	0.89
1993	0.00	0.35	0.87	1.13	1.51	1.55	1.25	1.35	1.29	0.26	1.29
1994	0.00	0.09	0.68	1.22	1.44	1.03	1.48	1.14	1.36	0.05	1.27
1995	0.00	0.04	0.15	0.26	0.50	0.32	0.43	0.32	0.39	0.01	0.36
1996	0.00	0.04	0.23	0.41	0.37	0.61	0.40	0.41	0.41	0.01	0.42
1997	0.00	0.09	0.32	0.64	0.79	0.86	0.99	0.90	0.97	0.04	0.74
1998	0.00	0.04	0.28	0.45	0.67	0.80	0.60	1.33	0.79	0.06	0.62
1999	0.00	0.08	0.26	0.55	0.64	0.59	1.00	0.98	1.00	0.03	0.61
2000	0.01	0.03	0.15	0.33	0.51	0.46	0.46	0.62	0.51	0.02	0.38
2001	0.00	0.10	0.30	0.47	0.69	0.82	0.95	0.78	0.88	0.04	0.64
2002	0.00	0.02	0.18	0.43	0.47	0.65	0.59	0.76	0.62	0.15	0.48
2003	0.00	0.03	0.34	0.61	0.88	0.79	1.01	0.95	1.00	0.08	0.80
2004	0.01	0.03	0.17	0.62	0.99	0.90	1.03	1.26	1.13	0.13	0.85
2005	0.00	0.04	0.21	0.35	0.49	0.58	0.71	1.10	0.78	0.11	0.43
2006	0.00	0.06	0.16	0.48	0.70	1.06	0.82	0.79	0.80	0.13	0.69
2007	0.00	0.10	0.34	0.44	0.37	0.83	0.74	0.99	0.83	0.05	0.49
2008	0.00	0.04	0.30	0.44	0.53	0.29	0.94	0.71	0.91	0.07	0.53
2009	0.01	0.10	0.26	0.48	0.57	0.61	0.28	0.88	0.49	0.06	0.54
2010	0.00	0.04	0.22	0.41	0.52	0.40	0.29	0.09	0.28	0.03	0.41

Table 19. Beginning of year population biomass (mt) for eastern Georges Bank cod using the "split M 0.2" benchmark model formulation.

Year/Age	1	2	3	4	5	6	7	8	9	10+	1+	3+
1978	1390	2961	17453	14210	7102	4458	5334	943	1133	732	55716	51365
1979	1173	8837	4589	16578	10119	3739	4216	4263	727	1497	55737	45727
1980	2774	6026	14264	4177	16605	8334	2523	2620	3130	1795	62248	53448
1981	1649	7001	11159	15666	4756	11828	6288	3326	2429	3774	67876	59226
1982	523	12378	13202	10155	10850	3427	7941	4117	1379	4568	68541	55641
1983	1134	5243	15911	7023	4978	7133	2132	3887	2554	3976	53972	47594
1984	715	2400	6041	11502	3727	3285	3620	976	2108	3908	38281	35167
1985	445	7493	6106	5793	9981	3745	2778	2508	768	3576	43194	35255
1986	3099	3215	12055	4302	4369	7275	2110	1442	1171	2824	41861	35547
1987	1140	16309	5123	9761	3228	3143	4766	1140	894	3084	48589	31139
1988	2030	5773	21601	5153	8112	2001	1900	3187	1279	3118	54153	46351
1989	640	9063	8216	16971	3394	5331	1105	629	1547	2616	49513	39810
1990	1349	2877	15308	9319	14223	2647	2964	652	409	2657	52405	48179
1991	775	4598	4553	12702	7219	7053	1740	1469	449	1983	42540	37167
1992	297	6067	6706	2813	6523	3604	3593	813	573	1533	32522	26158
1993	213	1770	6532	4220	1868	2893	1411	1043	348	1352	21649	19666
1994	281	1623	1533	3178	1511	561	626	410	265	976	10964	9060
1995	234	1274	2948	997	1013	349	147	126	147	856	8091	6584
1996	203	876	1959	3395	1091	884	242	141	112	798	9700	8622
1997	689	1352	1388	1789	2297	977	400	238	64	722	9916	7874
1998	110	1928	1954	1098	1071	1196	318	152	66	598	8492	6454
1999	393	1154	3156	1957	754	686	633	203	36	507	9478	7930
2000	84	2599	1388	3437	1340	490	435	239	87	423	10523	7840
2001	9	873	3277	1592	3132	1040	391	263	132	287	10996	10113
2002	25	376	1017	3190	1114	1561	432	152	130	271	8269	7868
2003	8	570	698	1077	2289	540	781	225	53	252	6493	5915
2004	60	118	1489	875	874	1038	257	287	112	212	5322	5144
2005	29	1331	377	1252	470	253	333	134	68	183	4429	3069
2006	31	126	2040	338	1069	253	162	159	27	177	4383	4226
2007	85	522	339	2175	282	681	131	86	101	146	4548	3940
2008	44	747	892	373	1617	207	247	69	38	162	4397	3605
2009	103	575	1499	920	258	1084	159	105	30	137	4870	4192
2010	65	482	921	1416	586	151	522	112	45	123	4422	3875
2011		325	685	766	900	300	82	344	74	137	3612	3288

Table 20. Beginning of year population abundance (numbers in thousands) for eastern Georges Bank cod using the "split M 0.5" benchmark model formulation.

Year/Age	1	2	3	4	5	6	7	8	9	10+	1+
1978	12452	3341	10750	3987	1312	714	618	105	111	50	33440
1979	10442	10187	2637	5535	2217	721	438	392	66	102	32738
1980	10041	8536	7538	1500	3167	1327	426	292	266	123	33216
1981	17443	8215	6112	4688	957	1724	769	262	216	258	40643
1982	5682	14250	5950	3330	2638	533	985	466	128	312	34276
1983	5073	4639	8507	3105	1590	1187	262	449	243	272	25327
1984	14194	4134	3093	4712	1382	798	615	109	205	267	29510
1985	5140	11606	3177	1809	2643	643	317	255	54	245	25889
1986	23705	4200	6932	1342	889	1280	284	161	110	193	39096
1987	7727	19371	3033	3643	573	421	640	172	89	211	35878
1988	13485	6306	12158	1724	1953	322	226	367	104	214	36858
1989	4637	11020	4902	6199	802	835	148	81	138	180	28942
1990	6513	3766	8409	3283	3299	452	350	70	31	184	26357
1991	9056	5315	2424	4094	1757	1472	240	150	47	138	24692
1992	2615	7356	3432	1082	1635	633	540	103	61	108	17564
1993	3436	2078	3693	1576	474	546	238	162	44	97	12344
1994	2310	2804	1253	1332	482	123	129	77	46	76	8632
1995	1487	1887	2130	593	390	155	41	33	24	57	6796
1996	2645	1216	1493	1530	401	225	80	20	17	46	7673
1997	4178	2159	959	1012	896	257	91	38	9	35	9635
1998	1639	3415	1637	601	507	413	93	27	13	23	8368
1999	3988	1339	2706	1057	347	274	149	39	7	17	9922
2000	1545	3258	1027	1778	563	186	120	48	13	12	8551
2001	1066	1258	2604	741	1116	326	84	56	20	13	7283
2002	1912	870	942	1645	417	556	119	27	21	14	6522
2003	699	1565	701	657	947	244	220	49	10	14	5106
2004	4123	573	1247	431	322	412	87	66	16	10	7287
2005	621	3356	457	890	218	133	146	26	18	9	5873
2006	1258	507	2670	325	557	128	57	58	8	11	5579
2007	1915	1027	396	1968	197	287	42	21	23	8	5885
2008	1180	1566	772	248	1246	133	109	17	7	13	5292
2009	1103	965	1242	499	149	798	69	41	7	10	4883
2010	994	897	725	821	289	87	381	35	17	9	4255
2011		813	708	491	480	170	42	205	19	14	2942

Table 21. Annual fishing mortality rate for eastern Georges Bank cod using the "split M 0.5" benchmark model formulation.

Year/Age	1	2	3	4	5	6	7	8	9	10+	F4-9
1978	0.00	0.04	0.46	0.39	0.40	0.29	0.26	0.26	0.26	0.24	0.36
1979	0.00	0.10	0.36	0.36	0.31	0.33	0.20	0.19	0.20	0.07	0.33
1980	0.00	0.13	0.27	0.25	0.41	0.35	0.29	0.10	0.21	0.20	0.33
1981	0.00	0.12	0.41	0.38	0.38	0.36	0.30	0.52	0.35	0.11	0.37
1982	0.00	0.32	0.45	0.54	0.60	0.51	0.58	0.45	0.54	0.19	0.56
1983	0.00	0.21	0.39	0.61	0.49	0.46	0.68	0.58	0.62	0.33	0.56
1984	0.00	0.06	0.34	0.38	0.57	0.72	0.68	0.49	0.65	0.33	0.48
1985	0.00	0.32	0.66	0.51	0.53	0.62	0.48	0.64	0.55	0.18	0.53
1986	0.00	0.13	0.44	0.65	0.55	0.49	0.30	0.39	0.34	0.07	0.54
1987	0.00	0.27	0.36	0.42	0.38	0.42	0.35	0.30	0.34	0.06	0.41
1988	0.00	0.05	0.47	0.56	0.65	0.58	0.82	0.78	0.79	0.21	0.64
1989	0.01	0.07	0.20	0.43	0.37	0.67	0.54	0.77	0.62	0.18	0.46
1990	0.00	0.24	0.52	0.43	0.61	0.43	0.65	0.21	0.57	0.20	0.51
1991	0.01	0.24	0.61	0.72	0.82	0.80	0.65	0.70	0.67	0.24	0.75
1992	0.03	0.49	0.58	0.62	0.90	0.78	1.01	0.65	0.95	0.12	0.81
1993	0.00	0.31	0.82	0.98	1.15	1.24	0.93	1.05	0.98	0.25	1.06
1994	0.00	0.08	0.55	1.03	0.94	0.59	0.88	0.66	0.79	0.05	0.96
1995	0.00	0.03	0.13	0.19	0.35	0.16	0.24	0.17	0.21	0.01	0.24
1996	0.00	0.04	0.19	0.34	0.24	0.41	0.24	0.26	0.24	0.01	0.32
1997	0.00	0.08	0.27	0.49	0.58	0.52	0.71	0.56	0.67	0.06	0.54
1998	0.00	0.03	0.24	0.35	0.42	0.52	0.36	0.92	0.49	0.12	0.42
1999	0.00	0.07	0.22	0.43	0.42	0.33	0.64	0.59	0.63	0.06	0.43
2000	0.01	0.02	0.13	0.27	0.35	0.29	0.27	0.39	0.30	0.06	0.29
2001	0.00	0.09	0.26	0.38	0.50	0.51	0.63	0.49	0.57	0.11	0.47
2002	0.00	0.02	0.16	0.35	0.34	0.43	0.38	0.51	0.41	0.35	0.37
2003	0.00	0.03	0.29	0.51	0.63	0.53	0.70	0.65	0.69	0.17	0.59
2004	0.01	0.02	0.14	0.48	0.69	0.54	0.69	0.82	0.75	0.31	0.58
2005	0.00	0.03	0.14	0.27	0.33	0.35	0.41	0.70	0.46	0.24	0.31
2006	0.00	0.05	0.10	0.29	0.46	0.62	0.50	0.45	0.48	0.23	0.43
2007	0.00	0.08	0.26	0.25	0.18	0.46	0.39	0.57	0.45	0.09	0.28
2008	0.00	0.03	0.23	0.30	0.24	0.14	0.47	0.35	0.46	0.09	0.26
2009	0.01	0.08	0.20	0.33	0.32	0.22	0.16	0.36	0.24	0.09	0.27
2010	0.00	0.03	0.17	0.31	0.30	0.21	0.11	0.09	0.11	0.05	0.25

Table 22. Beginning of year population biomass (mt) for eastern Georges Bank cod using the "split M 0.5" benchmark model formulation.

Year/Age	1	2	3	4	5	6	7	8	9	10+	1+	3+
1978	1391	2961	17453	14211	7102	4459	5335	943	1133	732	55720	51369
1979	1173	8838	4589	16579	10120	3739	4217	4264	727	1497	55743	45731
1980	2775	6028	14265	4178	16607	8335	2523	2621	3131	1795	62257	53455
1981	1650	7003	11161	15668	4757	11830	6289	3327	2429	3775	67890	59237
1982	523	12384	13206	10158	10853	3428	7943	4118	1379	4570	68563	55656
1983	1136	5246	15922	7026	4981	7136	2133	3889	2555	3978	54001	47619
1984	715	2404	6044	11514	3730	3288	3622	977	2109	3910	38314	35195
1985	448	7502	6117	5798	9996	3750	2782	2512	769	3580	43253	35303
1986	3110	3235	12074	4316	4374	7294	2116	1446	1174	2828	41965	35621
1987	1159	16369	5160	9784	3249	3150	4786	1144	898	3091	48788	31260
1988	2053	5868	21704	5205	8142	2020	1906	3206	1285	3128	54516	46595
1989	660	9167	8358	17101	3455	5368	1123	634	1567	2630	50064	40236
1990	1398	2966	15497	9517	14392	2716	3005	670	416	2689	53264	48901
1991	795	4766	4731	12966	7455	7207	1811	1507	464	2015	43718	38158
1992	332	6224	7019	3021	6805	3880	3771	879	604	1578	34112	27556
1993	241	1984	6812	4582	2141	3215	1666	1194	406	1426	23666	21441
1994	331	1841	1795	3501	1907	920	944	663	410	1109	13421	11249
1995	272	1498	3380	1332	1356	726	276	258	287	828	10213	8443
1996	232	1019	2318	3974	1567	1376	435	237	199	673	12029	10778
1997	794	1548	1625	2201	2883	1594	563	373	93	519	12192	9851
1998	128	2220	2263	1356	1539	1864	542	211	108	338	10568	8220
1999	442	1340	3652	2365	1032	1268	971	324	55	254	11703	9922
2000	93	2918	1630	4137	1821	830	780	393	152	176	12930	9918
2001	11	970	3691	1914	4018	1658	584	421	202	149	13617	12636
2002	30	430	1143	3732	1474	2439	694	230	207	159	10539	10078
2003	11	690	801	1236	2884	820	1124	329	76	165	8135	7434
2004	89	165	1813	1055	1112	1685	375	418	164	120	6995	6741
2005	36	1976	534	1575	647	437	573	202	114	106	6199	4187
2006	39	156	3073	511	1459	409	262	273	45	129	6357	6162
2007	103	643	425	3471	517	1178	242	142	180	97	6997	6251
2008	54	904	1120	507	3120	461	455	136	71	155	6983	6025
2009	126	699	1825	1239	403	2813	311	229	62	117	7825	7000
2010	79	589	1142	1818	921	304	1512	188	124	105	6781	6113
2011		392	844	1000	1302	607	153	919	97	167	5480	5088

Table 23. Projection inputs for eastern Georges Bank cod using the benchmark model formulations.

	Age Group									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
Natural Mortality("split M 0.2" model)										
2011-2012	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Natural Mortality("split M 0.5" model)										
2011-2012	0.2	0.2	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5
Fishery Partial Recruitment("split M 0.2" model)										
2011-2012	0.01	0.1	0.5	0.8	1	1	1	1	1	0.2
Fishery Partial Recruitment("split M 0.5" model)										
2011-2012	0.01	0.2	0.7	1	1	1	1	1	1	0.3
Fishery Weight at Age										
2011	0.40	1.32	2.09	2.87	3.60	4.38	5.58	6.08	8.92	11.65
2012	0.40	1.32	2.09	2.87	3.60	4.38	5.58	6.88	6.93	11.65
Population Beginning of Year Weight at Age										
2012	0.05	0.63	1.42	2.30	2.90	3.60	4.20	5.15	5.30	11.65
2013	0.05	0.63	1.42	2.30	2.90	3.60	4.20	5.15	7.13	9.94

Table 24. Deterministic projection results for eastern Georges Bank cod from benchmark model formulations. Shaded value show the 2003 year class (in grey) and the 2006 year class (in yellow).

A. "split M 0.2" model

	Age Group											
	1	2	3	4	5	6	7	8	9	10+	1+	4+
Fishing Mortality												
2011	0.003	0.035	0.174	0.278	0.347	0.347	0.347	0.347	0.347	0.069		
2012	0.002	0.018	0.09	0.144	0.18	0.18	0.18	0.18	0.18	0.036		
Projected Population Numbers												
2011	1210	681	568	374	321	85	22	78	14	13		
2012	1210	987	538	391	232	186	49	13	45	18		
2013	1210	989	794	403	277	159	127	34	9	45		
Projected Population Biomass												
2011	48	327	676	764	870	306	81	348	72	150	3643	2591
2012	61	622	765	900	673	669	207	66	238	211	4411	2964
2013	61	623	1127	927	804	572	534	174	62	448	5331	3520
Projected Catch Numbers												
2011	4	21	82	83	86	23	6	21	4	1		
2012	2	16	42	48	35	28	7	2	7	1		
Projected Catch Biomass												
2011	2	28	172	237	309	100	33	126	34	9	1050	
2012	1	21	88	137	125	122	41	13	47	7	602	

B. "split M 0.5" model

	Age Group											
	1	2	3	4	5	6	7	8	9	10+	1+	4+
Fishing Mortality												
2011	0.002	0.039	0.135	0.193	0.193	0.193	0.193	0.193	0.193	0.058		
2012	0.002	0.036	0.126	0.18	0.18	0.18	0.18	0.18	0.18	0.054		
Projected Population Numbers												
2011	1500	673	574	376	332	84	22	77	14	13		
2012	1500	1224	533	396	234	193	49	13	45	18		
2013	1500	1226	984	399	281	160	132	33	9	45		
Projected Population Biomass												
2011	60	390	843	1002	1302	607	153	918	97	167	5538	4245
2012	75	772	909	1165	961	1167	356	107	543	207	6262	4506
2013	75	772	1375	1063	1004	816	690	221	75	471	6562	4340
Projected Catch Numbers												
2011	3	28	81	78	77	24	6	29	3	1		
2012	2	39	69	76	50	42	11	3	13	1		
Projected Catch Biomass												
2011	1	37	170	225	276	103	32	174	24	7	1050	
2012	1	52	144	218	179	186	62	19	93	9	960	

Table 25. Comparison of eastern Georges Bank cod TRAC catch advice, TMGC quota decision, actual catch, and resulting fishing mortality and biomass changes.

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch[1] /Compared to Risk Analysis	Actual F Result[2]
		Amount	**Rationale**	**Amount**	**Rationale**		
1999[3]	1999	3,100 mt		NA	NA	3,000 mt	*Near* $F_{0.1}$
2000	2000	3,750 mt	$F_{0.1}$	NA	NA	2,250 mt	*Less than* $F_{0.1}$
2001	2001	3,500 mt	$F_{0.1}$	NA	NA	3,500 mt	*Above* $F_{0.1}$
2002	2002	1,900 mt	$F_{0.1}$	NA	NA	2,800 mt	*F = 0.23*
Transition to TMGC process in following year; note catch year differs from TRAC year in following lines							
2003	2004	1,300 mt	Neutral risk of exceeding Fref. 20% chance of decrease in biomass from 2004-2005.	1,300 mt	Neutral risk of exceeding Fref. 20% chance of decrease in biomass from 2004-2005.	2,332 mt Exceed Fref and biomass to decline	*F=0.16* *Biomass decreased 23%* Now F = 0.85 – 0.58 Age 3+ biomass decreased 40%/37% 04 - 05
2004	2005	1,100 mt	Neutral risk of exceeding Fref. Greater than 50% risk of decline in biomass from 2005 - 2006.	1,000 mt	Low risk of exceeding Fref, neutral risk of stock decline	1,287 mt Greater than neutral risk of exceeding $F_{0.1}$; biomass expected to decline 10%	*F=0.10* *Biomass stabled* Now F = 0.43 – 0.31 Age 3+ biomass increased 38%/47% 05 - 06
2005	2006	2,200 mt	Neutral risk of exceeding Fref. Low risk of less than 10% biomass increase from 2006 - 2007.	1,700 mt	Low risk of exceeding Fref, 75% probability of stock increase of 10%	1,705 mt Approx 25% risk of exceeding Fref; biomass increase not likely to be 20%	*F=0.15* *Biomass stabled* Now F = 0.69 – 0.43 Age 3+ biomass changed -7%/+2% 06 - 07
2006[4]	2007	(1) 2,900 mt (2) 1,500 mt	(1) Neutral risk of exceeding Fref. (2) Neutral risk of biomass decline from 2007 – 2008.	1,900 mt	Low risk of exceeding Fref, nominal decline in stock size	1,811mt No risk of exceeding Fref; neutral risk of biomass decline	*F=0.13* *Biomass stabled* Now F = 0.49 – 0.28; Age 3+ biomass decreased 9%/4% from 07-08

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch[1] /Compared to Risk Analysis	Actual F Result[2]
2007[4]	2008	2,700 mt	Neutral risk of exceeding Fref and a neutral risk of stock decline from 2008 - 2009	2,300 mt	Low risk of exceeding Fref, nominal stock size increase	1,780 mt No risk of exceeding Fref; biomass not expected to increase 10%	*F = 0.25 or 0.17* *Biomass increased 16%/19%* Now 0.53 or 0.26; Age 3+ biomass increased 16% from 08-09;
2008[4]	2009	(1) 2,100 mt (2) 1,300 mt	(1) Neutral risk of exceeding Fref (2) neutral risk of stock decline from 2009 - 2010	1,700 mt	Low risk of exceeding Fref, high risk biomass will not increase	1,837 mt Slightly less than neutral risk of exceeding Fref; biomass almost certain not to increase	*F = 0.33 or 0.20* *Biomass stable or declined 7%* Now 0.54 or 0.27; Age 3+ biomass decreased 8%/13% from 09-10
2009[4]	2010	(1) 1,300 – 1,700 mt (2) 1,800 mt – 900 mt	(1) Neutral risk of exceeding Fref (2) Neutral risk of stock decline from 2010 - 2011	1,350 mt	Neutral risk of biomass decline	1,326 mt	F = 0.41 or 0.25 Age 3+ biomass decreased 15%/ 17%
2010[4]	2011	(1) 1,000 – 1,400 mt (2) 1,850 mt – 1,350 mt	(1) Neutral risk of exceeding Fref (2) Neutral risk of stock decline from 2010 - 2011				

[1] All catches are calendar year catches.
[2] Values in italics are assessment results in year immediately following the catch year; values in normal font are results from this assessment.
[3] Prior to implementation of US/CA Understanding.
[4] Advice and results reported for two assessment models.

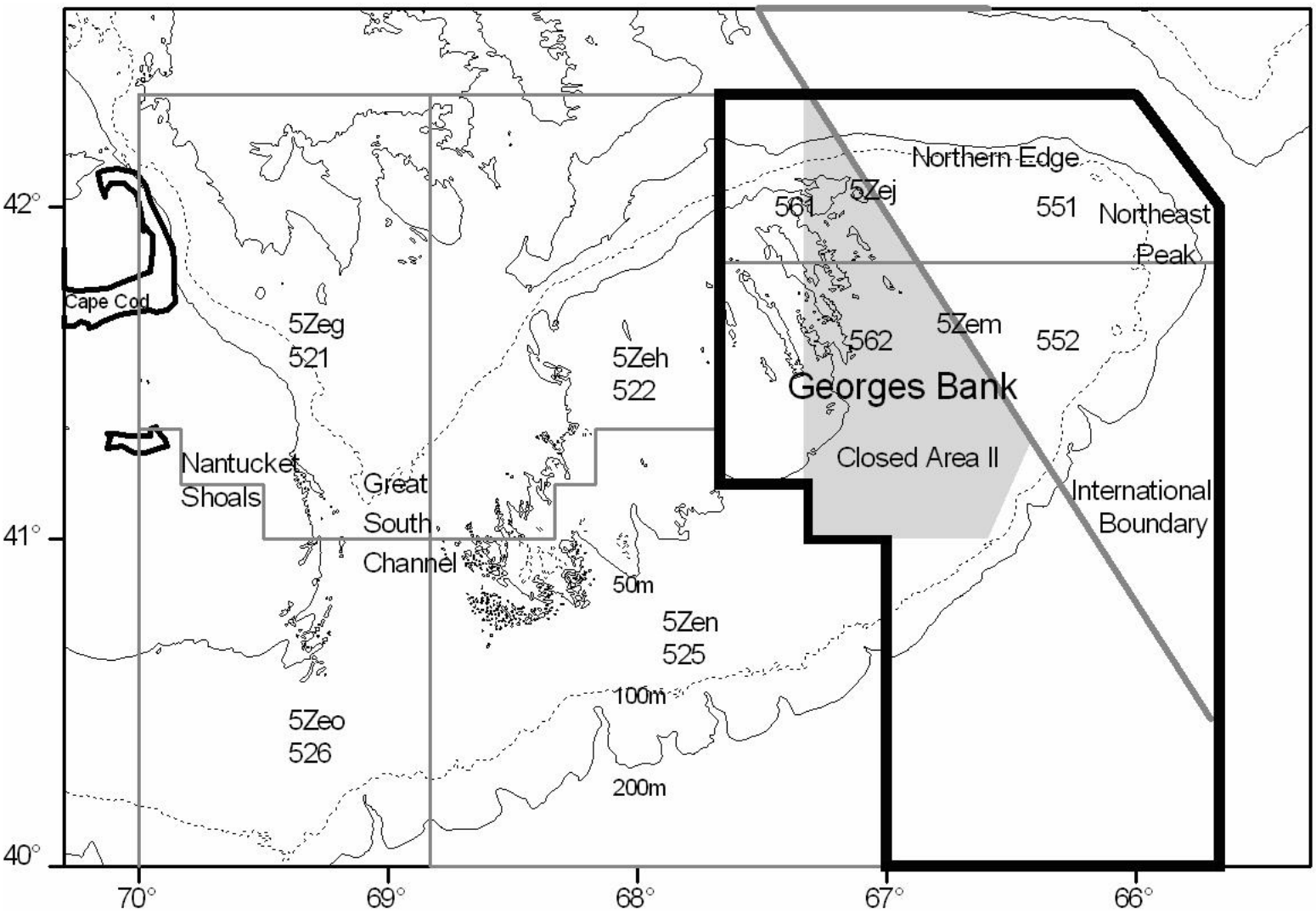


Figure 1. Fisheries statistical unit areas in NAFO Subdivision 5Ze. The eastern Georges Bank management unit is outlined by a heavy black line.

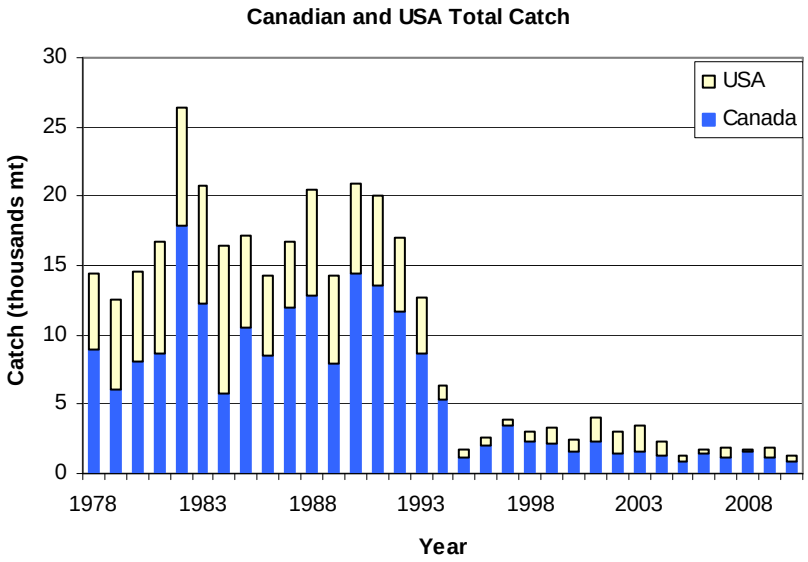


Figure 2. Catches of cod from eastern Georges Bank, 1978 to 2010.

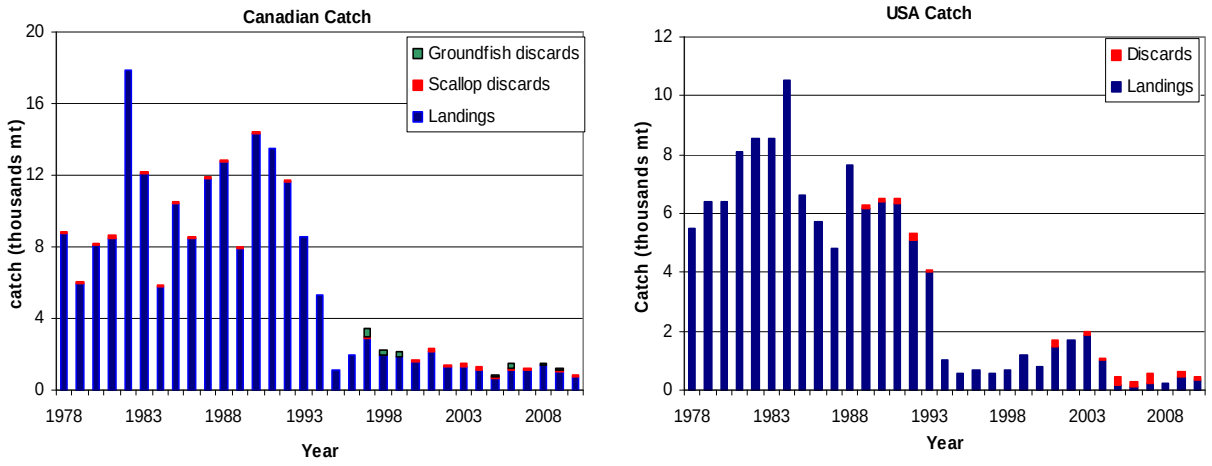


Figure 3. Canadian and USA landings and discards of cod from eastern Georges Bank, 1978 to 2010.

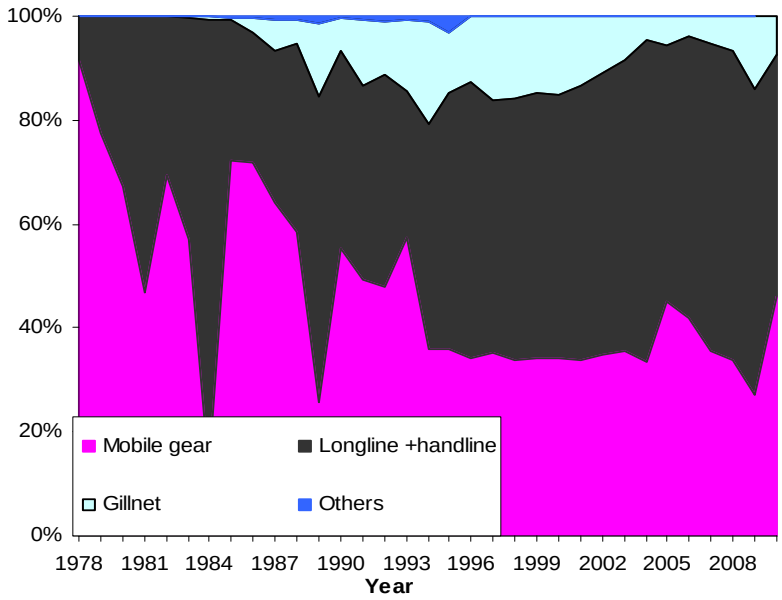


Figure 4. Proportion of Canadian gear specific landings of cod from eastern Georges Bank for 1978 to 2010.

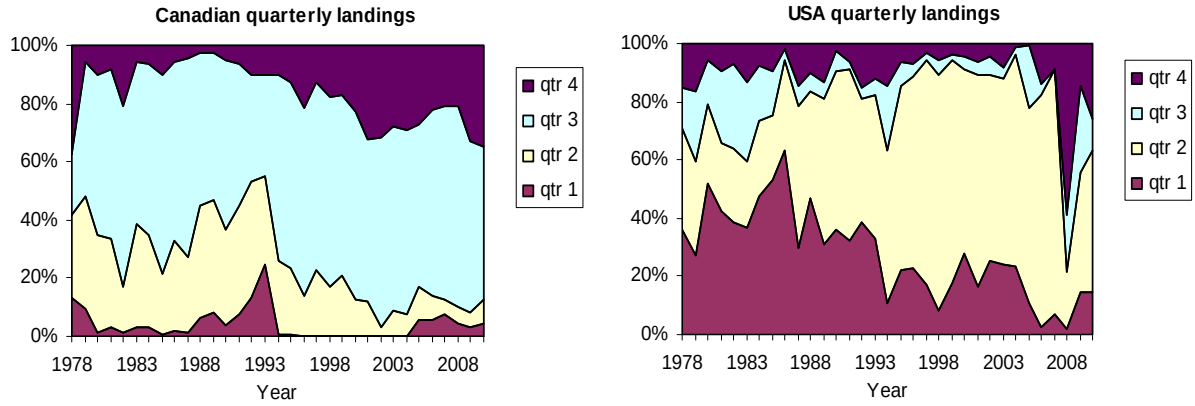


Figure 5. Proportion of Canadian and USA quarterly landings of cod from eastern Georges Bank, 1978 to 2010.

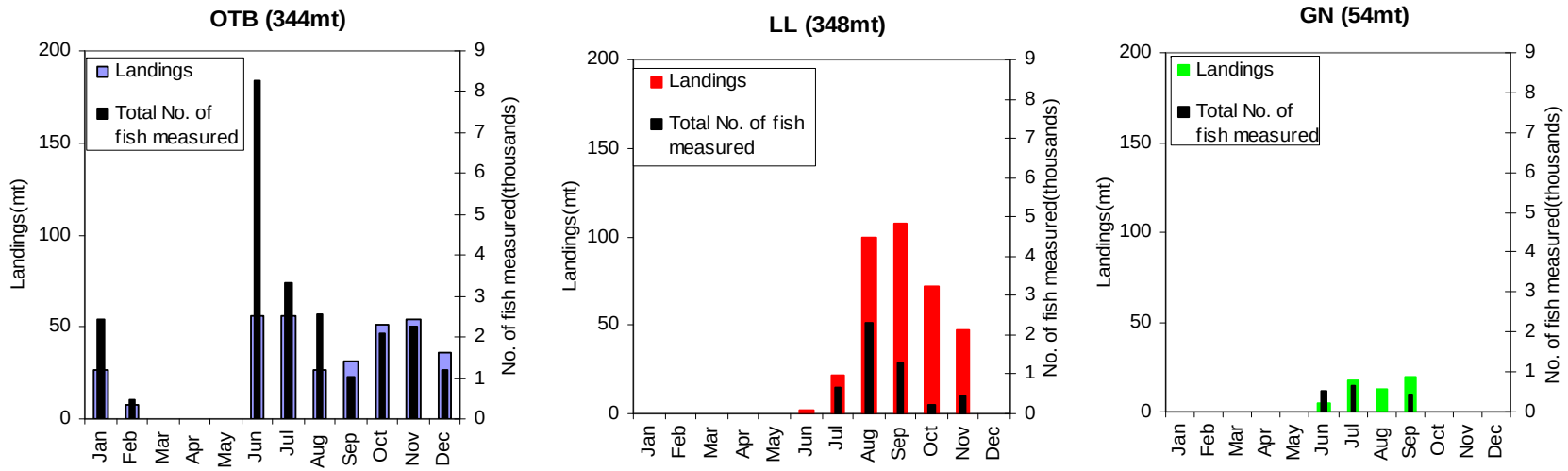


Figure 6. Landings (wide bars) and sampling (narrow dark bars) of cod by gear and month from the 2010 Canadian bottom trawl (OTB), longline (LL) and gillnet (GN) fisheries on eastern Georges Bank.

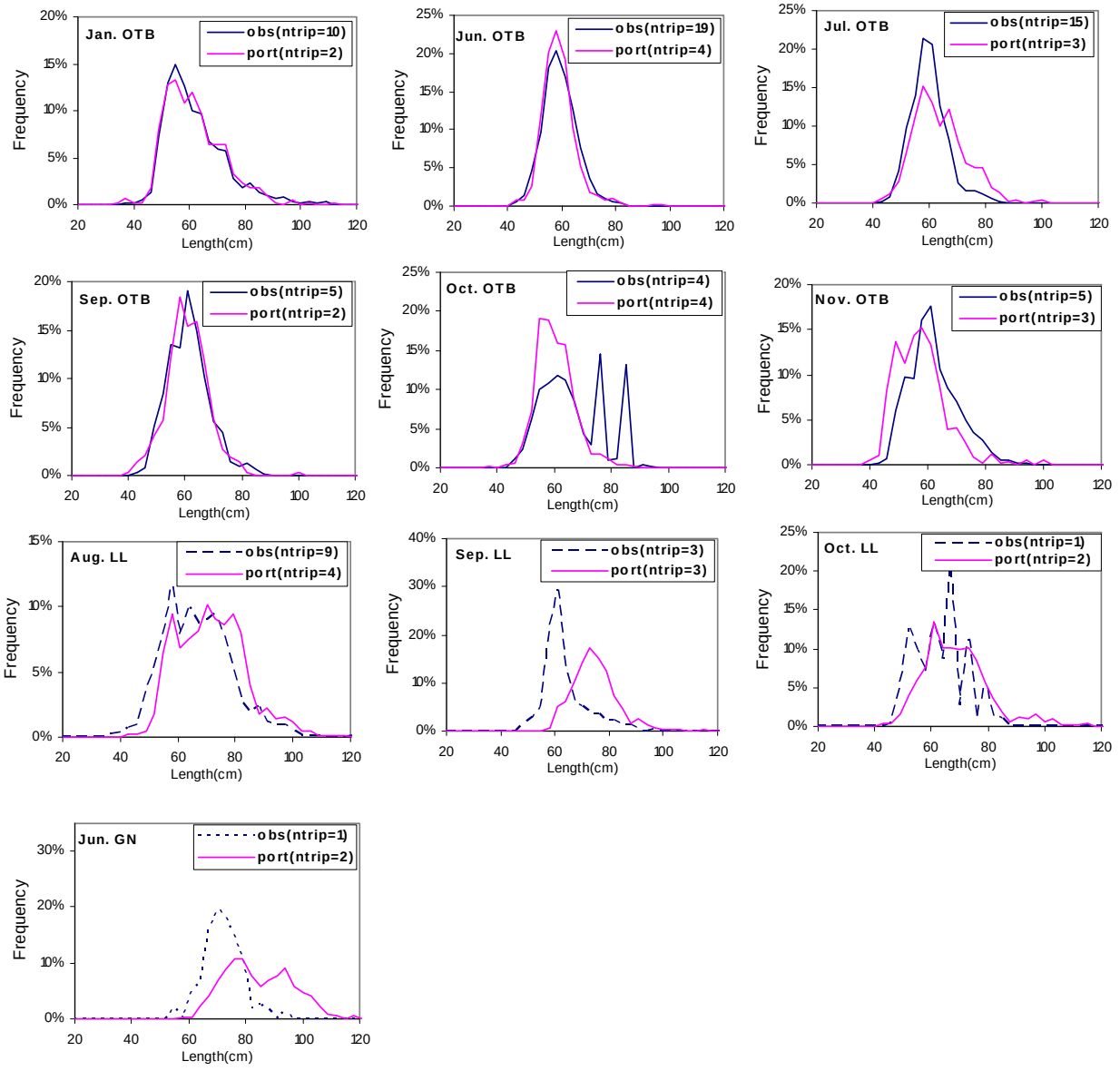


Figure 7. Comparison of cod length frequency composition from port and at sea observer sampling of the 2010 Canadian bottom trawl (OTB), longline (LL) and gillnet (GN) fisheries on eastern Georges Bank.

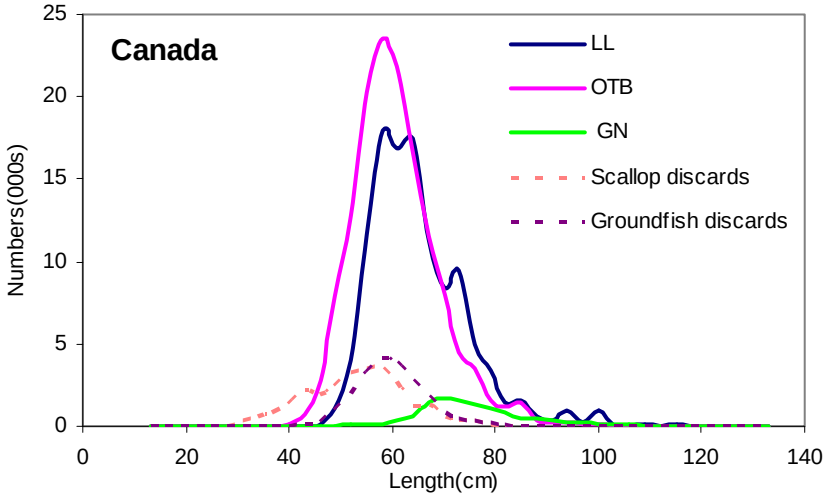


Figure 8. Cod catches at length by gear from the 2010 Canadian fisheries on eastern Georges Bank.

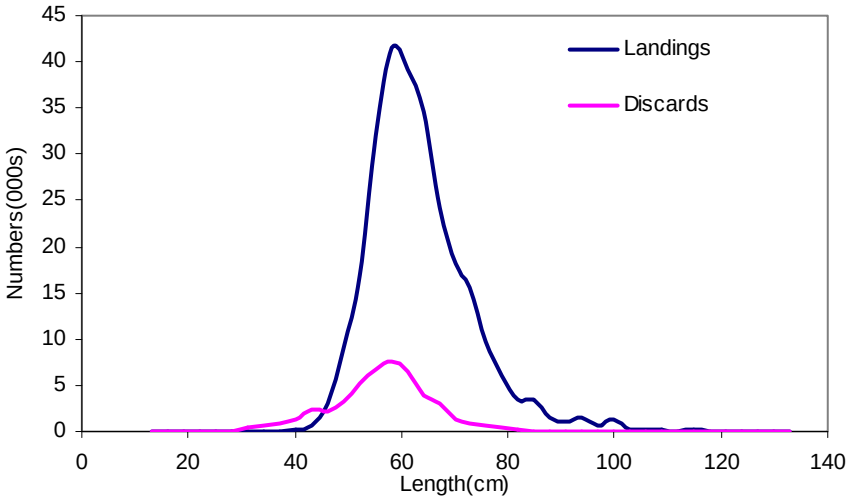


Figure 9. Cod landings and discards at length from the 2010 Canadian fisheries on eastern Georges Bank.

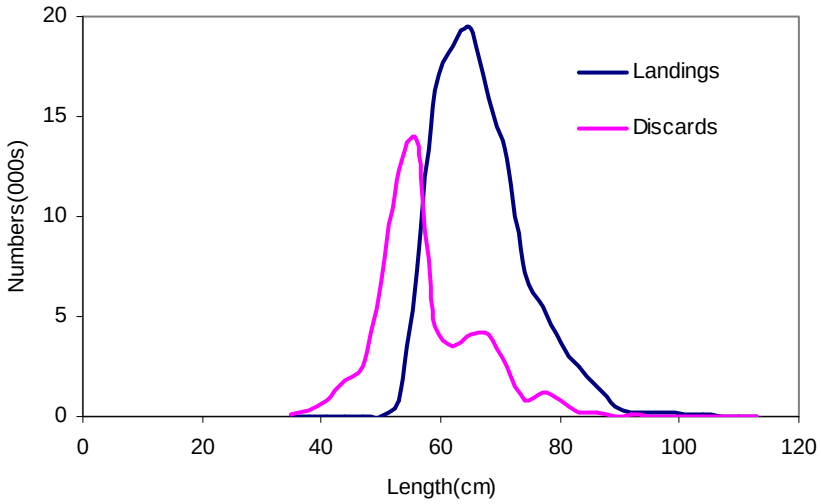


Figure 1. Cod landings and discards at length from the 2010 USA fisheries on eastern Georges Bank.

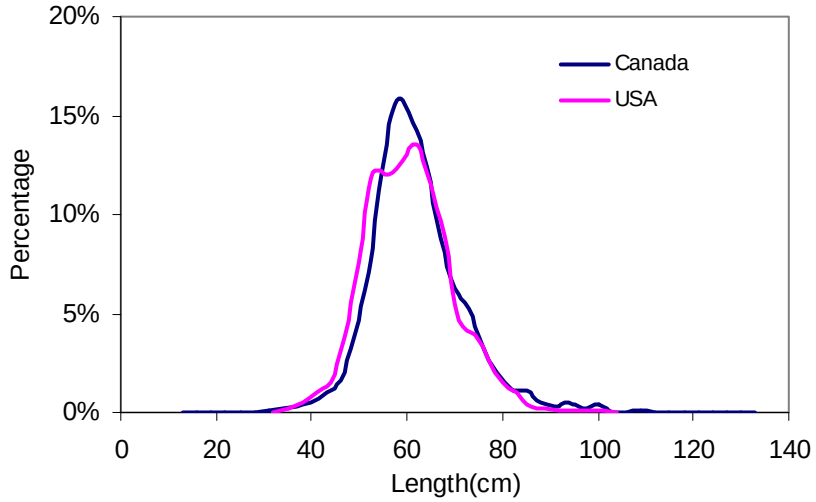


Figure 11. Catch length frequency composition from the 2010 Canadian and USA fisheries on eastern Georges Bank.

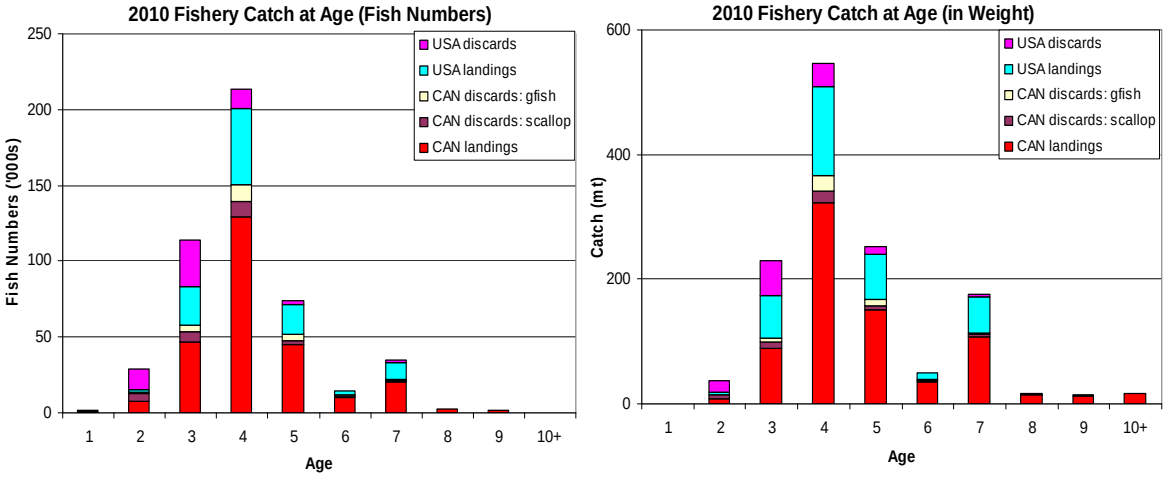


Figure 12. Catch at age in numbers (left) and weight (right) for landings and discards of cod from the 2010 eastern Georges Bank fisheries.

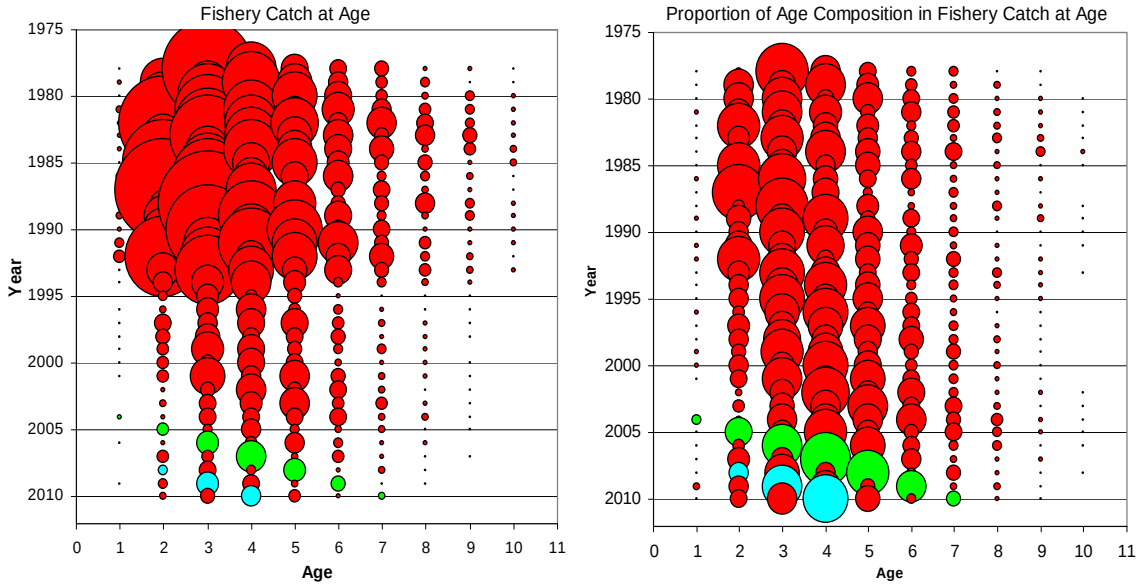


Figure 13. Total catch at age (numbers) of cod (left) and proportion of catch at age from eastern Georges Bank for 1978 to 2010. The bubble area is proportional to the magnitude. The light green circles are the 2003 year class and the light blue circles are the 2006 year class.

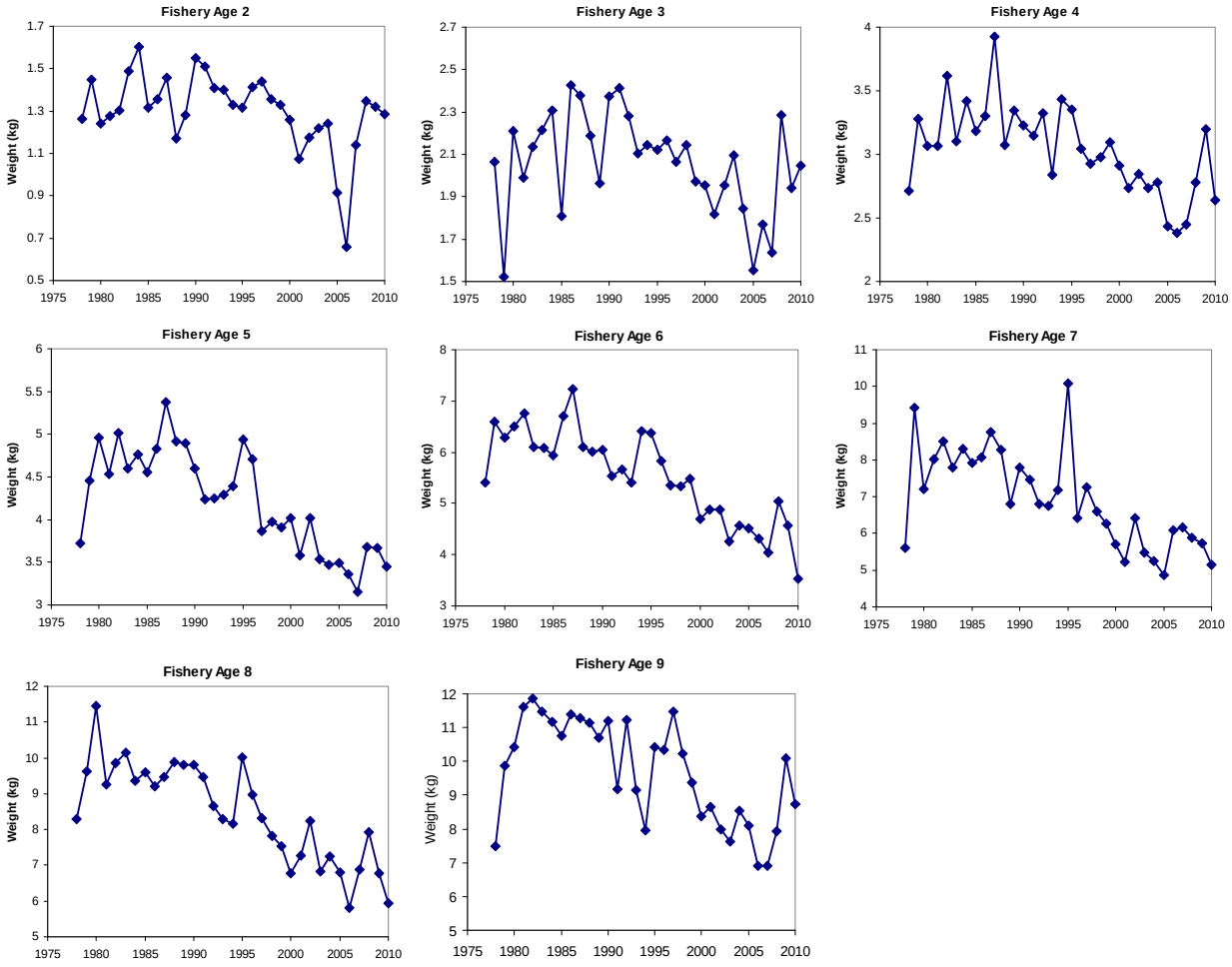


Figure 14. Average weights at ages 2 to 9 of cod from the eastern Georges Bank fishery, 1978 to 2010.

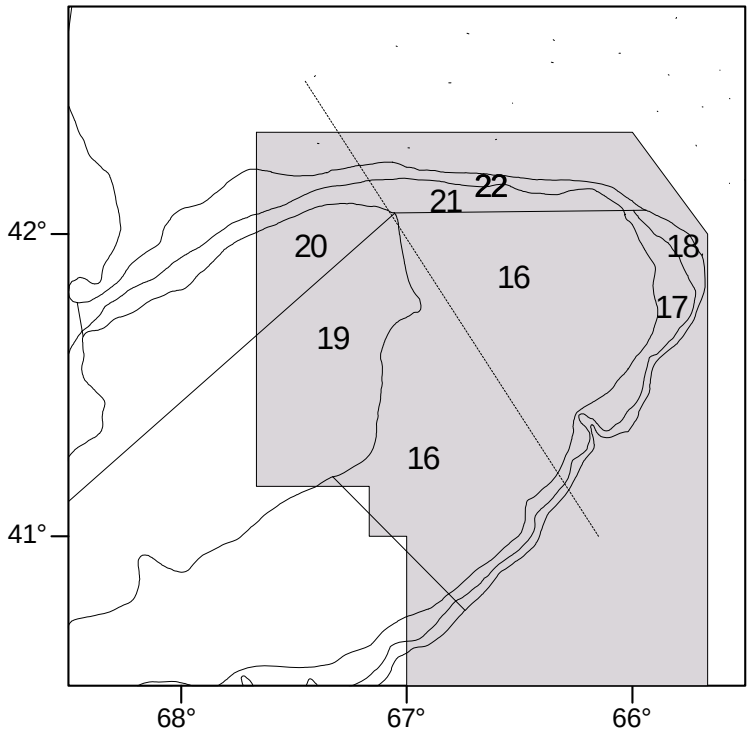


Figure 15. Stratification used for the NMFS surveys. The eastern Georges Bank management unit is indicated by shading.

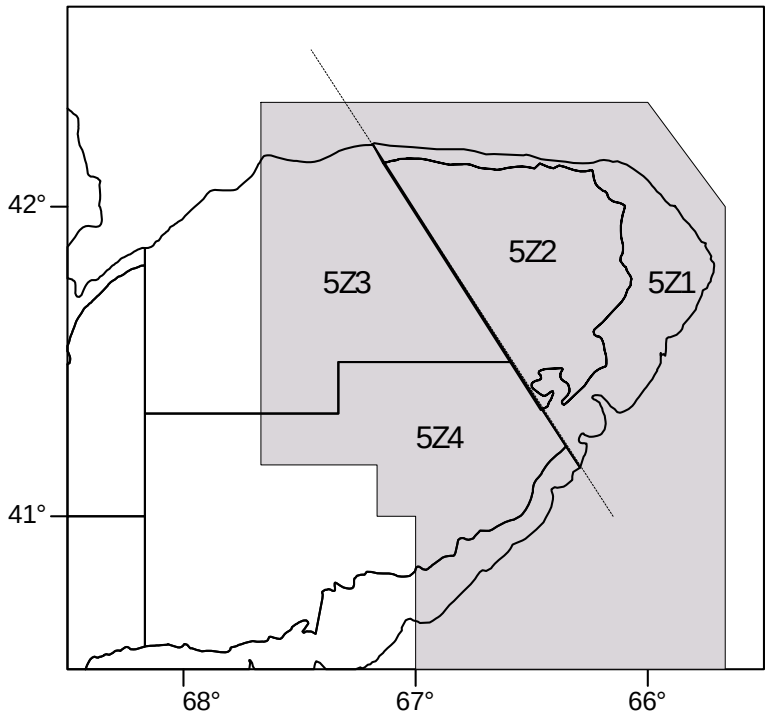


Figure 16. Stratification used for the DFO survey. The eastern Georges Bank management unit is indicated by shading.

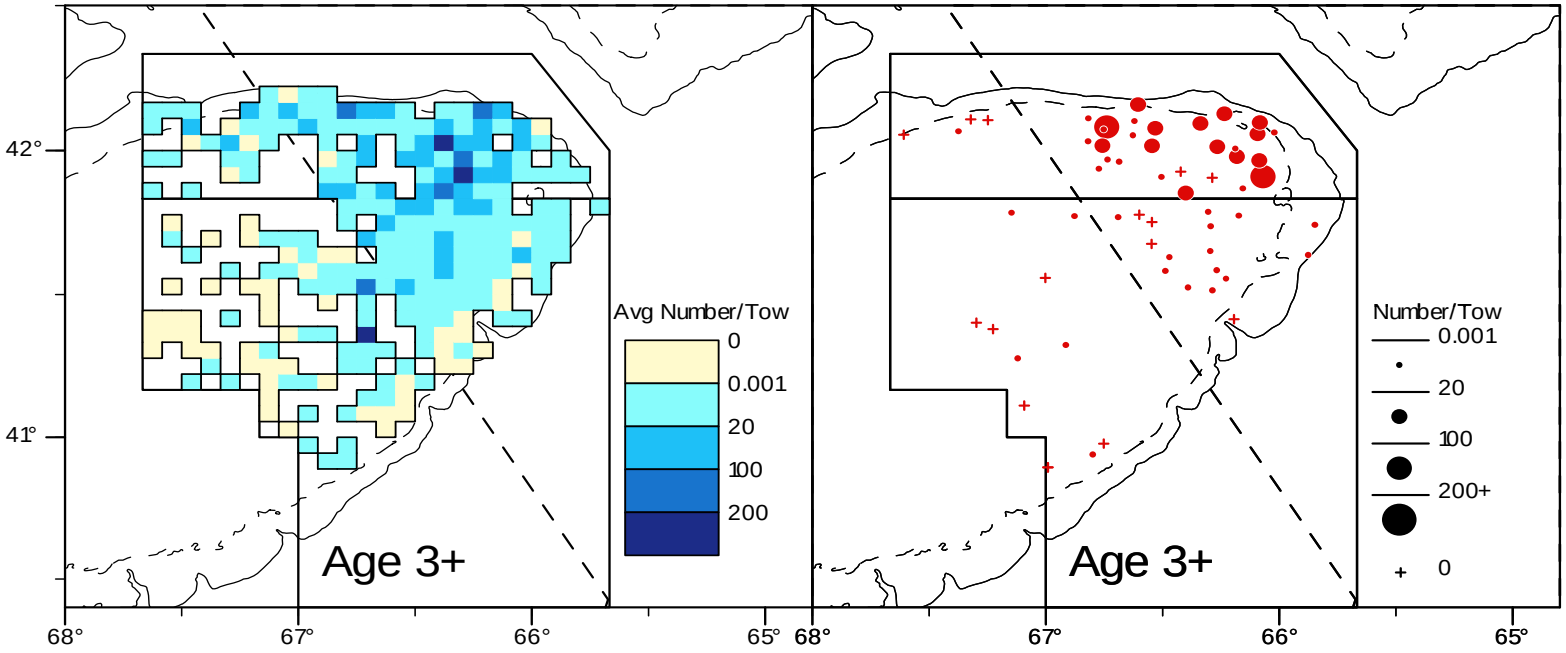


Figure 17. Spatial distribution of age 3+ cod on eastern Georges Bank from the DFO survey for 2011 (right panel) compared to the average for 2001 to 2010 (left panel).

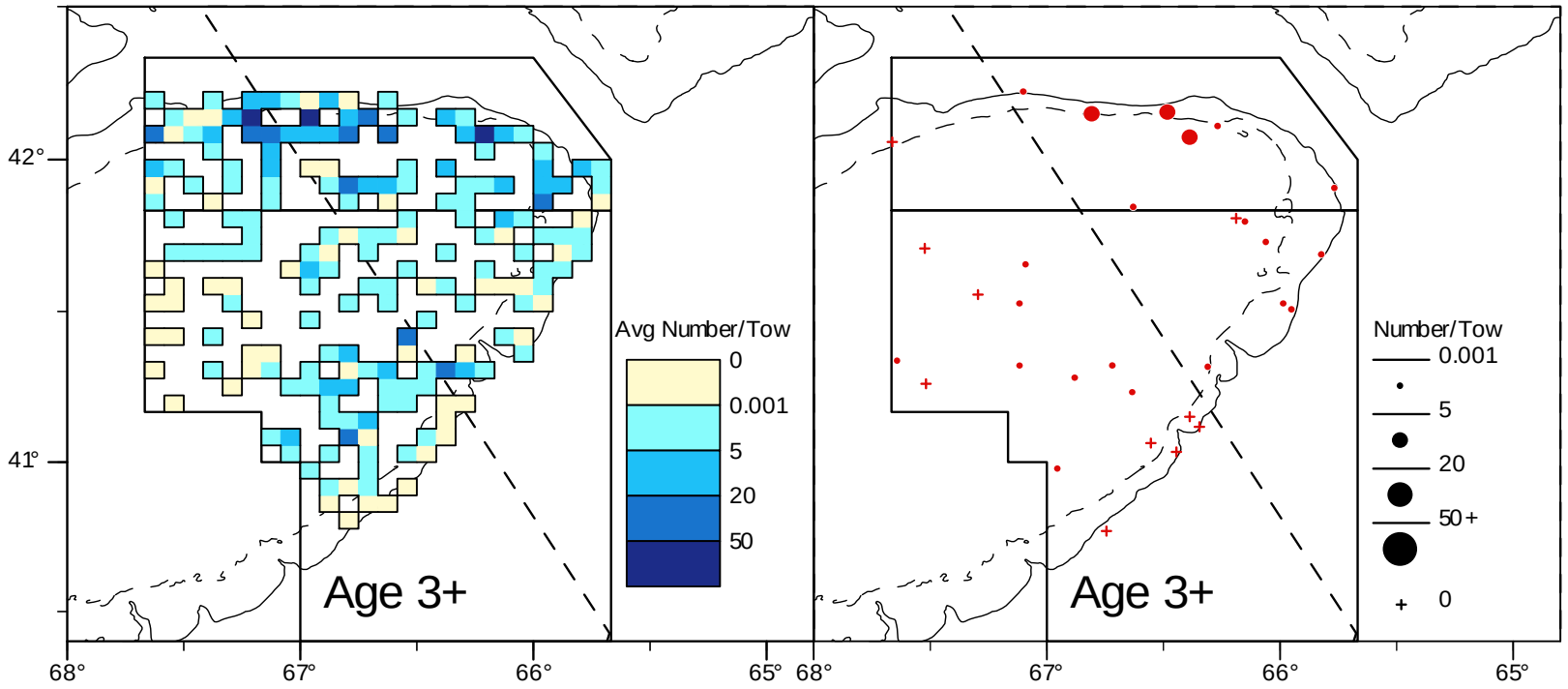


Figure 18. Spatial distribution of age 3+ cod on eastern Georges Bank from the NMFS spring survey for 2011 (right panel) compared to the average for 2001-2010 (left panel).

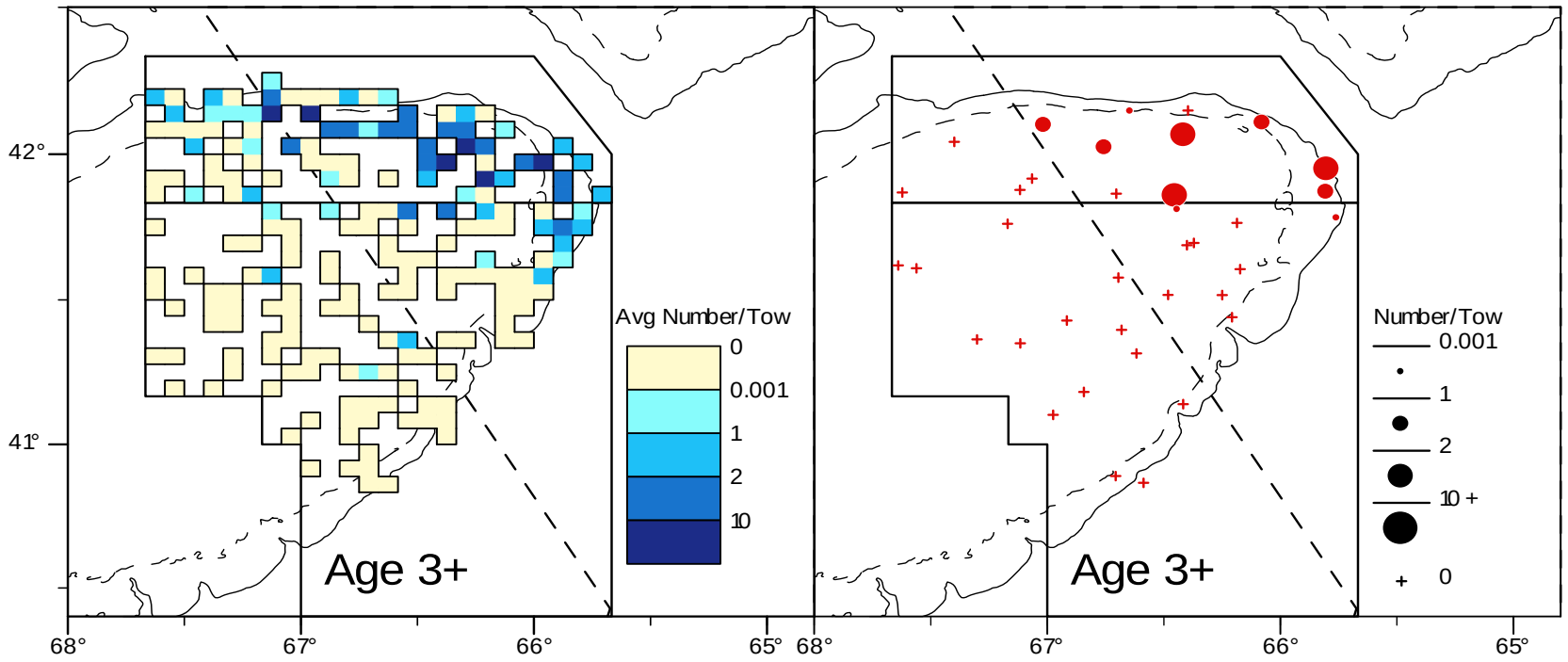


Figure 19. Spatial distribution of age 3+ cod on eastern Georges Bank from the NMFS fall survey for 2010 (right panel) compared to the average for 2000-2009 (left panel).

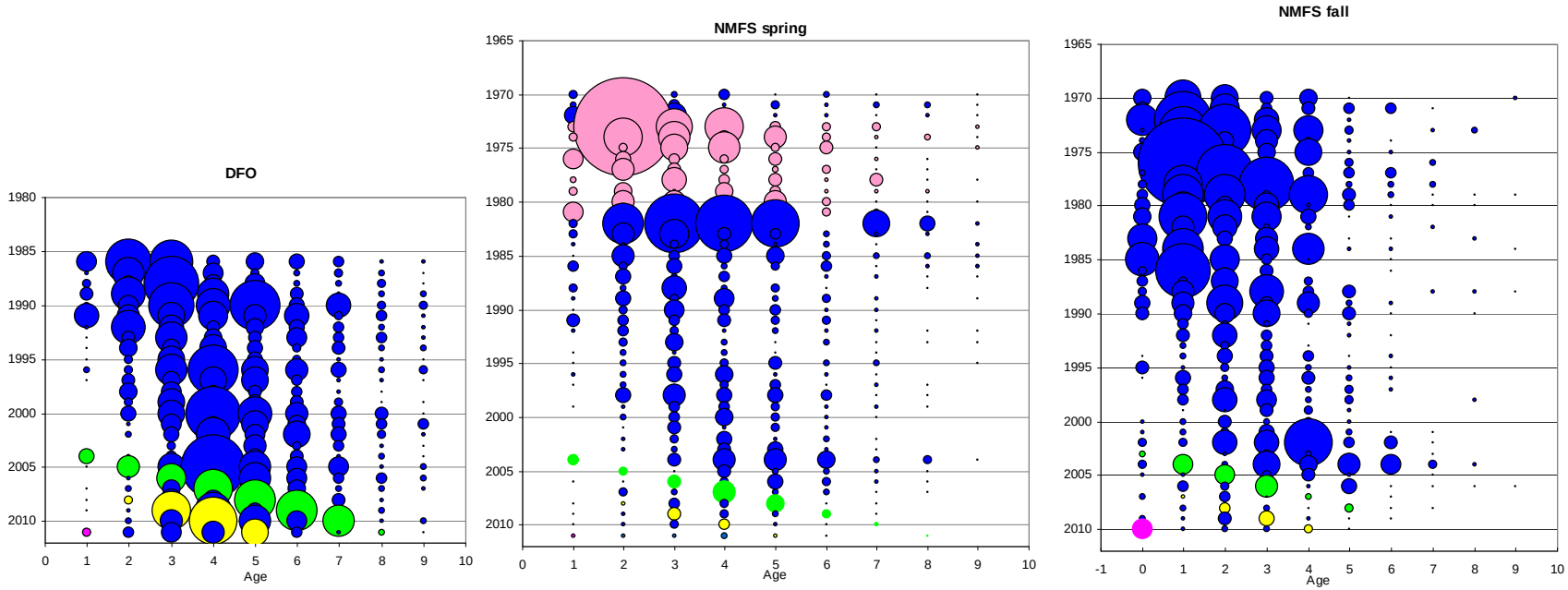


Figure 20. Survey abundance at age (numbers) of eastern Georges Bank cod. The bubble area is proportional to magnitude within each survey. Conversion factors to account for changes in door type, net and survey vessel were applied to the NMFS surveys. The NMFS spring survey was conducted using a modified Yankee 41 during 1978 to 1981 (lighter bubbles). The 2003 year class is identified with green bubbles whilst the 2006 year class is identified with yellow bubbles, the fuschia bubbles show 2010 year class.

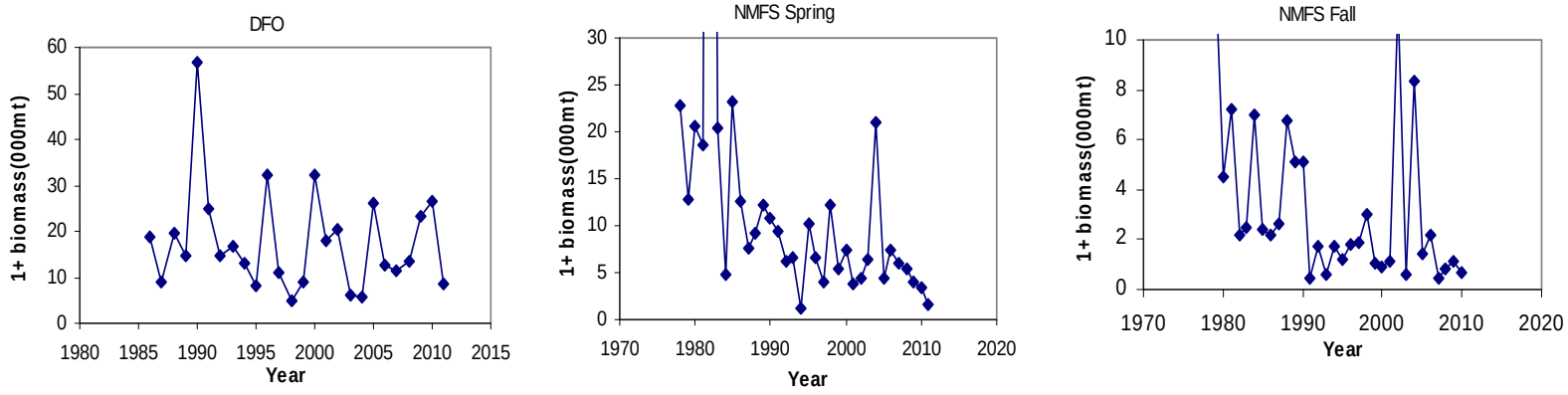


Figure 21. Survey biomass indices (ages 1+) for eastern Georges Bank cod from the DFO spring and NMFS spring and fall surveys.

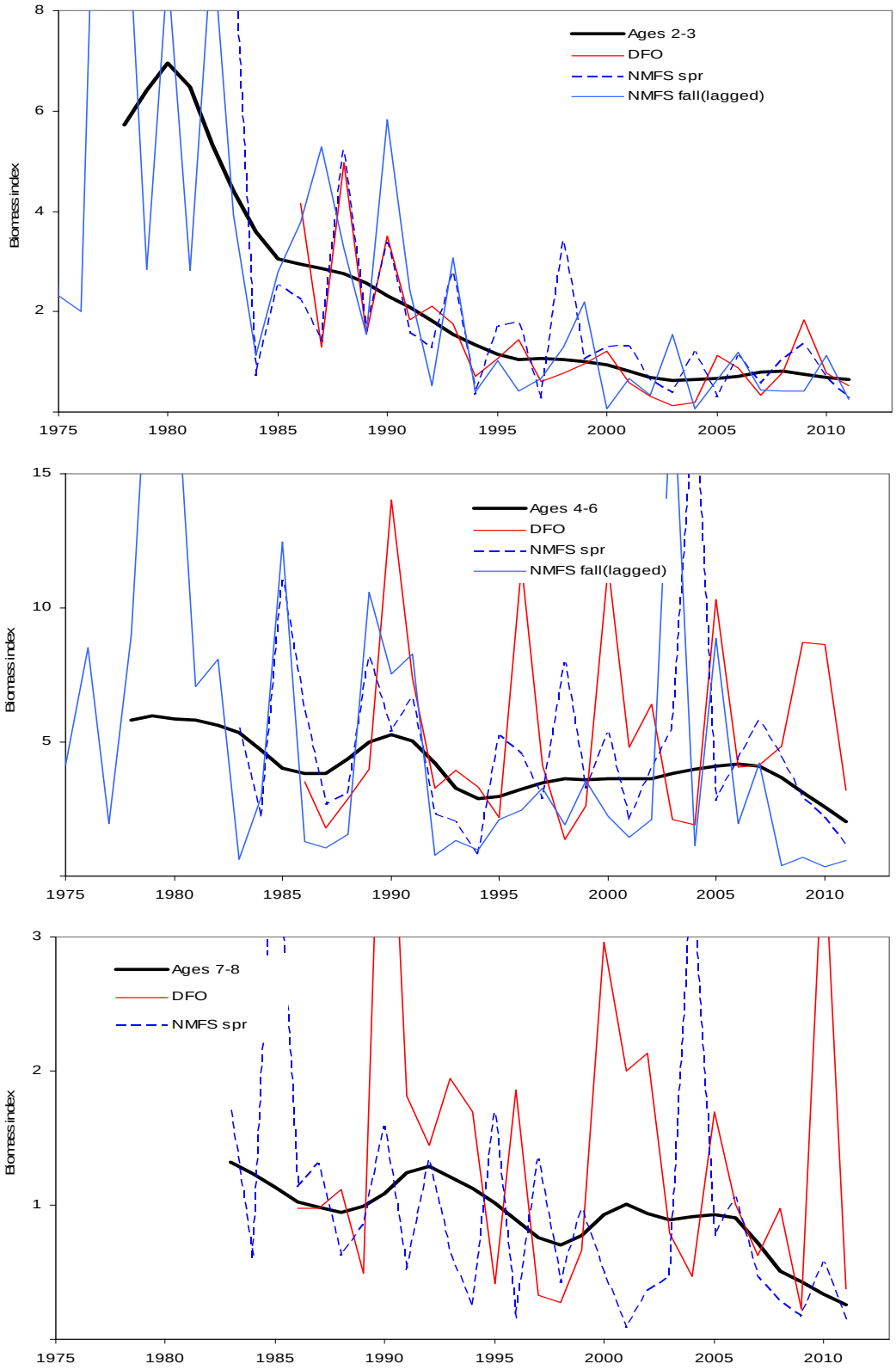


Figure 22. Survey biomass indices for ages 2-3, ages 4-6, and ages 7-8 for the DFO spring and NMFS spring and fall surveys. The black line represents the smoothed trends for different age groups of eastern Georges Bank cod.

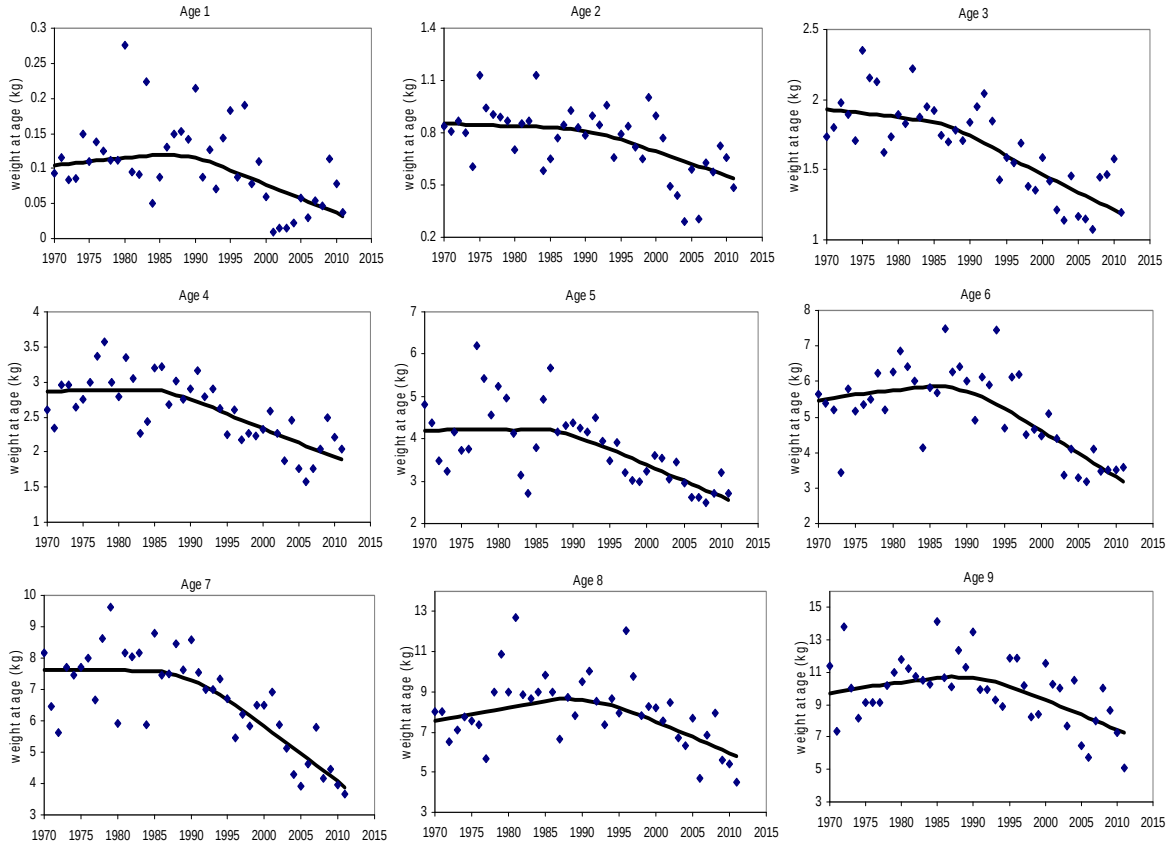


Figure 23. Beginning of year weight at age of eastern Georges Bank cod from DFO and NMFS spring surveys. The lines show the smoothed values using LOESS method.

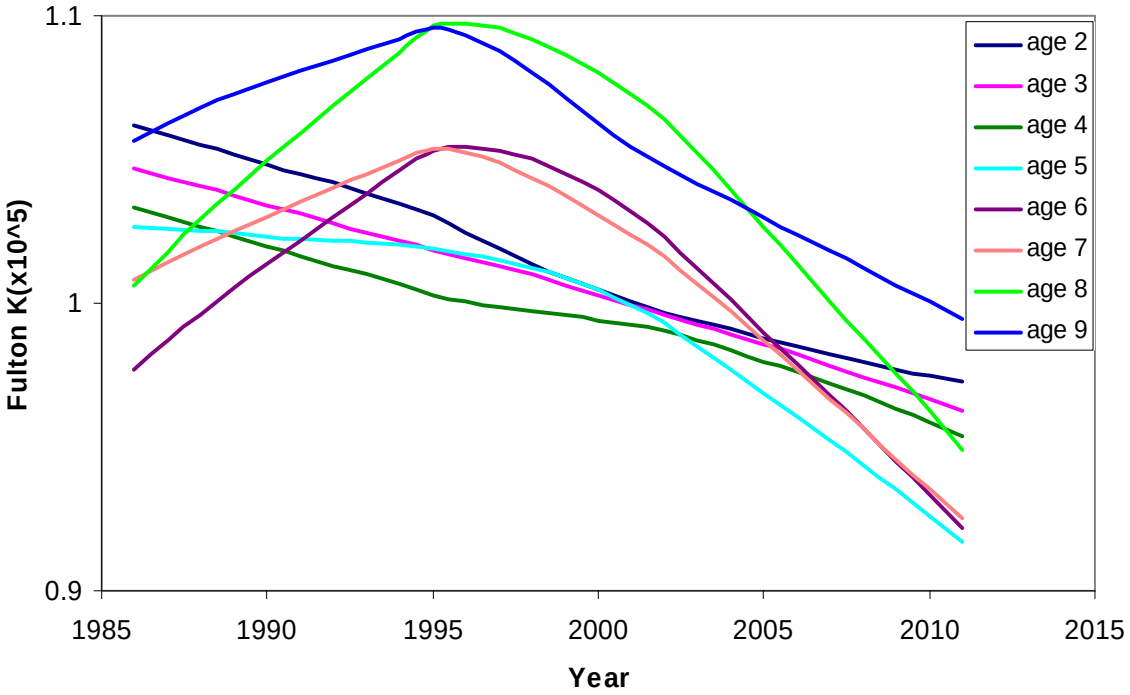


Figure 24. Smoothed condition factor (Fulton's K by age) for eastern Georges Bank cod from the DFO survey.

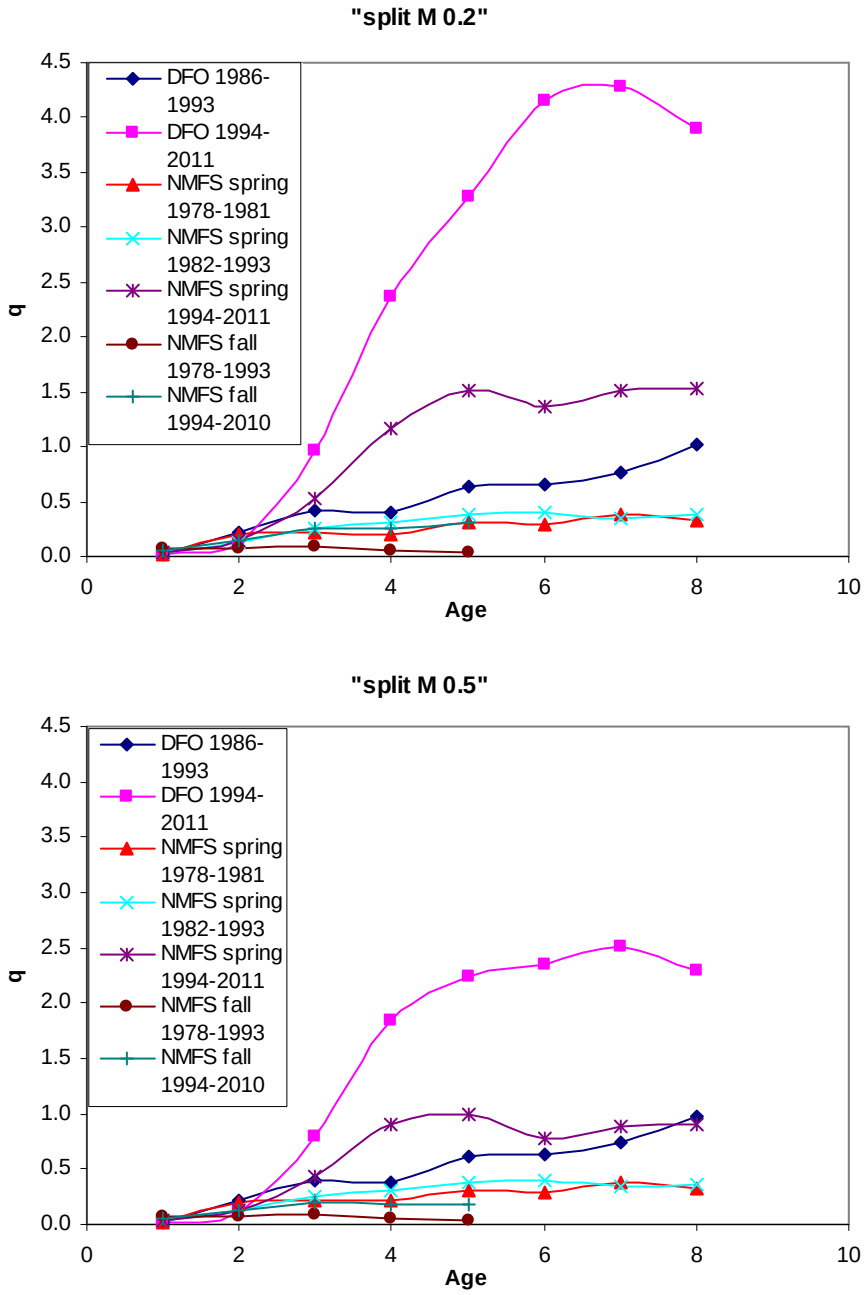


Figure 25. Survey catchability (q) for the DFO, NMFS spring and NMFS fall surveys from the "split M 0.2" and "split M 0.5" model formulations.

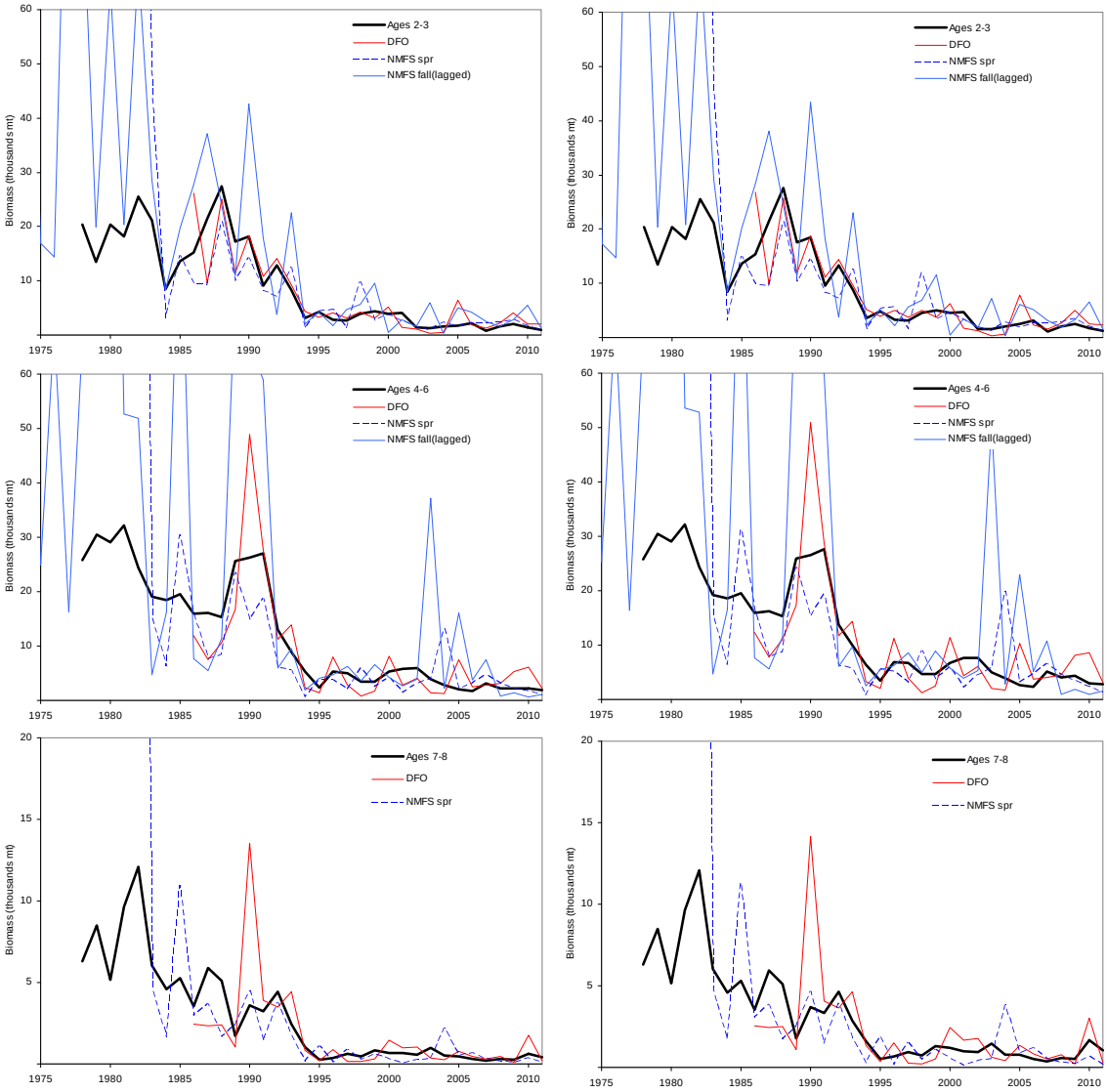


Figure 26. Assessment biomass trends comparison with DFO, NMFS spring and NMFS fall surveys.

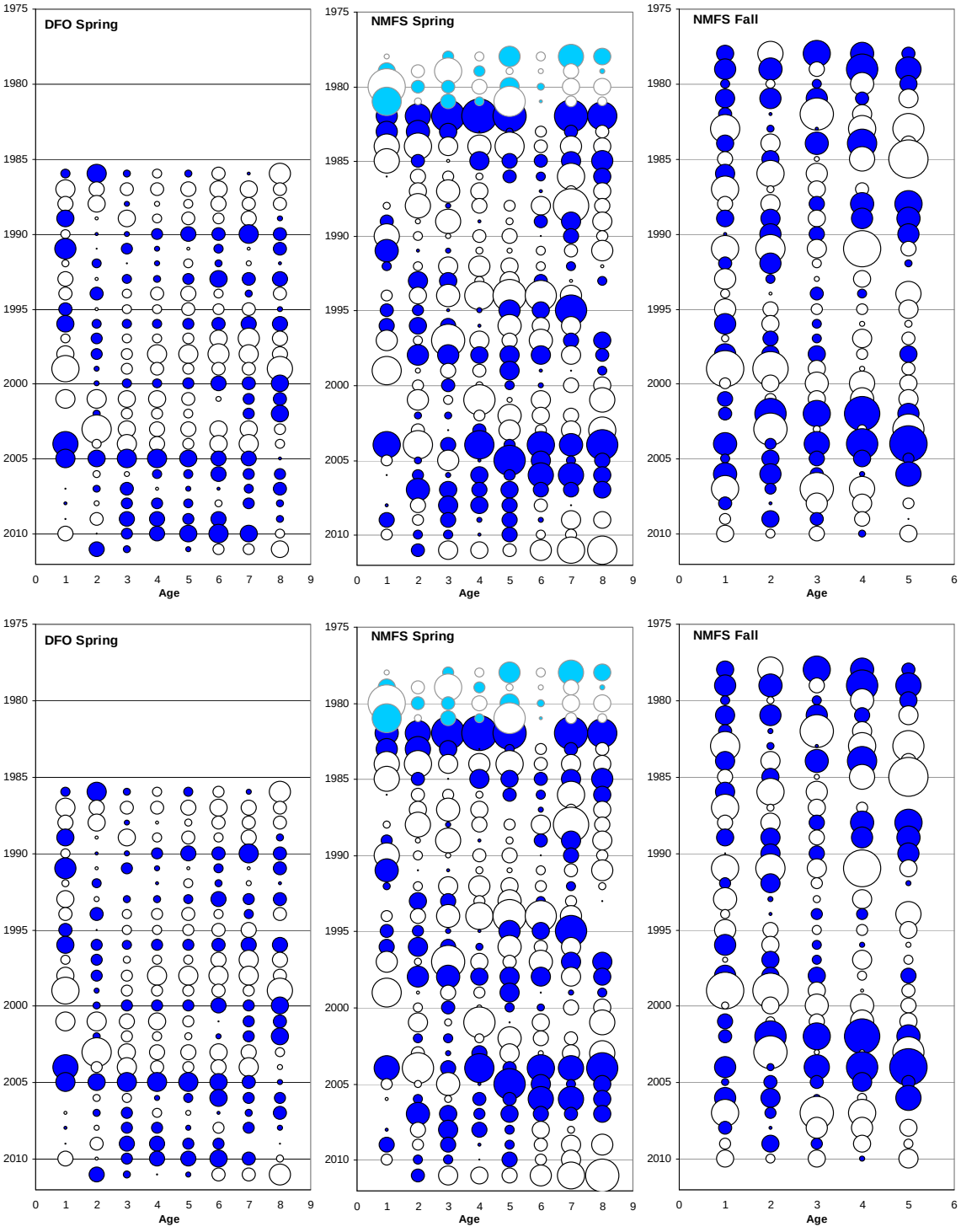
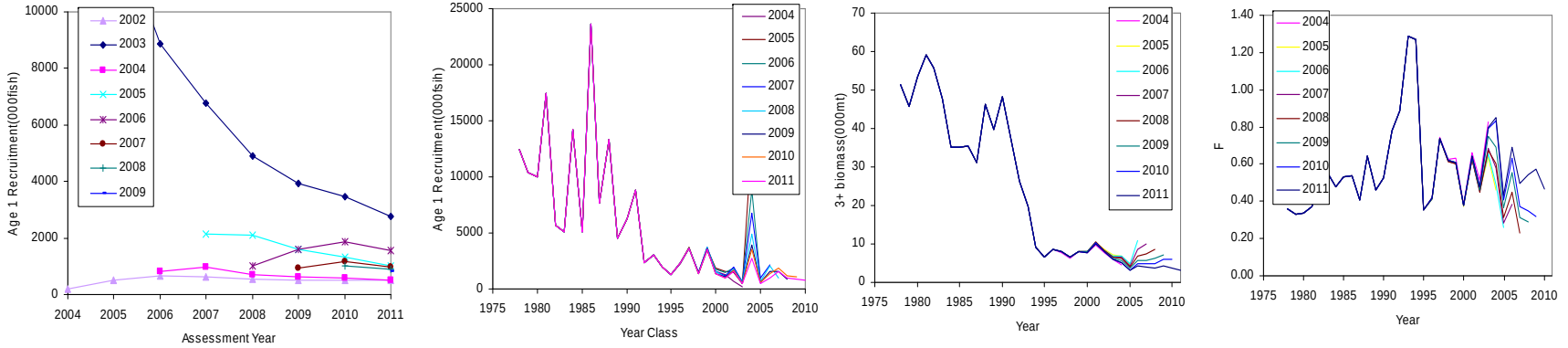
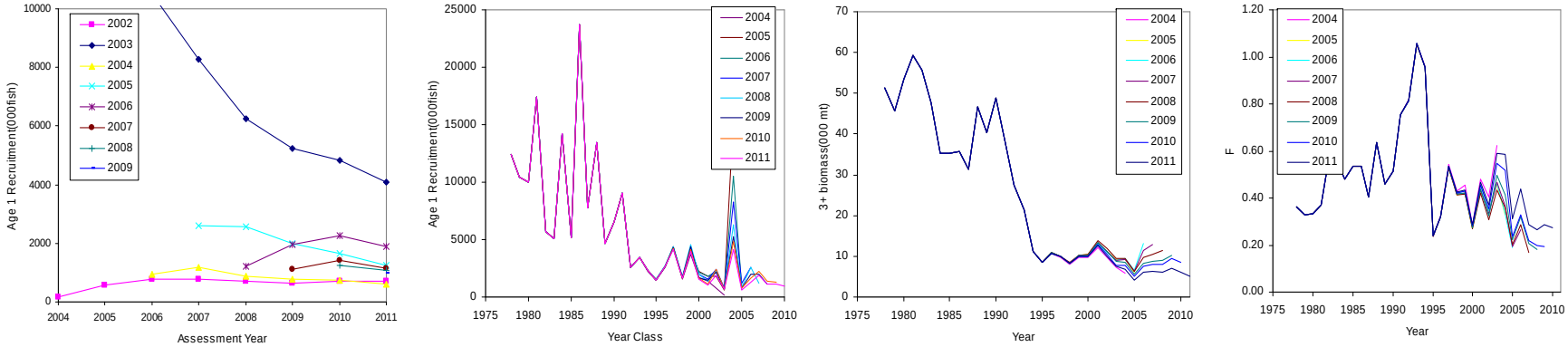


Figure 27. Residuals by year and age group from survey indices for eastern Georges Bank cod. Solid bubbles indicate positive values, open bubbles indicate negative values and the bubble area is proportional to magnitude. The NMFS spring survey was conducted using a modified Yankee 41 from 1978 to 1981 (pale blue bubbles). The upper figures are from the "split M 0.2" model and the lower figures are from the "split M 0.5" model.

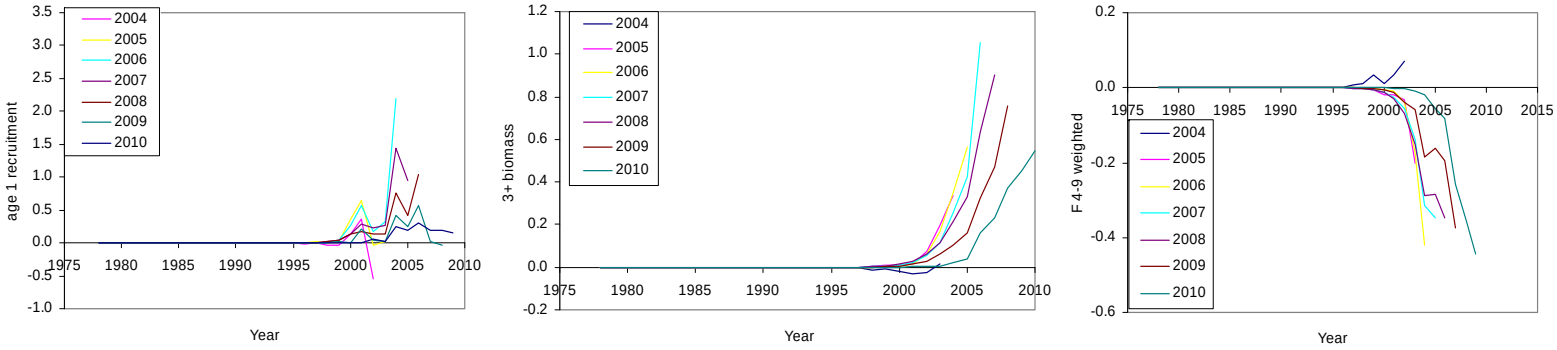


"split M 0.2"

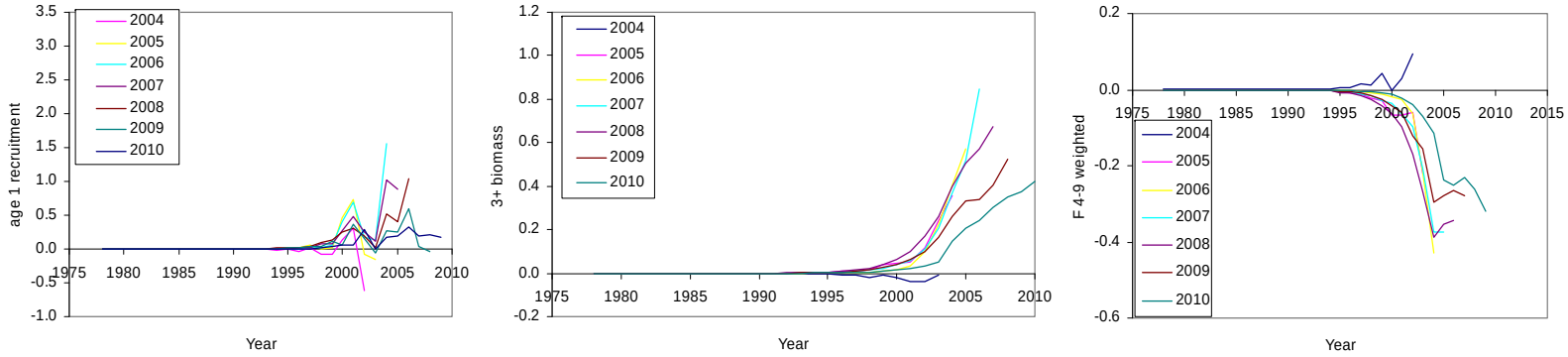


"split M 0.5"

Figure 28. Retrospective patterns for recruitment at age 1, 3+ biomass and fishing mortality of eastern Georges Bank cod for the "split M 0.2" and "split M 0.5" models.



"split M 0.2"



"split M 0.5"

Figure 29. Relative retrospective patterns for recruitment at age 1, 3+ biomass and fishing mortality of eastern Georges Bank cod for the "split M 0.2" and "split M 05" models.

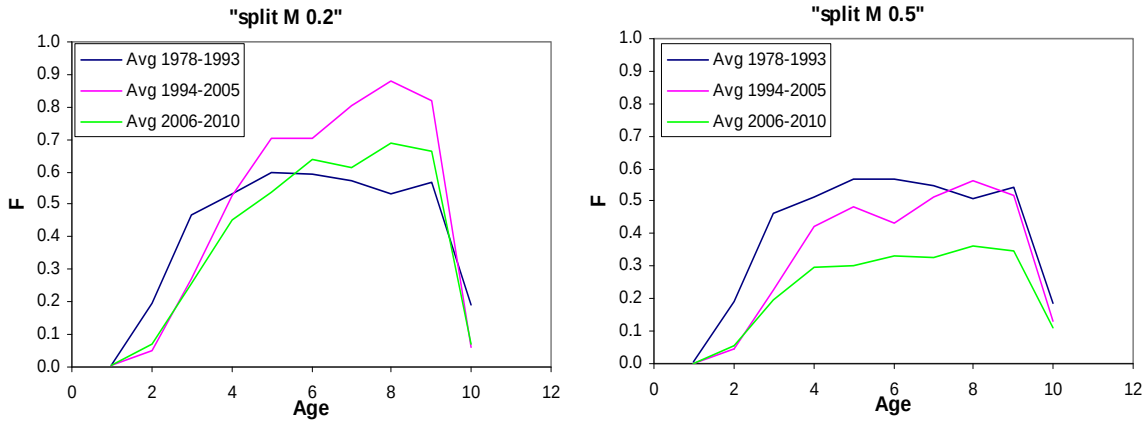


Figure 30. Average fishing mortality (F) for eastern Georges Bank cod in 3 time series blocks (1978-1993, 1994-2005, 2006-2010) from the "split M 0.2" (left) and "split M 0.5 (right) model formulations.

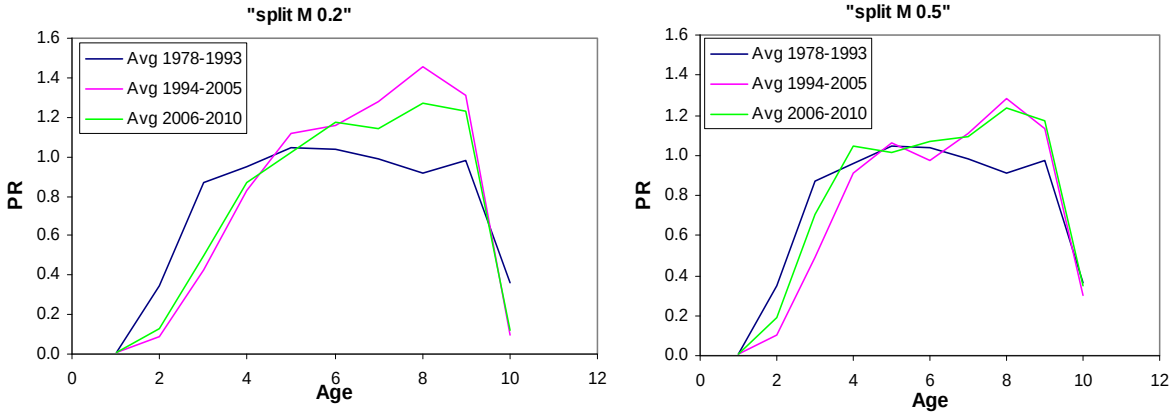


Figure 31. The fishing partial recruitment (PR) for eastern Georges Bank cod in 3 time series blocks (1978-1993, 1994-2005, 2006-2010) from the "split M 0.2" (left) and "split M 0.5 (right) model formulations.

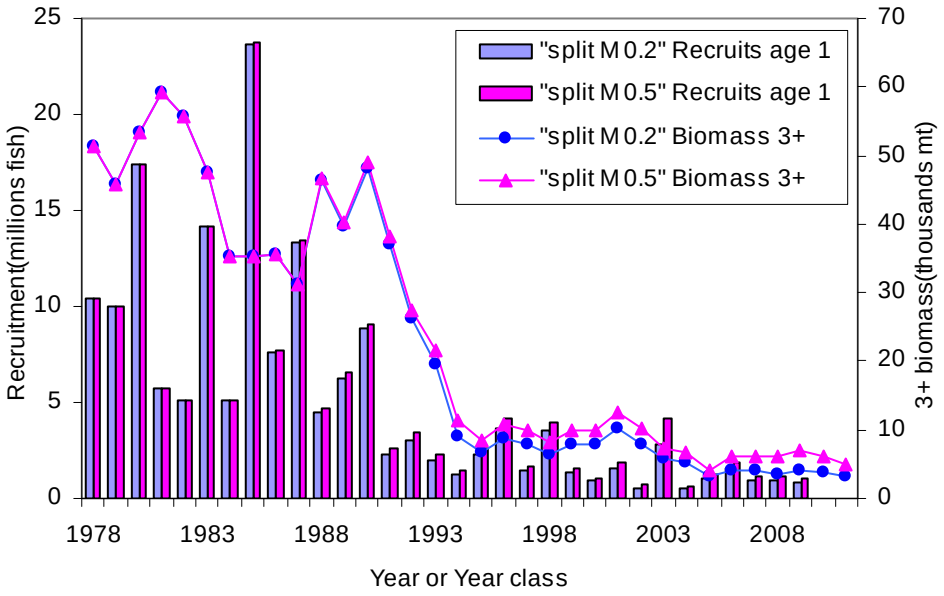


Figure 32. Adult biomass (ages 3+) and year class abundance at age 1 for eastern Georges Bank cod.

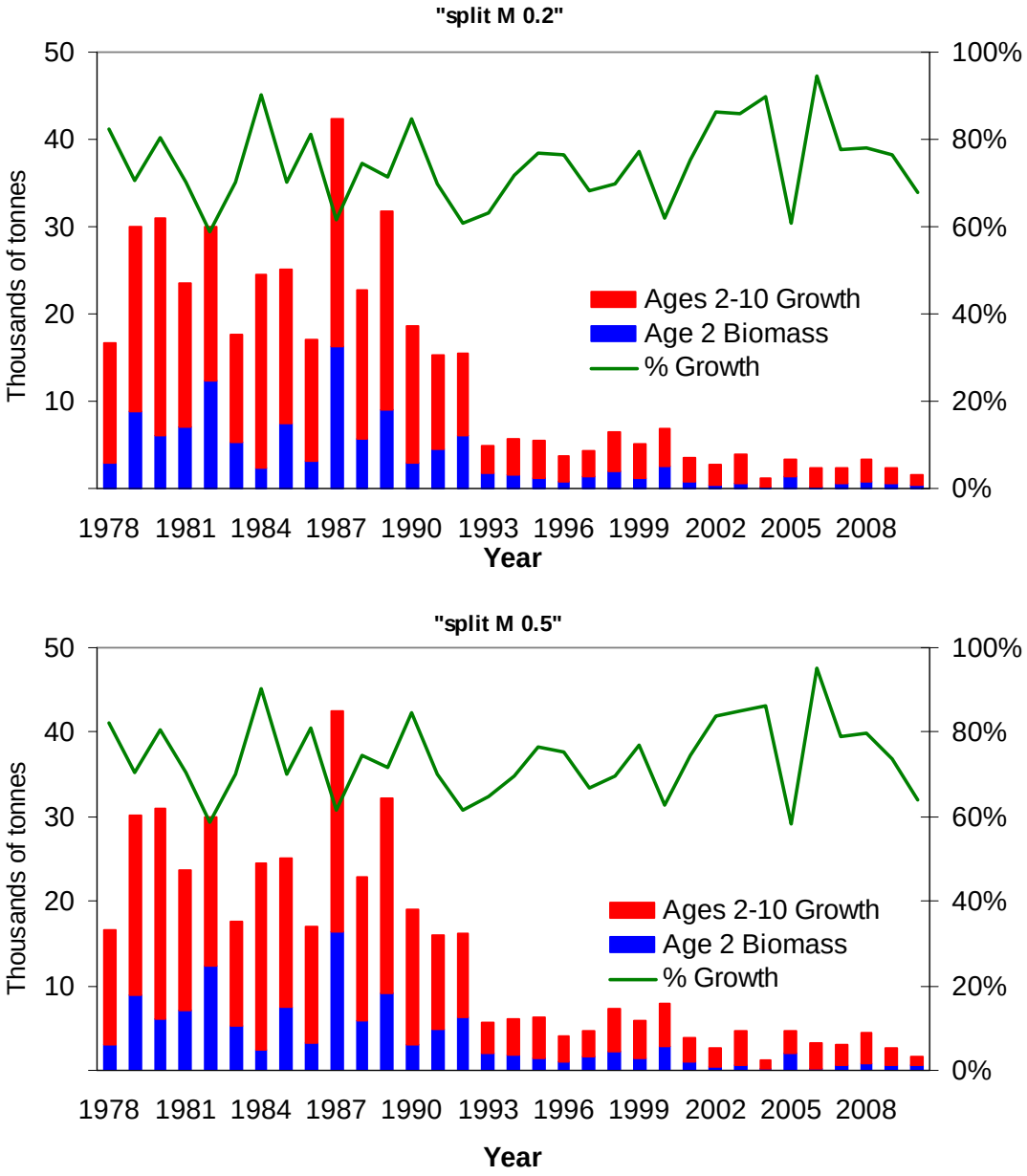


Figure 33. Components of annual production for eastern Georges Bank cod attributable to growth of ages 2 to 10 and to the amount contributed by incoming year classes at age 2.

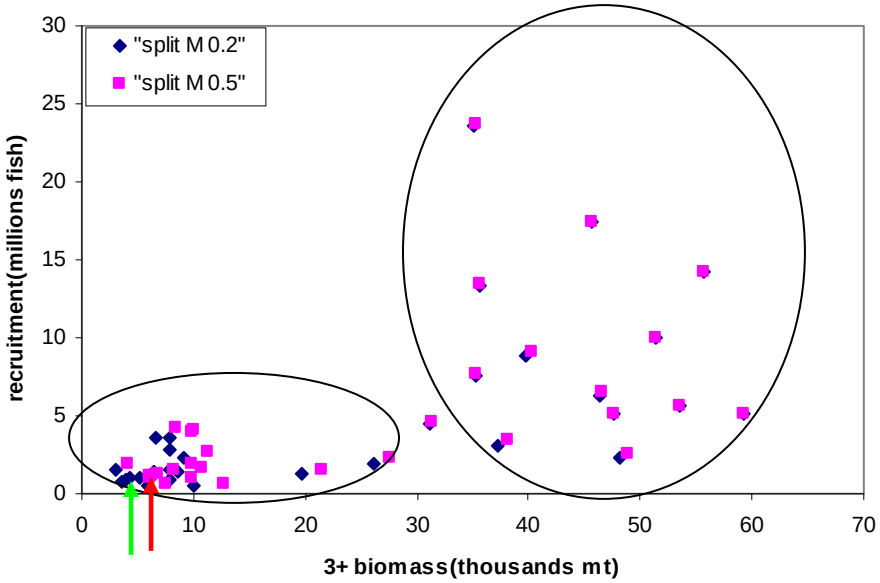


Figure 34. Relationship between adult biomass (ages 3+) and recruits at age 1 for eastern Georges Bank cod. The green and red arrows indicate the 2009 year class at age 1 from the "split M 0.2" and "split M 0.5" model, respectively.

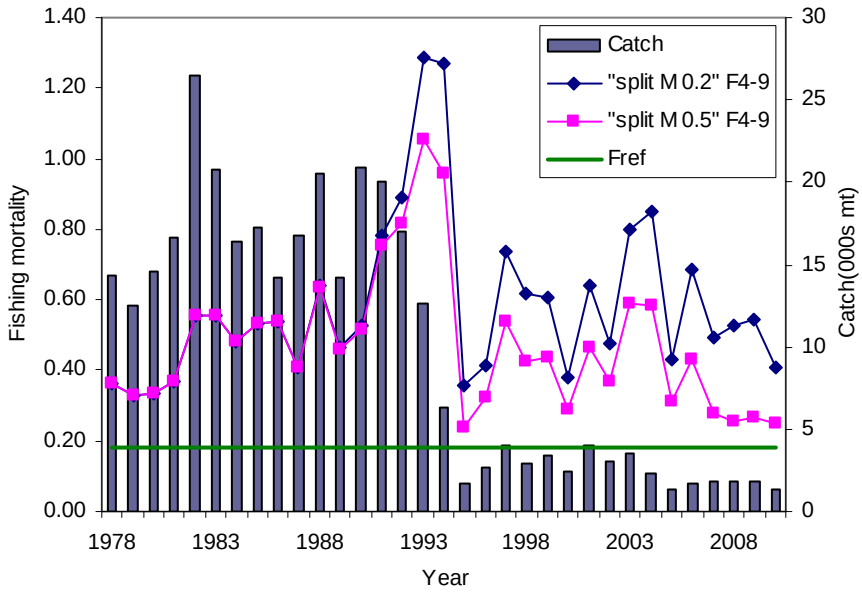


Figure 35. Average fishing mortality rate at ages 4 to 9 and catches for eastern Georges Bank cod. The established fishing mortality threshold reference, F_{ref}=0.18, is indicated.

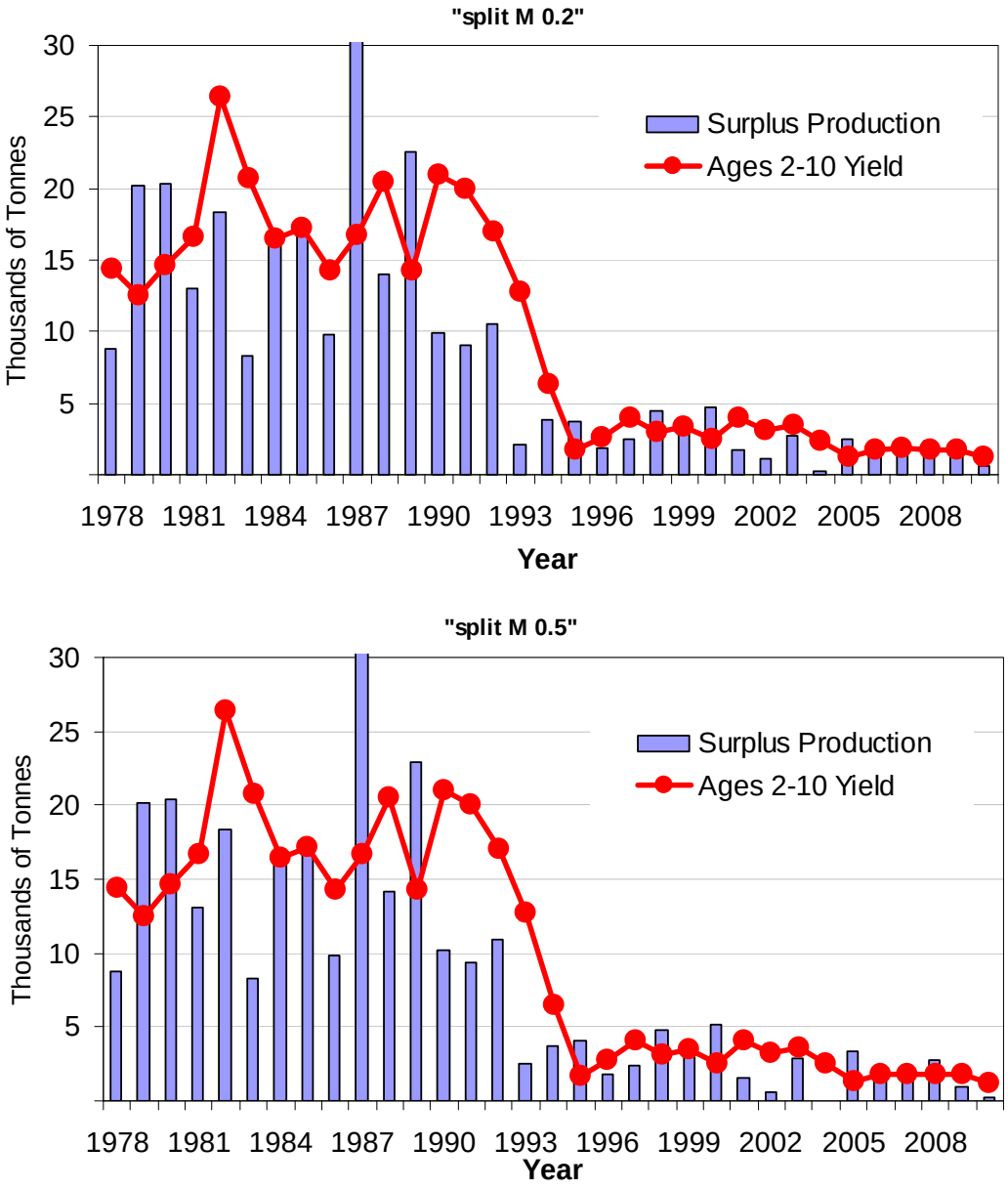


Figure 36. Surplus production of eastern Georges Bank cod compared to harvested yield.

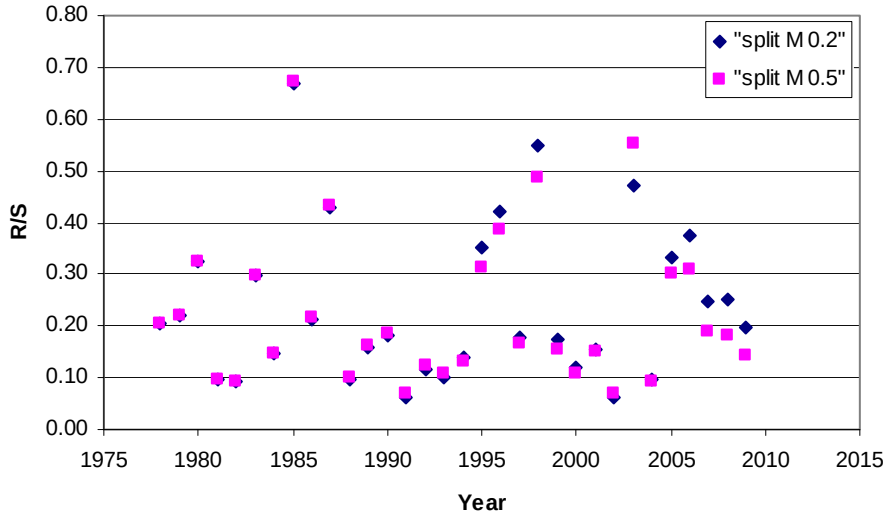


Figure 37. Recruitment rate (R/3+biomass) for eastern Georges Bank cod.

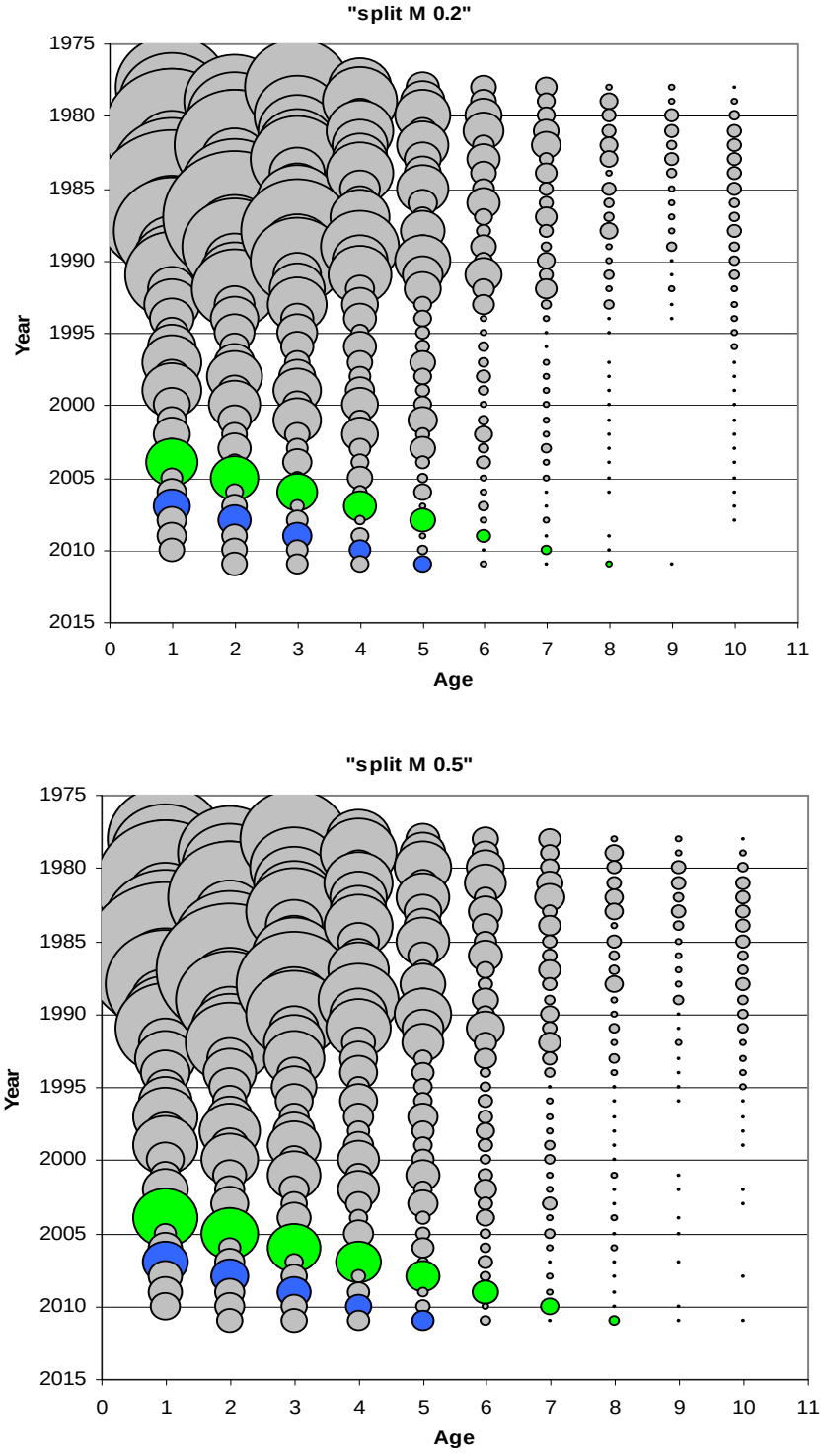


Figure 38. Population numbers from the 2011 assessment of eastern Georges Bank cod. Bubble sizes are proportional to population numbers. Light green bubbles are the 2003 year class and light blue bubbles are the 2006 year class.

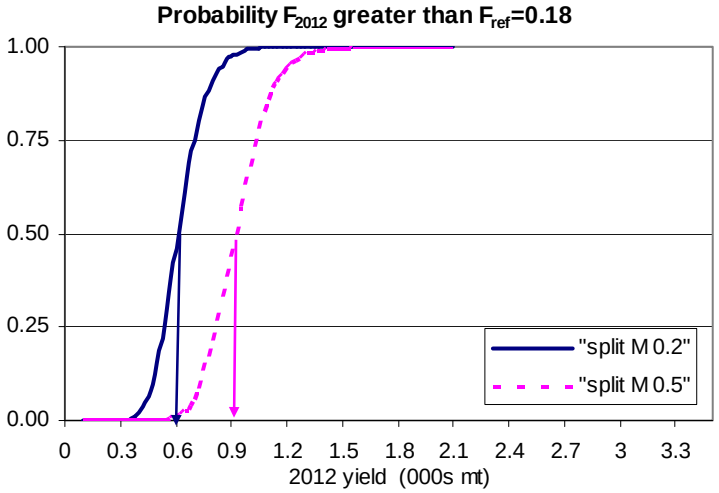


Figure 39. Risk of 2012 fishing mortality exceeding F_{ref} = 0.18

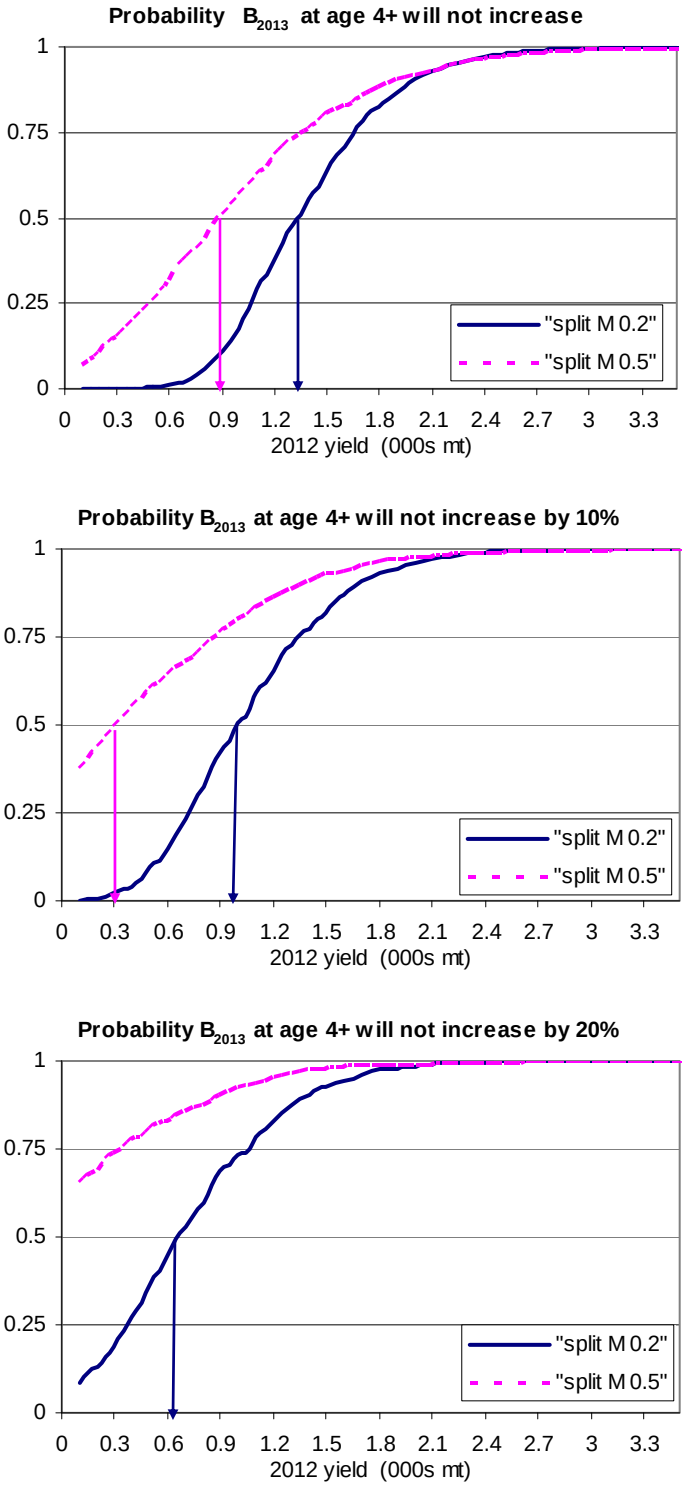


Figure 40. Risk of 2013 biomass not increasing, not increasing by 10% or 20% from 2012 for alternative total yields of eastern Georges Bank cod.

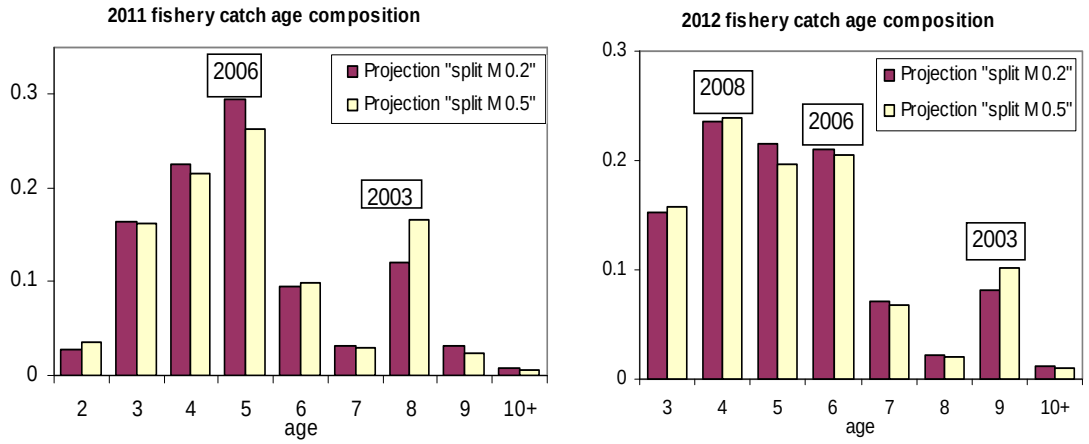


Figure 41. Projected fishery catch age composition of eastern Georges Bank in 2011 and 2012 if the catch is 1,050 mt in 2011 and F_{2012}=0.18, the year label represent the year class.

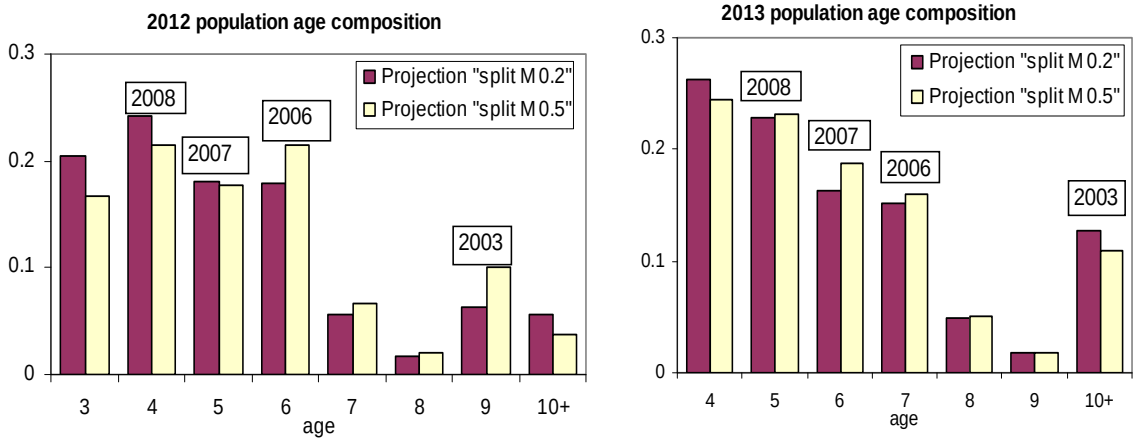


Figure 42. Projected fish population age composition of eastern Georges Bank in 2012 and 2013 if the catch is 1,050 mt in 2011 and F_{2012}=0.18, the year label represent the year class.

APPENDIX A: Discards of Cod from the 2010 Canadian Groundfish Fishery on Eastern Georges Bank

Data and Methods

Discards of cod from the Canadian groundfish fishery were estimated using the ratio of sums estimator methods described by Gavaris et al. (2007b). Landings of cod and haddock for 2010 were obtained from the fisheries statistics database maintained by the Maritimes Region of Fisheries and Oceans Canada. Trips were classified as observed or unobserved. Following Gavaris et al. (2007b), the basic record unit was the aggregate of catches from a trip within each zone, referred to as a sub-trip. Although the use of a separator panel when fishing with a bottom otter trawl on Georges Bank was mandatory in 2010, there were a couple of trips where the panel was not used and these trips were excluded from the analysis. Trips where the observer deployment was for management purposes, rather than routine monitoring, were excluded as these might not be representative.

Virtually all the cod for 2010 were caught in Zones A, B, C and D during fishing targeting for haddock (Table A1, Figure A1). Discards were only derived for the designated fleets targeting haddock. Very few cod were caught by pollock and yellowtail flounder targeted fishing by mobile gear. Sub-trips that sought pollock were identified as those where the catch of pollock exceeded the catch of cod and haddock or observed sub-trips where the declared species sought was pollock. Cod are also taken by limited fisheries using gillnet and handline that direct for cod and there fore are not considered to discard cod. The calculation of discards uses a landings multiplier that is based on ratios of cod to haddock. Factors that are expected to affect the species composition include fishing fleet, fishing ground location and season.

The Canadian quotas are sub-allocated to quota groups. Sub-allocation of shares to quota groups varies by species. Therefore, the quota mix varies substantially by quota group. The quota mix can be an important determining factor in discarding behaviour. Accordingly, fishing fleets were defined by quota groups (Table A2). Generally, quota groups comprise vessels that are similar with respect to size and gear. A quota group's allocation may be fished by vessels smaller than those in the group under the Temporary Vessel Replacement Program (TVRP is a mechanism by which a fleet can contract another fleet to catch their quota without transferring the quota). Almost all of the 2010 catch by the MG 65'-100' and the >100' fleets was taken by vessels less than 65' under the TVRP program.

Zones were defined for Georges Bank based on areas of fishing concentration and homogeneity of species composition (Figure A1). While there appears to be considerable local scale variation in species composition, the zones could not be made smaller given the observer sampling intensity.

The data for each fishing fleet, zone and quarter grouping were analyzed separately to derive an estimator of the landings multiplier that was used to compute discards.

Results and Discussion

The ratio of sums method was applied to obtain the landings multipliers by fishing fleet, zone and quarter (Table A3). The associated standard errors from the bootstrap analyses are also shown. Bootstrap confidence distributions of the landings multiplier were examined to determine if it could be inferred that discarding occurred. The percentile and bias corrected confidence distributions were generally coincident, indicating that the bias is small. Discards were calculated for cases where the reference landings multiplier of 1 intersected the bias corrected

confidence distribution at a probability of 0.05 or less. Discarding was only inferred for MG<65' and First Nations fleets in quarter 2 and 3, zone B (Figure A2) and MG<65' in quarter 2 and 3, zone C (Figure A3). There was insufficient data to estimate landings multipliers for FG 45-65 and FG 65-100. In total, discards of cod from the Canadian groundfish fisheries on Georges Bank in 2010 were 48 mt (Table A4).

Table A1. *Landings (mt) of cod used in the analysis of cod discards from the Canadian fisheries on Georges Bank in 2010. Trips targeting pollock, yellowtail and cod were removed. Discards may occur during unobserved fishing. Discard calculations were examined for haddock targeted fishing in Zones A, B, C and D by quarter for the designated fleets (shaded cells).*

	Zone A				Zone B				other zones	Total
FLEET	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**all Q**	
Observed										**80**
FG<45			1					19	1	
MG<65 & FN	0.1	0.02	1	1	5	12	11	4	4	
MG 65-100					3					
>100	0.01	0.01	1	2	3	4	7		2	
Unobserved										**466**
FG<45			20	17		2	207		1	
MG<65 & FN	0.2	0.2	8	14	10	18	34	36	13	
MG 65-100	0.02			1	1					
>100	0.1		4	6	6	11	54		4	
Total										**546**

Table A2. *Designated fisheries participating in the Canadian groundfish fishery on Georges in 2010.*

Designation	Description
FG<45	fixed gear (longline only), vessels less than 45’
FG 45-65	fixed gear (longline only), vessels between 45’ and 65’
MG<65	mobile gear (bottom trawl only), vessels less than 65’
FG 65-100	fixed gear (longline only), vessels between 65’ and 100’
MG 65-100	mobile gear (bottom trawl only), vessels between 65’ and 100’
>100	vessels greater than 100’ (bottom trawl only)
FN	first nations (bottom trawl only)

Table A3. *Estimated landings multipliers (± standard errors) for designated fleets by zone and quarter for 2010. Shaded values indicate that discarding was not inferred. * indicates that this multiplier refers only to the MG<65' fleet.*

	Zone A				Zone B			
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
FG<45							0.85±0.14	
MG<65 and FN			0.96±0.34	0.82±0.35	1.16±0.36	2.06±0.37	1.79±0.37	1.17±0.24
MG 65-100					7.19±6.21			
>100			1.49±0.75	0.86±0.37	1.43±0.56	1.66±0.53	1.19±0.44	

	Zone C				Zone D			
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
FG<45								
MG<65 and FN		1.78±0.29*				0.71±0.22		
MG 65-100								
>100			1.19±0.44					

Table A4. *Estimated discards(mt) of Atlantic cod from the Canadian groundfish fishery on Georges Bank in 2010. * indicates that this discard calculation refers only to the MG<65' fleet.*

	Zone A		Zone B			Zone C			Zone D		
	Q3	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q2**	**Q3**	**Q4**	**Q2**	**Q3**	**Total**
FG<45												
MG<65 & FN				19	27		2*					**48**
MG 65-100												
>100												
Total												**48**

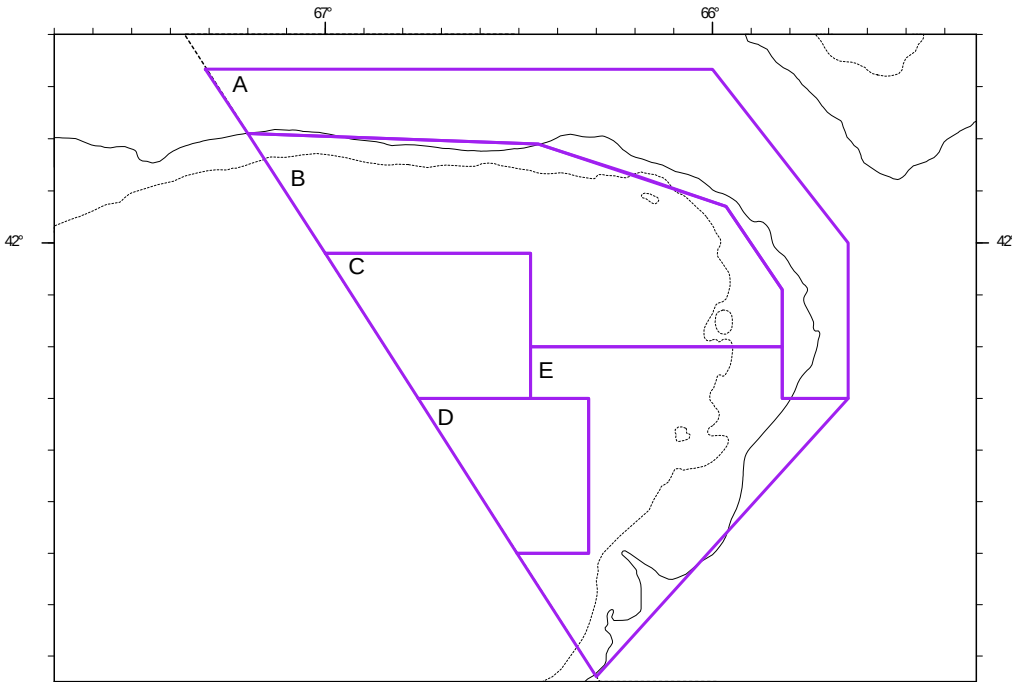


Figure A1. *The Canadian portion of Georges Bank was partitioned into five zones that were used for the analysis.*

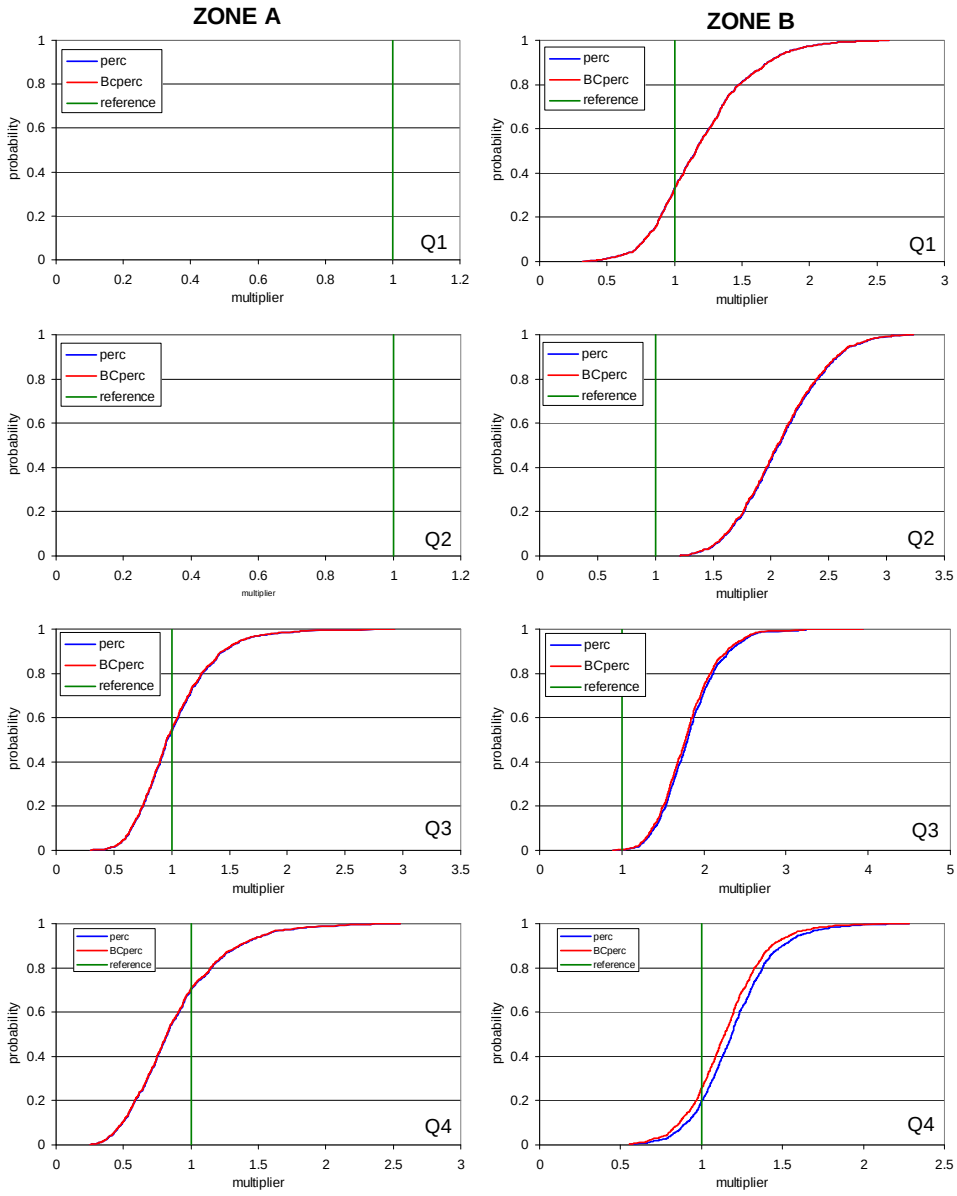


Figure A2. *Confidence distributions of the landings multipliers for the MG<65' and First Nations fleets in zones A and B, the legend of perc refer to percentile from bootstrap and BCpec refer to bias corrected percentile.*

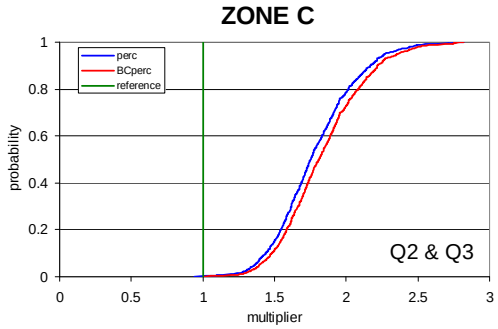


Figure A3. *Confidence distributions of the landings multipliers for the MG<65' in zone C, quarter 2 and 3 combined fleet, the legend of perc refer to percentile from bootstrap and BCpec refer to bias corrected percentile.*