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Assessment of Eastern Georges Bank Atlantic Cod for 2012

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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 2011 were 1,037 mt, including 69 mt of discards. Canadian and USA catches were 743 mt and 294 mt in 2011, 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 has fluctuated between 3,000 mt and 10,100 mt from the “split M 0.2” model and between 4,000 mt and 12,600 mt from the “split M 0.5” model. Biomass at the beginning of 2012 was 2,845 mt from the “split M 0.2” model and 4,192 mt from the “split M 0.5” model, the second lowest in the time series according to both models.

Recruitment at age 1 has been low in recent years. The 2003 and 2010 year classes were 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 lowest on record. Recruitment indices from the bottom trawl surveys for the 2011 year class are weak.

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 2011 was estimated to be 0.49 from the “split M 0.2” model and 0.28 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 2012 catch equal to the 675 mt total quota, a combined Canada/USA catch of about 875 mt (“split M 0.2” model) and 1,400 mt (“split M 0.5” model) in 2013 will result in a neutral risk (50%) that the fishing mortality rate in 2013 will exceed F_{ref}. A catch of about 2,475 mt according to both models will result in a neutral risk (50%) that the 2014 adult biomass (ages 3+) will be lower than 2013. A catch of 1,775 mt (“split M 0.2” model) and 1,525 mt (“split M 0.5” model) will result in a neutral risk (50%) that 2014 adult biomass will not increase by 10%. A catch of 1,050 mt (“split M 0.2” model) and 575 mt (“split M 0.5” model) will result in a neutral risk (50%) that 2014 adult biomass will not increase by 20%.

Considering the strong retrospective bias from both models, the Mohn’s rho adjusted deterministic projection and stochastic projections are also provided from each of the model results. Assuming a 2012 catch equal to the 675 mt total quota, a combined Canada/USA catch of about 400 mt (“split M 0.2” model) and 775 mt (“split M 0.5” model) in 2013 will result in a neutral risk (50%) that the fishing mortality rate in 2013 will exceed F_{ref}. A catch of 1,175 mt (“split M 0.2” model) and 1,450 mt (“split M 0.5” model) will result in a neutral risk (50%) that the 2014 adult biomass (ages 3+) will be lower than 2013. A catch of about 900 mt according to both models will result in a neutral risk (50%) that 2014 adult biomass will not increase by 10%. A catch of 575 mt (“split M 0.2” model) and 400 mt (“split M 0.5” model) will result in a neutral risk (50%) that 2014 adult biomass will not increase by 20%.

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 2011 se chiffraient à 1 037 tm, dont 69 tm de rejets, soit 743 tm pour le Canada et 294 tm pour les États-Unis.

Deux formes d'analyse de population virtuelle (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 3 000 tm et 10 100 tm selon le « modèle fractionné M = 0,2 » et entre 4 000 tm et 12 600 tm selon le « modèle fractionné M = 0,5 ». Elle se chiffrait au début de 2012 à 2 845 tm selon le « modèle fractionné M = 0,2 » et à 4 192 tm 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.

Le recrutement à l'âge 1 a été faible ces dernières années. Les classes d'âge 2003 et 2010 ont représenté le plus fort recrutement observé depuis 2000, mais elles n'atteignaient pas la moitié de la moyenne (environ 10 millions de poissons) de 1978 à 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. Pour ce qui est de la classe d'âge 2011, les indices de recrutement provenant des relevés au chalut de fond sont faibles.

La mortalité par pêche ($F_{4\text{-}9}$) était élevée avant 1994. En 1995, F a diminué 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 2011, F a été estimée à 0,49 d'après le « modèle fractionné M = 0,2 » et à 0,28 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 675 tm en 2012, des captures combinées du Canada et des États-Unis qui seraient en 2013 de 875 tm (« modèle fractionné M = 0,2 ») et de 1 400 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 2 475 tm selon les deux modèles se solderaient par un risque neutre (50 %) que la biomasse des adultes (âges 3 +) en 2014 soit inférieure à celle de 2013. Des captures de 1 775 tm (« modèle fractionné M = 0,2 ») et de 1 525 tm (« modèle fractionné M = 0,5 ») se traduiraient par un risque neutre (50 %) que la biomasse des adultes en 2014 n'augmente pas de 10 %. Des captures de 1 050 tm (« modèle fractionné M = 0,2 ») et de 575 tm (« modèle fractionné M = 0,5 ») se traduiraient par un risque neutre (50 %) que la biomasse des adultes en 2014 n'augmente pas de 20 %.

En tenant compte du fort biais rétrospectif de chacun des deux modèles, la projection déterministe avec correction rho de Mohn et les projections stochastiques sont également tirées des résultats de chaque modèle. Si les captures sont égales au quota total de 675 tm en 2012, des captures combinées du Canada et des États-Unis qui seraient en 2013 de 400 tm (« modèle fractionné M = 0,2 ») et de 775 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 1 175 tm (« modèle fractionné M = 0,2 ») et de 1 450 tm (« modèle fractionné M = 0,5 ») se solderaient par un risque neutre (50 %) que la biomasse des adultes (âges 3 +) en 2014 soit inférieure à celle de 2013. Des captures d'environ 900 tm selon les deux modèles se traduiraient par un risque neutre (50 %) que la biomasse des adultes en 2014 n'augmente pas de 10 %. Des captures de 575 tm (« modèle fractionné M = 0,2 ») et de 400 tm (« modèle fractionné M = 0,5 ») se traduiraient par un risque neutre (50 %) que la biomasse des adultes en 2014 n'augmente pas de 20 %.

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 2011 including commercial landings and discards, the Fisheries and Oceans Canada (DFO) survey updated to 2012, the National Marine Fisheries Services (NMFS) spring survey updated to 2012 and the NMFS fall survey updated to 2011.

FISHERY

COMMERCIAL FISHERY CATCHES

Historical catch data were updated at the 2009 benchmark meeting (Wang *et al.*, 2009a). In 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, peaked at 26,463 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 2011 were 1,037 mt, including 69 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 1995-2010, Canadian catches fluctuated between 840 mt and 3,405 mt (Table 1). In 2011, total catch (extracted landings Jan 26, 2012, 702 mt) including discards were 743 mt against a quota of 850 mt, taken primarily between July and December by otter trawl and longline (Table 3, Figure 4 and 5). All 2011 landings were subject to dockside monitoring and at sea observers monitored close to 19% by weight of the mobile gear fleet landings (20% of trips), 20% by weight of the fixed gear landings (20% of trips) and 3% of the gillnet fleet landings (9% 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, 2007a) (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 to 2011 assessment (Wang *et al.,* 2009b, 2011, Clark *et al*., 2010). Cod discards from the 2011 Canadian groundfish fishery were estimated at 13 mt from the mobile gear fleet, no discards were detected from the fixed gear fishery (Table 1).

Since 1996, the Canadian scallop fishery has not been permitted to land cod. Landings until 1995 included those catches reported by the scallop fishery. 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*., 2007b). Estimated discards of cod by the Canadian scallop fishery ranged between 36 mt to 200 mt annually since 1978 (Van Eeckhaute *et al.,* 2005). In 2011, estimated discards of cod by the Canadian scallop fishery were 29 mt (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 for haddock that started in 2004 (from August 1st to the following January 31st). Minimum mesh size limits were increased in 1994, 1999 and 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, then subsequently declined. Total USA catch (landings and discards combined) was 294 mt for calendar year 2011. The majority of USA landings are usually taken by the second calendar quarter with the least amount landed during the third quarter (Figure 5). Otter trawl gear accounted for 83% and longline gear about 17% of the landings, with the remainder taken by gillnet and other unknown gears during 2011.

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 1989-2011. A ratio of discarded cod to total kept 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 26.5 mt in 2011, a decrease from 129 mt discarded in 2010 (Table 1, Figure 3). Otter trawl gear accounted for almost all of the 2011 discarded fish (25.5 mt) with scallop gear accounting for the remainder. Observers noted that the majority of fish (80%) were discarded because of minimum size restrictions, 15% were discarded because retention was prohibited and 5% were discarded because there was either no market or the reason for discarding was not specified.

SIZE AND AGE COMPOSITION

The size and age compositions of the 2011 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 and fixed gear fishery over all the fishing months. Comparison of port and at-sea length frequencies did not indicate any discrepancies for otter trawlers. There were some fixed gear observer samples which had more small fish than the port sample, indicating that discarding might have occurred although discarding could not be inferred using the ratio of sums method, perhaps because of the low observer coverage (Figure 7). At-sea samples were pooled with port samples to derive catch at length and age. Landings peaked at 55 cm (22 in) for bottom trawlers and 70 to 73 cm (28 to 29 in) for longliners. Gillnetters caught fewer cod but these fish were larger, peaking at 73 cm (29 in) (Figure 8). The gear combined landings peaked at 59 to 65 cm (23 to 26 in) (Figure 9).The size composition of cod discards from the 2011 Canadian scallop fishery was derived from at-sea sampling. Cod discards from the scallop fishery peaked at 40 cm (16 in) (Figure 8). The discards from the groundfish fishery were assumed to have the same size composition as the groundfish landings. The Canadian combined cod discards in 2011 from otter trawl and scallop fishery peaked at 49 to 55 cm (19 to 22 in) (Figure 9).

The size and age compositions of the 2011 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 and age composition of discarded fish were estimated using at-sea observer samples of length frequency and commercial and NEFSC survey age keys from the same area and season. Landings in 2011 peaked at 59-65cm (23-26 in) and discards peaked at 47 cm (19in) (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: 55cm (22 in); USA: 56-65 cm (23 to 26 in)).

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 2011 DFO survey was used to augment the first quarter key.

The age composition of the 2011 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 2011.

Total discards at age from the USA groundfish and scallop fisheries (1989-2011), the Canadian groundfish fishery (1997-2011) and the Canadian scallop fishery (1978-2011) were included in the assessment.

The combined Canada/USA 2011 fishery age composition, by number, was dominated by the 2006 year class at age 5 (30%), followed by the 2007 year class at age 4 (24%) and the 2008 year class at age 3 (20%). The 2003 year class at age 8 made little contribution contribution to the 2011 catch (2%)(Table 6, Figure 12). By weight, the 2006 year class still dominated the 2011 fishery (39%) followed by the 2007 (23%) and 2008 year classes (13%) (Figure 12). The contribution of ages 7 and older continued to be small in recent years, 5% by number and 10% by weight in 2011(Table 6, Figure 12 and 13).

Fishery weights at age showed a declining trend starting in the early 1990s (Table 7, Figure 14). Compared to 2010, the weights at age in 2011 increased except for ages 2, 3 and 7, but still at low levels.

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 to 2012 NMFS spring survey and the 2009- 2011 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 NMFS fall, 2012 NMFS spring and 2012 DFO survey were similar to the observed from those surveys over the previous decade, with most fish concentrated on the northeastern part of Georges Bank (Figure 17-19). Total catch in numbers in the 2012 DFO survey was the lowest in the history (1986-2012), less than one third of 2011 survey (Table 10). The 2003 year class at age 9 is less than 0.4% by number in this survey. The 2008 and 2009 year classes are dominant in the 2012 survey (27% and 28% by number respectively) (Table 10, Figure 20). The 2006 year class at age 6 is moderate from this survey (16% by number, and was dominant in the 2011 DFO survey 33% by number). Initial indication of the 2010 year class at age 1 was promising in the 2011 DFO survey (5% by number), and 13% by number at age 2 in the 2012 DFO survey.

The total 2012 spring survey catch in numbers increased since 2011 and was similar to 2010, however, continued to remain among the lowest in the time series (Table 11). There was no catch of the 2003 year class at age 9 from this survey. The 2008 year class at age 4 dominated the catch (35% by number) followed by the 2009 year class at age 3 (26% by number). The 2010 year class at age 2 accounted for 18% of the catch, by number, in the 2012 survey (Table 11, Figure 20).

For the 2011 NMFS fall survey, there were 2 large tows on stratum 01210, in which the 2010 year class at age 1 was dominant (90% and 95% by number respectively). Compared to the 2010 survey, the total catch in numbers of ages 0+ was 2.4 times higher and age 1+ was 5.2 times higher, which could be partly due to a year effect. The 2010 year class at age 2 accounted for the largest catch by number at 34% (Table 12).

The coefficient of variation (CV) of mean catch number/tow for the three surveys is shown in Table 13, 14 and 15 and Figure 21. The CV of mean catch weight/tow is presented in Figure 22. Median CV values indicate the most variable catch for ages 1 and 8 for DFO and NMFS spring survey as well as ages 1 and 5 for NMFS fall survey. The CV values were similar between the DFO and NMFS spring surveys and smaller compared to the NMFS fall survey values. The catch from all the three surveys became more variable after mid-1990s, which might be caused by patchy distribution at low abundance.

With the exception of the 1996, 1998, 2003, 2006 and potentially the 2010 year classes (all of which were below the time series average), the survey abundance at age (Tables 10-12, Figure 20) shows poor recruitment since the 1990 year class in all three surveys. The 2003 year class has appeared strong in the spring surveys until age 7 and in the fall surveys until age 3. The 2006 year class was prominent in the 2011 surveys and fishery catch, but not as strong as the 2003 year class. Initial indications for the 2010 year class are promising from the 2011 DFO and 2010 and 2011 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 (Figure 23). The survey biomasses in 2012 for all 3 surveys are at low level in the time series, and the DFO survey is the lowest since the starting of the survey in 1986 (Figure 24). Survey biomass indices have been lower since the mid-1990s, and continue to decline for all ages (Figure 24).

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 the weights at age display a declining trend since the early 1990s (Table 16, Figure 25). Except for ages 1, 3, 5 and 9, weights at age in 2012 are higher than in 2011. Fulton’s K, an indicator which uses the 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 26).

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 2011 (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 2011, 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… 2011.17, 2012.00

$I_{3,a,t}$ = 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… 2011.28, 2012.00

$I_{6,a,t}$ = 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… 2010.79, 2011.79.

The population was calculated to the beginning of 2012; therefore the DFO and NMFS spring survey indices for 2012 were designated as occurring at the beginning of the year, i.e. 2012.00. 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 2011 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 = 2012

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

$K_{2,a}$ = *ln* DFO survey catchability for ages a = 1 at time t =1994 to 2011 and a=2 to 8 at time t=1994 to 2012

$K_{3,a}$ = *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 =1994 to 2011 and a=2 to 8 at time t=1994 to 2012

$K_{6,a}$ = *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=1994-2011.

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

The population abundance estimate of the 2005 and 2004 year classes at age 7 and 8 at beginning of 2012 exhibited the largest relative bias of 19% and 18% followed by the estimate for the 2010 year class at age 2 which showed a relative bias of 10%. The relative bias for other ages ranged between 4% and 8%. The relative error ranged between 32% and 76% (Table 17). Survey catchability (q) at age progressively increased until about age 6 for DFO 1994-2012 and age 5 for NMFS spring Y36 1994-2012 survey (Figure 27). Compared with the survey catchability prior to 1994, both DFO and NMFS spring survey catchability has abruptly increased starting at about age 3, the DFO survey catchability at fully recruited ages increased fourfold at 4.32. Survey catchability at age for the NMFS fall survey was very low (Figure 27).

B. "split M 0.5" Model

The population abundance estimate of the 2005 year class at age 7 at beginning of 2012 exhibited the largest relative bias of about 12%, followed by 9% for the 2004 year class at age 7 and 7% for the 2010 year class at age 2, whilst for other ages/times it ranged between 2% and 6%. The relative error ranged between 30% and 60% (Table 18). 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 1994-2012 survey and the NMFS spring Y36 1994-2012 survey, remaining relatively flat at older ages (Figure 27). Compared with the survey catchability prior to 1994, both the DFO and NMFS spring surveys catchability after 1994 has increased starting at about age 3, the DFO survey catchability at fully recruited ages increased twofold at 2.5. Survey catchability at age for the NMFS fall survey was very low (Figure 27).

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 of younger ages 2-3 for 2007 and 2009, ages 4-6 for 2006, and older ages 7-8 for 2006 and 2007 were lower than the survey observations, ages 2-6 for 2001 and older ages 7-8 for 1998, 1999, 2003, 2009 and 2011 were higher than the survey observations (Figure 28). There were residual patterns for the 2012

DFO and 2011 NMFS fall surveys from both models, which suggested strong year effects (Figure 29).

Retrospective analyses were used to detect any bias of consistently overestimating or underestimating fishing mortality, biomass and recruitment relative to the terminal year estimates. Both model formulations exhibited similar strong patterns, with the “split M 0.2” model exhibiting a stronger retrospective bias than the “split M 0.5” model. The 2003 and 2005 year classes were initially overestimated at age 1. There was a tendency to initially overestimate 3+ biomass and underestimate fishing mortality in recent years, and the bias appears even stronger in the 2012 assessment (Table 19, Figures 30 and 31). As in the current stock assessment , the population numbers at age 1 were not estimated in the retrospective analysis.

Average fishing mortality (F) at age by time block (1978-1993,1994-2006,2007-2011) calculated from each of the models show equivalent F estimates for the first time block, when M=0.2 in both models for all ages. Average F increases by time block in the “split M 0.2” model, whereas, in the “split M 0.5” model , F decreases as mortality on older ages shifts from F to M (Figure 32). Both models indicated flat fishery partial recruitment except for the 10+ group (Figure 33).

STATE OF RESOURCE

Given the strong retrospective bias, alternative approaches were considered to address the retrospective bias to characterize uncertainty and risk in catch advice. The adult biomass, recruitment, and fishing mortality estimates (Tables 20-25) presented below are from the unadjusted benchmark model formulations.

Adult population biomass (ages 3+) declined substantially from about 50,000 mt in 1990 to below 10,000 mt in 1995, the lowest observed (Table 20 and 23, Figure 34), regardless of model formulation. From the “split M 0.2” model, biomass subsequently fluctuated between 3,000 mt and 10,100 mt. Biomass was 2,845 mt (80% confidence interval: 2,409 mt – 3,705 mt) at the beginning of 2012 (Table 20). From the “split M 0.5” model, since 1995 biomass fluctuated between 4,000 mt and 12,600 mt. Biomass was 4,192 mt (80% confidence interval: 3,586 mt – 5,474 mt) at the beginning of 2012 (Table 23), slightly decreased from 4,207 mt in 2011. In both models, the increase since 2005 was largely due to recruitment and growth of the 2003 year class (Figure 35). Lower weights at age in the population in recent years and generally poor recruitment have contributed to the lack of sustained rebuilding. Survey biomass indices have been lower since the mid-1990s. In 2012, the survey biomasses for DFO and NMFS spring survey continue to remain among the lowest in the time series (Figure 24). The estimated adult population biomass at the beginning of 2012 from the VPA was only 5.5% (“split M 0.2” model) and 8% (“split M 0.5” model) of the 1978 biomass, which are the second lowest in the time series according to both models (Figure 34).

Recruitment at age 1 has been low in recent years (Table 21 and 24, Figure 34). Since 2000, the 2003 year class (2.8 million fish from the “split M 0.2” model and 4.4 million fish from the “split M 0.5” model) is the highest recruitment estimated by either model (excluding 2010). The initial estimate of the 2010 year class at 4.0 million from the “split M 0.2” model and 4.8 million from the “split M 0.5” model, is stronger than the 2003 year class based on the 2012 assessment. However, the uncertainties on the 2010 year class are high, with a 46% relative standard error on age 2 from both models. Both the 2003 and 2010 year classes are less than half of the average (about 10 million) during 1978-1990, when the productivity was considered to be higher (Figure 35). Recruitment for the 2002 and 2004 year classes was the lowest on record in both models. The 2006 year class at age 1 was 1.4 million from the “split M 0.2” model and at

1.6 million from the “split M 0.5” model. The 2007, 2008, and 2009 year classes were similar in strength, which was only about 10% of the 1978-1990 average recruitment in both models. The current biomass is well below 25,000 mt, above which there is expected to be a better chance for higher recruitment (Figure 36). Recruitment indices from the bottom trawl surveys for the 2011 year class were weak; although some fish of this year class were caught on the NMFS fall survey, no age 1 fish were caught by the 2012 NMFS spring survey and few by the DFO survey.

Fishing mortality (population number weighted average of ages 4-9) was high prior to 1994 (Table 22 and 25, Figure 37). 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 and then fluctuated between 0.42 and 0.86 for the “split M 0.2” model and 0.25 and 0.61 for the “split M 0.5” model. F in 2011 was estimated to be 0.49 (80% confidence interval: 0.40-0.65) from the “split M 0.2” model and 0.28 (80% confidence interval: 0.24-0.38) 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 38). 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. 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 38).

If the retrospective bias observed in this assessment continues, the 2011 fishing mortality rate estimate is expected to increase from 0.49 to 0.89 (“split M 0.2” model) and increase from 0.28 to 0.45 (“split M=0.5” model) while the 2012 spawning stock biomass estimate is expected to decrease from 2,845 mt to 1,395 mt (“split M 0.2” model) and decrease from 4,192 mt to 2,382 mt (“split M=0.5” model) in future assessments. These changes are based on the Mohn’s rho (Mohn, 1999) adjustment from seven year peels which will be used in the projections (Table 19).

PRODUCTIVITY

Recruitment, age structure, fish growth and spatial distribution reflect changes in the productive potential. Recruitment, while highly variable, has generally been higher when age 3+ biomass exceeded 25,000 mt (Figure 36). The current biomass is well below 25,000 mt. The number of recruits per spawner has not increased when the biomass has been low except for the 2010 year class based on the initial estimate in 2012 assessment (Figure 39). This lack of compensation hampers stock rebuilding. Although the 2003 year class is present in the population as age 9 at the highest magnitude since 1989 in both models, the population age structure since 1995 displays a very low number of ages 7+ compared to the 1980s (Figure 40). Average weight at length, used to reflect condition, has been stable in the past, but has started to decline in recent years. Length and weight at age has also declined in recent years, which could hamper biomass rebuilding due to potential changes in fecundity. Size at age in the 2011 fishery continued to stay at low levels (Figure 14). The research survey spatial distribution patterns of adult (3+) cod have not changed 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 2013 (Gavaris and Sinclair 1998, Rivard and Gavaris 2003b). Uncertainty about current biomass generate uncertainty in forecast result, which is expressed here as the risk of exceeding F_{ref} = 0.18 and change of adult biomass from 2013 to 2014. 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, and/or retrospective bias.

For projections, the 2009-2011 average values were assumed for the fishery weight at age. The 2010-2012 survey average values were assumed for the beginning of year population weights at age in 2013-2014. However, for the slower growing 2003 year class, fishery weight at age 9 in 2012 was based on a cohort regression. The 2007-2011 average partial recruitment were assumed for the partial recruitment pattern in 2012 and 2013 (Table 26). The 2007-2011 geometric mean of recruitment at age 1 from each model was used for 2012-2014 projections. Catch in 2012 was assumed to be equal to the 675 mt quota, and F=0.18 in 2013. Deterministic (Table 27, Figures 41 and 42) and stochastic (Table 28, Figure 43) projections are provided from each of the model results.

A. "split M 0.2" Model

A combined Canada/USA catch of 750 mt corresponds to a low (25%) probability that F will exceed F_{ref}=0.18, whereas catches of 875 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 43). Catches of 2,475 mt will result in a neutral risk (50%) that the 2014 adult biomass (3+) will be lower than the 2013 adult biomass, a catch of 1,775 mt will result in a neutral risk (50%) that 2014 adult biomass will not increase by 10% and a catch of 1,050 mt will result in a neutral risk (50%) that 2014 adult biomass will not increase by 20% (Figure 43).

B. "split M 0.5" Model

A combined Canada/USA catch of 1,175 mt corresponds to a low (25%) probability that F will exceed F_{ref}=0.18, whereas catches of 1,400 mt correspond to a neutral (50%) probability and catches of 1,625 mt correspond to a high (75%) probability that F will exceed F_{ref} (Figure 43). Catches of 2,475 mt will result in a neutral risk (50%) that the 2014 adult biomass (3+) will be lower than the 2013 adult biomass, a catch of 1,525 mt will result in a neutral risk (50%) that 2014 adult biomass will not increase by 10% and a catch of 575 mt will result in a neutral risk (50%) that 2014 adult biomass will not increase by 20% (Figure 43).

Mohn's Adjusted Projection and Risk Analysis

Due to the benchmark methods not accounting for the retrospective pattern in projections, alternative projections in which the retrospective pattern was accounted for were made for the "split M 0.2" and "split M 0.5" models. The rho adjustments in both cases were computed as the average Mohn's rho from seven year peels for the 3+ biomass (SSB) applied to all ages. The SSB rho values for the two models were 1.04 and 0.76, respectively, causing each bootstrap initial abundance at age to be multiplied by 1/(1+rho) = 0.4908 and 0.5669 respectively. The results of these projections are described below. Deterministic (Table 29, Figures 44-45) and stochastic (Table 28, Figure 46) projections are provided from each of the model results.

A. "split M 0.2" Model

A combined Canada/USA catch of 325 mt corresponds to a low (25%) probability that F will exceed F_{ref}=0.18, whereas catches of 400 mt correspond to a neutral (50%) probability and catches of 475 mt correspond to a high (75%) probability that F will exceed F_{ref} (Table 28, Figure 46). Catches of 1,175 mt will result in a neutral risk (50%) that the 2014 adult biomass (3+) will be lower than the 2013 adult biomass, a catch of 900 mt will result in a neutral risk (50%) that 2014 adult biomass will not increase by 10% and a catch of 575 mt will result in a neutral risk (50%) that 2014 adult biomass will not increase by 20% (Figure 46).

B. "split M 0.5" Model

A combined Canada/USA catch of 625 mt corresponds to a low (25%) probability that F will exceed F_{ref}=0.18, whereas catches of 775 mt correspond to a neutral (50%) probability and catches of 875 mt correspond to a high (75%) probability that F will exceed F_{ref} (Figure 46). Catches of 1,450 mt will result in a neutral risk (50%) that the 2014 adult biomass (3+) will be lower than the 2013 adult biomass, a catch of 900 mt will result in a neutral risk (50%) that 2014 adult biomass will not increase by 10% and a catch of 400 mt will result in a neutral risk (50%) that 2014 adult biomass will not increase by 20% (Table 28, Figure 46).

While management measures have resulted in decreased exploitation rate since 1995, fishing mortality has remained above F_{ref} and adult biomass has fluctuated at a low level. The continuing poor recruitment since the early 1990s is an important factor for this lower productivity. The initial estimate of the 2010 year class is higher than adjacent year classes, but is still well below the average of 1978-1990, when the productivity is considered to have been higher. Rebuilding will not occur without improved recruitment.

SPECIAL CONSIDERATIONS

The management advice and performance since 1999 are summarized in Table 30, 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 bias 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. Although the VPA used in both models for management advice assumes a split in the survey indices, the mechanisms for the large changes in survey catchability are not easily explained. These changes in survey catchability are assumed to alias an unknown mechanism that produces a better fitting model. 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, 1978-2011.

	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	8,092		8,092	16,698
1982	17,827	71		17,898	8,565		8,565	26,463
1983	12,131	65		12,196	8,572		8,572	20,769
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	4,793		4,793	16,713
1988	12,741	83		12,824	7,645		7,645	20,470
1989	7,895	76		7,971	6,182	100	6,282	14,253
1990	14,364	70		14,434	6,414	92	6,506	20,940
1991	13,467	65		13,532	6,353	149	6,501	20,034
1992	11,667	71		11,738	5,080	235	5,315	17,053
1993	8,526	63		8,589	4,019	69	4,088	12,677
1994	5,277	63		5,340	998	6	1,005	6,344
1995	1,102	38		1,140	543	0.3	544	1,683
1996	1,924	56		1,980	676	1	677	2,658
1997	2,919	58	428	3,405	549	6	555	3,960
1998	1,907	92	273	2,272	679	7	686	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	1,317	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	171	253	424	1,282
2006	1,096	112	237	1,445	131	126	257	1,702
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
2011	702	29	13	743	267	27	294	1,037
Minimum	630	29	13	743	131	1	251	1,037
Maximum	17,827	200	428	17,898	10,550	355	10,550	26,463
Average	5,751	82	182	5,881	3,535	91	3,600	9,481

Table 2. Canadian and USA fishery management history of cod on eastern Georges Bank, 1978-2011.

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.
2011	TAC=1,050mt; Winter fishery from Jan. 1 to Feb. 5, 2011; At sea observer coverage 19% by weight of the mobile gear fleet landings, 20% by weight of the fixed gear landings and 3% by weight of the gillnet fleet 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 areaon 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 uimplemented. 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
April : All multispecies vessels fishing on a Category A DAS allowed to use a flounder trawl net in the Eastern US/CA area. 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).
Special Management Programs: *US/Canada Area*: Opening delayed until August 1 for trawl vessels. Prohibition on discarding legal sized fish. *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.

May 27: Changes to common pool trip limits: GB haddock: 10,000 lbs./trip, GB yellowtail flounder: 1,000 lbs./trip (offshore)
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 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, 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.
2011
March 31: Groundfish common pool trip limit changes. Increase: GB cod 3,000 lbs/DAS, 30,000 lbs/trip' Decrease: GOM cod 100 lb/trip
May 1: Start of groundfish fishing year. Common pool trip limits revert to cahrt (see attached for May 2011). Differential DAS counting areas in GOM and GB. CAII SAP modified to allow targeting haddock, August 1 – January 31. Gen Cat scallop fishing GSC spawning closure eliminated
August 1: CAI, CAII, and Hudson Canyon scallop access areas open
August 30: Groundfish common pool trip limit reductions.GOM cod: 350 lb/DAS, 1,000 lb/trip;GB cod: 300 lb/DAS, 600 lb/trip
September 14: Haddock catch cap regulations for herring fishery change. Cap increased to 1% of GB haddock ABC and 1% of GOM haddock ABC. Applies to MIWT gear. Based on catch estimate.
September 19: Dockside monitoring program suspended.
October 3: Handgear B trip limits reduced to GOM cod 50 lb/trip, GB cod 25 lb/trip

Table 3. Nominal landings (mt) of cod from eastern Georges Bank by gear and month for Canada 2002-2011.

Year	Gear	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
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
2011	Mobile	33	7				18	35	33	42	38	27	45	279
	Gillnet						4	15	24	15	7			65
	Longline						14	56	109	79	65	34		358
	Total	23	7				36	107	165	136	111	61	45	702

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.

	USA		Canada	
Year	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	4,147	897
1982	4,466[1]	778	4,705	1,126(268)
1983	3,906[1]	903	3,822	754(150)
1984	3,891	1,130	1,889	1,243(858)
1985	2,076	597	7,031	1,309(351)
1986	2,145	643	5,890	991(103)
1987	1,865	524	9,133	1,429(193)
1988	3,229	797	11,350	2,437(510)
1989	1,572	347	8,726	1,561
1990	2,395	552	31,974	2,825(1,153)
1991	1,969	442	27,869	1,782
1992	2,048	489	29,082	2,215(359)
1993	2,215	569	31,588	2,146
1994	898	180	27,972	1,268
1995	2645[1]	14	6,660	548
1996	4,895[1]	1,163	26,069	828
1997	1,761[1]	82	31,617	1,216
1998	1,301[1]	338	26,180	1,643
1999	726	228	26,232	1,290(410)
2000	500	121	20,582	1,374
2001	1,434	397	19,055	1,505
2002	1,424	429	16,119	1,252
2003	1,367	416	19,757	1,070
2004	1,547	517	18,392	1,357
2005	2971	65	23,937	1,483(697)
2006	446	151	44,708	1,460(648)
2007	589	183	141,607	1,647(456)
2008	972	295	64,387	1,709(495)
2009	1,286	326	48,335	1,725(246)
2010	1,446	333	30,594	1,455(433)
2011	1,203	213	40,936	1,655(536)

[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	Age Reader	Sample Size	Agreement (%)
DFO RV survey NED2010001	EGB	exchange	Nov. 2011	NS vs. BH	19	95
DFO RV survey NED2011002	EGB	exchange	Nov. 2011	NS vs. BH	123	93
DFO comm. Sample Q2	EGB	exchange	Nov. 2011	NS vs. BH	15	93
DFO comm. Sample Q3	EGB	exchange	Nov. 2011	NS vs. BH	15	86
DFO comm. Sample Q4	EGB	exchange	Nov. 2011	NS vs. BH	14	87
NMFS RV survey 200709	EGB	exchange	Nov. 2011	NS vs. BH	20	90
NMFS RV survey 200807	EGB	exchange	Nov. 2011	NS vs. BH	28	86
NMFS RV survey 200904	EGB	exchange	Nov. 2011	NS vs. BH	55	89
NMFS RV survey 201004	EGB	exchange	Nov. 2011	NS vs. BH	43	86

[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 1978-2011.

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1978	1	8	108	3644	1167	394	163	127	22	23	6	2	1	0	0	0	0	5668
1979	1	15	890	735	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	1865	1337	279	475	181	96	59	21	2	1	0	0	0	0	5216
1982	0	15	3516	1971	1269	1087	196	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	231	805	1354	546	377	279	39	90	38	17	7	2	3	0	1	3806
1985	33	9	2861	1409	661	987	271	110	110	21	27	3	4	1	1	0	0	6508
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	4189	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	1037	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	3	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	485	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	37	159	240	405	81	89	19	4	1	0	0	0	0	0	0	1048
2004	0	21	13	146	151	147	139	35	30	7	1	1	0	0	0	0	0	690
2005	0	2	86	56	192	54	34	37	10	5	1	0	0	0	0	0	0	478
2006	0	3	21	242	75	191	47	18	17	2	2	0	0	0	0	0	0	618
2007	0	2	76	84	406	32	86	11	7	7	0	0	0	0	0	0	0	712
2008	0	1	45	148	60	247	15	33	4	2	1	0	0	0	0	0	0	557
2009	1	8	68	220	134	39	134	9	10	1	1	0	0	0	0	0	0	626
2010	0	1	29	114	213	74	15	35	3	2	0	0	0	0	0	0	0	485
2011	0	6	49	76	92	115	26	12	7	0	0	0	0	0	0	0	0	383

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	10
1978	0.44	1.26	2.07	2.72	3.72	5.41	5.61	8.28	7.50	11.32
1979	0.73	1.45	1.52	3.28	4.45	6.59	9.41	9.62	9.86	14.18
1980	0.38	1.24	2.21	3.07	4.96	6.29	7.22	11.46	10.41	12.54
1981	0.52	1.28	1.99	3.06	4.54	6.50	8.02	9.25	11.62	15.19
1982	0.56	1.30	2.13	3.61	5.01	6.76	8.51	9.86	11.86	13.98
1983	0.90	1.49	2.21	3.10	4.60	6.10	7.81	10.15	11.47	13.20
1984	0.68	1.60	2.31	3.42	4.76	6.09	8.30	9.35	11.16	12.03
1985	0.54	1.32	1.81	3.19	4.55	5.95	7.91	9.60	10.75	12.52
1986	0.54	1.36	2.43	3.30	4.83	6.70	8.08	9.20	11.38	11.46
1987	0.58	1.46	2.38	3.93	5.38	7.23	8.76	9.46	11.27	12.01
1988	0.62	1.17	2.19	3.07	4.91	6.10	8.27	9.89	11.14	12.49
1989	0.65	1.28	1.96	3.35	4.89	6.02	6.79	9.80	10.70	12.77
1990	0.69	1.55	2.38	3.22	4.60	6.04	7.80	9.81	11.19	12.82
1991	0.73	1.51	2.41	3.14	4.24	5.53	7.45	9.46	9.18	13.28
1992	0.86	1.41	2.28	3.32	4.25	5.67	6.80	8.66	11.21	14.85
1993	0.60	1.40	2.11	2.84	4.29	5.40	6.76	8.29	9.14	11.13
1994	0.59	1.33	2.14	3.44	4.39	6.42	7.19	8.15	7.97	11.40
1995	0.29	1.32	2.12	3.35	4.94	6.38	10.10	10.01	10.44	15.35
1996	0.49	1.42	2.17	3.05	4.70	5.83	6.42	8.96	10.35	10.38
1997	0.72	1.44	2.07	2.93	3.86	5.36	7.26	8.31	11.48	9.88
1998	0.78	1.36	2.15	2.98	3.97	5.33	6.59	7.83	10.23	12.88
1999	0.56	1.32	1.98	3.10	3.91	5.48	6.27	7.54	9.38	13.52
2000	0.65	1.26	1.96	2.91	4.02	4.70	5.72	6.77	8.35	14.05
2001	0.21	1.07	1.82	2.73	3.58	4.87	5.22	7.27	8.65	11.07
2002	0.32	1.17	1.96	2.85	4.01	4.89	6.41	8.23	7.98	10.11
2003		1.22	2.10	2.73	3.54	4.27	5.47	6.84	7.63	8.13
2004	0.24	1.24	1.84	2.78	3.47	4.56	5.24	7.25	8.54	8.64
2005	0.17	0.91	1.57	2.44	3.50	4.48	4.89	6.81	8.05	8.94
2006	0.20	0.66	1.77	2.38	3.36	4.34	6.09	5.79	6.89	7.20
2007	0.48	1.10	1.58	2.43	3.07	3.94	6.29	6.83	6.89	9.30
2008	0.22	1.25	2.19	2.80	3.66	5.04	5.82	7.92	7.97	8.73
2009	0.64	1.34	1.94	3.12	3.71	4.53	5.74	6.82	10.08	10.26
2010	0.43	1.25	2.02	2.56	3.40	3.46	5.12	6.08	9.11	10.86
2011	0.31	1.06	1.74	2.58	3.52	4.28	4.23	6.06	9.85	9.37
Min	0.17	0.66	1.52	2.38	3.07	3.46	4.23	5.79	6.89	7.20
Max	0.90	1.60	2.43	3.93	5.38	7.23	10.10	11.46	11.86	15.35
Avg[1].	0.42	1.20	1.89	2.70	3.47	4.25	5.44	6.74	8.78	9.70

[1]for 2007-2011

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 2012 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
2012		9	149	327	315	195	158	7	18	4	0	0	0	0	0	0	0	1182

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
2012	0	0	280	413	545	188	123	14	0	0	0	0	0	0	0	0	0	1563

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
2011	126	600	472	260	177	110	32	0	0	0	0	0	0	0	0	0	0	1776

Table 13. Coefficients of variation (CV) of mean catch number/tow for DFO survey.

Year\Age	1	2	3	4	5	6	7	8	CV of Mean Num/tow	Mean Num/tow
1987	0.75	0.43	0.52	0.50	0.36	0.33	0.36	0.28	0.42	9.2
1988	0.38	0.26	0.38	0.37	0.33	0.28	0.28	0.29	0.33	18.6
1989	0.34	0.23	0.21	0.19	0.25	0.27	0.33	0.27	0.16	14.1
1990	0.41	0.20	0.19	0.18	0.25	0.29	0.33	0.34	0.18	31.6
1991	0.54	0.20	0.19	0.20	0.21	0.23	0.34	0.35	0.16	19.0
1992	0.37	0.21	0.20	0.19	0.23	0.33	0.36	0.39	0.16	19.0
1993	0.57	0.21	0.23	0.25	0.28	0.25	0.24	0.22	0.21	10.8
1994	1.00	0.25	0.22	0.30	0.49	0.71	0.66	0.61	0.32	9.3
1995	0.60	0.34	0.39	0.38	0.31	0.35	0.46	0.55	0.34	7.4
1996	0.53	0.28	0.21	0.25	0.29	0.40	0.33	0.54	0.24	23.1
1997	0.72	0.28	0.26	0.27	0.26	0.28	0.30	0.41	0.25	9.4
1998	0.70	0.33	0.20	0.19	0.21	0.25	0.29	0.32	0.19	5.8
1999	1.00	0.21	0.21	0.24	0.32	0.46	0.59	0.84	0.24	8.6
2000	0.00	0.61	0.72	0.64	0.52	0.45	0.44	0.48	0.55	25.9
2001	1.00	0.34	0.32	0.33	0.35	0.39	0.47	0.47	0.37	10.2
2002	0.00	0.53	0.27	0.26	0.33	0.39	0.47	0.55	0.31	13.2
2003	0.00	0.85	0.19	0.15	0.15	0.16	0.23	0.27	0.15	5.0
2004	0.48	0.52	0.17	0.17	0.24	0.27	0.32	0.35	0.20	5.0
2005	0.57	0.53	0.75	0.73	0.56	0.55	0.47	0.44	0.66	31.5
2006	0.00	0.48	0.27	0.28	0.30	0.32	0.32	0.32	0.27	12.8
2007	0.85	0.22	0.24	0.20	0.22	0.32	0.43	0.41	0.21	11.1
2008	0.75	0.36	0.25	0.25	0.28	0.29	0.32	0.34	0.27	13.4
2009	1.00	0.42	0.48	0.62	0.67	0.76	0.00	0.81	0.58	20.2
2010	1.00	0.56	0.40	0.53	0.67	0.69	0.72	0.73	0.59	23.2
2011	0.43	0.34	0.22	0.26	0.27	0.30	0.29	0.27	0.22	9.5
2012	0.74	0.21	0.19	0.22	0.25	0.23	0.56	0.56	0.18	2.8
Median	**0.65**	**0.33**	**0.24**	**0.26**	**0.28**	**0.32**	**0.34**	**0.40**	**0.25**	**11.9**

Table 14. Coefficients of variation (CV) of mean catch number/tow for NMFS spring survey**.** During 1973-1981 a Yankee 41 net was used rather than the standard Yankee 36 net.

Year\Age	1	2	3	4	5	6	7	8	CV of Mean Num/tow	Mean Num/tow
1970	0.44	0.19	0.70	0.35	2.90	0.80	4.45	0.00	0.38	3.58
1971	0.58	0.30	0.28	0.40	0.42	0.45	0.53	0.58	0.26	3.02
1972	0.27	0.35	0.23	0.29	0.53	0.36	0.49	0.47	0.19	7.95
1973	0.30	0.70	0.60	0.53	0.48	0.45	0.38	0.00	0.64	60.20
1974	0.52	0.39	0.31	0.28	0.29	0.33	0.62	0.33	0.28	16.18
1975	0.00	0.15	0.21	0.17	0.16	0.14	0.67	0.00	0.17	10.96
1976	0.50	0.36	0.28	0.37	0.30	0.00	0.45	0.78	0.25	6.16
1977	0.00	0.14	0.26	0.32	0.34	0.32	0.63	0.43	0.15	4.79
1978	0.60	0.00	0.25	0.46	0.38	0.33	0.31	0.49	0.26	6.94
1979	0.30	0.35	0.25	0.20	0.25	0.32	0.52	0.38	0.21	4.90
1980	1.00	0.53	0.36	0.36	0.37	0.37	0.41	0.67	0.37	8.87
1981	0.40	0.35	0.27	0.23	0.37	0.19	0.27	0.67	0.22	11.18
1982	0.64	0.53	0.89	0.88	0.88	0.00	0.89	0.89	0.83	68.83
1983	0.26	0.06	0.12	0.12	0.30	0.51	0.96	0.81	0.13	9.48
1984	0.44	0.51	0.29	0.33	0.36	0.42	0.64	1.00	0.20	1.87
1985	0.84	0.43	0.51	0.37	0.30	0.25	0.33	0.35	0.35	11.46
1986	0.57	0.38	0.29	0.38	0.38	0.28	0.74	0.53	0.21	6.71
1987	0.00	0.34	0.34	0.41	0.00	0.41	0.35	0.74	0.23	4.32
1988	0.66	0.49	0.41	0.44	0.32	0.49	1.03	0.64	0.34	7.87
1989	0.34	0.51	0.41	0.33	0.28	0.33	0.39	1.08	0.32	9.78
1990	0.76	0.56	0.58	0.40	0.27	0.24	0.41	0.62	0.42	8.72
1991	0.32	0.26	0.21	0.19	0.18	0.23	0.28	0.73	0.15	9.04
1992	0.80	0.32	0.40	0.33	0.24	0.25	0.25	0.43	0.22	3.34
1993	0.00	0.68	0.45	0.37	0.67	0.38	0.48	0.36	0.41	4.30
1994	0.59	0.54	0.57	0.46	0.30	0.49	0.49	0.00	0.37	1.75
1995	0.40	0.52	0.34	0.49	0.55	0.52	0.55	0.00	0.36	6.52
1996	0.34	0.36	0.48	0.47	0.59	0.53	0.62	0.00	0.39	5.44
1997	1.04	0.69	0.40	0.36	0.28	0.59	0.33	0.38	0.28	3.15
1998	0.00	0.44	0.51	0.49	0.49	0.50	1.03	0.55	0.46	11.01
1999	0.78	0.31	0.26	0.19	0.24	0.38	0.43	0.49	0.21	3.92
2000	0.00	0.44	0.30	0.28	0.29	0.26	0.59	1.03	0.28	5.47
2001	0.00	0.37	0.44	0.54	0.50	0.65	0.00	1.03	0.44	2.76
2002	0.00	0.65	0.46	0.35	0.30	0.39	0.56	0.00	0.32	4.15
2003	0.00	0.23	0.38	0.48	0.57	0.44	0.65	0.62	0.48	5.94
2004	0.38	1.16	0.43	0.51	0.63	0.70	0.61	0.71	0.54	13.70
2005	1.03	0.50	0.56	0.20	0.23	0.22	0.31	1.03	0.24	3.35
2006	1.04	0.74	0.38	0.35	0.32	0.40	0.31	0.34	0.26	5.50
2007	0.00	0.37	0.32	0.32	0.25	0.26	0.31	0.80	0.29	6.39
2008	0.74	0.41	0.30	0.29	0.28	0.33	0.28	0.00	0.26	4.94
2009	0.32	0.53	0.61	0.28	0.24	0.18	0.31	0.35	0.30	3.05
2010	0.72	0.41	0.19	0.17	0.31	0.30	0.35	0.00	0.25	2.19
2011	0.38	0.40	0.29	0.36	0.37	0.41	0.49	0.77	0.24	1.19
2012	0.00	0.47	0.45	0.32	0.31	0.35	0.38	0.00	0.38	3.38
Median	**0.54**	**0.41**	**0.36**	**0.35**	**0.32**	**0.37**	**0.48**	**0.62**	**0.28**	**5.50**

Table 15. Coefficients of variation (CV) of mean catch number/tow for NMFS fall survey.

Year\Age	1	2	3	4	5	CV of Mean Num/tow	Mean Num/tow
1970	0.31	0.36	0.37	0.32	1.04	0.22	3.77
1971	0.70	0.13	0.58	0.25	0.79	0.37	3.41
1972	0.61	0.46	0.42	0.75	1.43	0.59	6.65
1973	0.47	0.33	0.52	0.59	0.68	0.33	9.16
1974	0.58	0.42	0.40	0.48	1.00	0.41	1.72
1975	0.51	0.41	0.57	0.49	1.00	0.41	2.89
1976	0.47	0.37	0.44	0.00	0.78	0.44	10.97
1977	0.00	0.22	0.17	0.19	0.39	0.19	6.97
1978	0.31	0.27	0.25	0.25	0.29	0.24	7.80
1979	0.43	0.36	0.28	0.23	0.27	0.32	8.13
1980	0.39	0.29	0.32	0.54	0.39	0.27	3.54
1981	0.27	0.35	0.33	0.33	0.85	0.26	7.64
1982	0.69	0.48	0.56	0.86	0.00	0.52	1.63
1983	0.50	0.45	0.63	1.35	1.35	0.29	2.22
1984	0.59	0.35	0.62	0.75	0.75	0.43	4.32
1985	0.46	0.93	0.99	0.83	1.04	0.53	4.77
1986	0.63	0.48	0.37	0.00	0.00	0.57	6.13
1987	0.77	0.47	0.56	0.56	0.00	0.47	2.45
1988	0.73	0.39	0.39	0.45	0.50	0.36	4.44
1989	0.38	0.46	0.49	0.46	0.51	0.42	7.20
1990	0.75	0.78	0.68	0.73	0.77	0.58	5.10
1991	0.66	0.64	0.60	0.52	0.74	0.55	0.91
1992	0.45	0.42	0.49	0.00	1.03	0.41	2.05
1993	0.74	0.45	0.59	0.78	0.00	0.48	0.83
1994	0.55	0.46	0.93	0.96	0.85	0.68	1.44
1995	1.08	0.47	0.54	0.77	0.66	0.47	1.41
1996	0.57	0.64	0.50	0.48	0.44	0.47	1.85
1997	0.74	0.80	1.04	0.88	1.08	0.88	1.64
1998	0.63	0.39	0.31	0.38	0.15	0.35	2.90
1999	1.03	0.90	0.78	0.70	0.40	0.74	0.78
2000	0.66	0.69	0.47	0.41	0.39	0.41	0.89
2001	1.10	0.52	0.56	0.95	0.98	0.45	1.08
2002	0.70	0.39	0.50	0.66	0.78	0.54	8.07
2003	0.00	0.50	0.43	0.51	0.70	0.36	0.67
2004	0.47	0.47	0.48	0.66	0.84	0.59	5.36
2005	1.00	0.44	0.59	0.46	0.54	0.44	1.76
2006	0.60	0.69	0.62	0.74	0.90	0.66	2.23
2007	0.64	0.43	1.00	0.36	0.00	0.33	0.54
2008	0.60	0.41	0.39	1.00	0.32	0.27	0.80
2009	0.44	0.41	0.39	0.39	0.55	0.55	3.98
2010	0.41	0.60	0.43	0.34	0.75	0.43	2.48
2011	0.49	0.54	0.59	0.68	0.89	0.29	2.59
Median	**0.60**	**0.45**	**0.50**	**0.53**	**0.75**	**0.43**	**2.67**

Table 16. 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	0.093	0.838	1.735	2.597	4.797	5.644	8.153	7.990	11.427	14.635
1971	0.116	0.811	1.798	2.347	4.372	5.377	6.450	7.990	7.384	14.635
1972	0.085	0.866	1.979	2.959	3.482	5.212	5.608	6.539	13.806	14.635
1973	0.085	0.802	1.890	2.958	3.247	3.434	7.722	7.129	9.998	14.635
1974	0.149	0.606	1.705	2.641	4.173	5.806	7.452	7.754	8.153	14.635
1975	0.109	1.132	2.354	2.745	3.734	5.184	7.714	7.567	9.150	14.635
1976	0.138	0.946	2.156	2.999	3.753	5.342	8.011	7.384	9.150	14.635
1977	0.124	0.905	2.130	3.365	6.182	5.503	6.667	5.664	9.150	14.635
1978	0.112	0.886	1.624	3.564	5.414	6.247	8.626	8.973	10.226	14.635
1979	0.112	0.868	1.740	2.995	4.565	5.188	9.629	10.885	10.976	14.635
1980	0.276	0.706	1.892	2.786	5.244	6.281	5.919	8.973	11.762	14.635
1981	0.095	0.852	1.826	3.342	4.971	6.862	8.184	12.712	11.262	14.635
1982	0.092	0.869	2.219	3.050	4.114	6.427	8.061	8.828	10.776	14.635
1983	0.224	1.131	1.871	2.263	3.132	6.011	8.153	8.653	10.525	14.635
1984	0.050	0.582	1.954	2.443	2.699	4.121	5.890	8.973	10.279	14.635
1985	0.087	0.646	1.926	3.205	3.781	5.834	8.771	9.866	14.114	14.635
1986	0.131	0.770	1.742	3.217	4.920	5.698	7.439	8.988	10.684	14.635
1987	0.150	0.845	1.701	2.686	5.672	7.487	7.480	6.659	10.100	14.635
1988	0.152	0.931	1.785	3.020	4.169	6.268	8.438	8.724	12.330	14.635
1989	0.142	0.832	1.705	2.759	4.306	6.432	7.615	7.813	11.320	14.635
1990	0.215	0.787	1.843	2.899	4.362	6.003	8.589	9.518	13.493	14.635
1991	0.088	0.897	1.952	3.167	4.243	4.895	7.544	10.059	9.973	14.635
1992	0.127	0.846	2.045	2.793	4.163	6.127	6.979	8.555	10.448	14.635
1993	0.070	0.955	1.845	2.907	4.513	5.889	6.999	7.383	9.341	14.635
1994	0.143	0.657	1.433	2.629	3.954	7.458	7.330	8.661	9.211	14.635
1995	0.183	0.794	1.587	2.245	3.474	4.697	6.692	7.920	11.833	14.635
1996	0.088	0.838	1.553	2.597	3.908	6.112	5.458	12.028	11.920	14.635
1997	0.190	0.717	1.694	2.176	3.218	6.200	6.204	9.796	10.174	14.635
1998	0.078	0.650	1.382	2.258	3.034	4.516	5.831	7.787	8.211	14.635
1999	0.111	1.001	1.350	2.237	2.973	4.635	6.513	8.250	8.568	14.635
2000	0.060	0.896	1.587	2.326	3.234	4.461	6.501	8.211	11.523	14.635
2001	0.010	0.771	1.418	2.584	3.602	5.089	6.909	7.552	10.089	11.653
2002	0.016	0.495	1.214	2.269	3.538	4.385	5.856	8.436	10.001	11.653
2003	0.016	0.441	1.141	1.882	3.046	3.361	5.120	6.702	7.661	11.653
2004	0.022	0.288	1.454	2.447	3.449	4.086	4.312	6.320	9.923	11.653
2005	0.058	0.589	1.167	1.770	2.972	3.297	3.936	7.655	6.448	11.653
2006	0.031	0.307	1.151	1.574	2.621	3.182	4.615	4.684	5.729	11.653
2007	0.054	0.625	1.073	1.764	2.622	4.098	5.789	6.810	7.981	11.653
2008	0.046	0.577	1.450	2.041	2.504	3.465	4.165	7.931	10.050	11.653
2009	0.114	0.724	1.470	2.482	2.701	3.527	4.479	5.594	8.285	11.653
2010	0.079	0.657	1.575	2.214	3.194	3.501	3.963	5.380	6.520	11.653
2011	0.038	0.482	1.193	2.036	2.709	3.581	3.670	4.484	5.080	11.653
2012	0.027	0.512	1.181	2.130	2.889	3.771	5.106	6.329	3.872	11.653
Average	0.104	0.758	1.674	2.601	3.828	5.165	6.653	8.042	9.882	13.825
Minimum	0.010	0.288	1.073	1.574	2.504	3.182	3.670	4.484	5.080	11.653
Maximum	0.276	1.132	2.354	3.564	6.182	7.487	9.629	12.712	14.114	14.635

Table 17. Statistical properties of estimates for population abundance (numbers in thousands) at beginning of year 2012 and survey catchability (unitless) 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[2012 2]	3588	1651	46%	349	10%
N[2012 3]	671	243	36%	51	8%
N[2012 4]	396	127	32%	21	5%
N[2012 5]	191	69	36%	7	4%
N[2012 6]	109	50	46%	8	7%
N[2012 7]	6	4	70%	1	19%
N[2012 8]	6	4	76%	1	18%
N[2012 9]	66	34	51%	5	7%
DFO 1986-1993 age 1	0.024	0.008	33%	0.001	5%
DFO 1986-1993 age 2	0.217	0.072	33%	0.012	6%
DFO 1986-1993 age 3	0.412	0.141	34%	0.021	5%
DFO 1986-1993 age 4	0.398	0.131	33%	0.014	3%
DFO 1986-1993 age 5	0.642	0.206	32%	0.026	4%
DFO 1986-1993 age 6	0.663	0.224	34%	0.048	7%
DFO 1986-1993 age 7	0.770	0.253	33%	0.043	6%
DFO 1986-1993 age 8	1.029	0.342	33%	0.063	6%
DFO 1994-2011 age 1	0.013	0.003	25%	0.000	1%
DFO 1994-2011 age 2	0.122	0.025	21%	0.002	2%
DFO 1994-2011 age 3	0.975	0.204	21%	0.017	2%
DFO 1994-2011 age 4	2.370	0.493	21%	0.029	1%
DFO 1994-2011 age 5	3.328	0.711	21%	0.118	4%
DFO 1994-2011 age 6	4.371	0.939	21%	0.105	2%
DFO 1994-2011 age 7	4.090	0.915	22%	0.035	1%
DFO 1994-2011 age 8	4.318	0.906	21%	0.116	3%
NMFS Spring Y41 1978-1981 age 1	0.017	0.009	54%	0.002	11%
NMFS Spring Y41 1978-1981 age 2	0.193	0.115	60%	0.024	12%
NMFS Spring Y41 1978-1981 age 3	0.216	0.107	49%	0.019	9%
NMFS Spring Y41 1978-1981 age 4	0.209	0.115	55%	0.033	16%
NMFS Spring Y41 1978-1981 age 5	0.309	0.154	50%	0.026	8%
NMFS Spring Y41 1978-1981 age 6	0.296	0.151	51%	0.036	12%
NMFS Spring Y41 1978-1981 age 7	0.380	0.199	52%	0.041	11%
NMFS Spring Y41 1978-1981 age 8	0.332	0.162	49%	0.031	9%
NMFS Spring Y36 1982-1993 age 1	0.028	0.008	29%	0.001	3%
NMFS Spring Y36 1982-1993 age 2	0.131	0.035	27%	0.005	4%
NMFS Spring Y36 1982-1993 age 3	0.258	0.070	27%	0.006	2%
NMFS Spring Y36 1982-1993 age 4	0.315	0.085	27%	0.008	2%
NMFS Spring Y36 1982-1993 age 5	0.385	0.107	28%	0.016	4%
NMFS Spring Y36 1982-1993 age 6	0.407	0.114	28%	0.018	4%
NMFS Spring Y36 1982-1993 age 7	0.348	0.095	27%	0.014	4%
NMFS Spring Y36 1982-1993 age 8	0.382	0.101	26%	0.011	3%
NMFS Spring Y36 1994-2011 age 1	0.036	0.010	27%	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	0.562	0.117	21%	0.008	1%
NMFS Spring Y36 1994-2011 age 4	1.256	0.270	21%	0.019	1%
NMFS Spring Y36 1994-2011 age 5	1.604	0.328	20%	0.026	2%
NMFS Spring Y36 1994-2011 age 6	1.532	0.324	21%	0.036	2%
NMFS Spring Y36 1994-2011 age 7	1.718	0.371	22%	0.048	3%
NMFS Spring Y36 1994-2011 age 8	1.549	0.415	27%	0.038	2%
NMFS Fall 1978-1993 age 1	0.071	0.017	24%	0.003	4%
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%	0.003	3%
NMFS Fall 1978-1993 age 4	0.055	0.013	24%	0.001	2%
NMFS Fall 1978-1993 age 5	0.045	0.012	26%	0.001	2%
NMFS Fall 1994-2010 age 1	0.060	0.013	22%	0.001	2%
NMFS Fall 1994-2010 age 2	0.161	0.035	22%	0.004	2%
NMFS Fall 1994-2010 age 3	0.283	0.063	22%	0.006	2%
NMFS Fall 1994-2010 age 4	0.284	0.062	22%	0.005	2%
NMFS Fall 1994-2010 age 5	0.340	0.078	23%	0.013	4%

Table 18. Statistical properties of estimates for population abundance (numbers in thousands) at beginning of year 2012 and survey catchability (unitless) 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[2012 2]	4258	1956	46%	309	7%
N[2012 3]	803	299	37%	48	6%
N[2012 4]	491	159	32%	19	4%
N[2012 5]	270	96	36%	13	5%
N[2012 6]	206	79	38%	9	5%
N[2012 7]	18	11	60%	2	12%
N[2012 8]	14	7	54%	1	9%
N[2012 9]	142	43	30%	3	2%
DFO 1986-1993 age 1	0.023	0.008	35%	0.001	5%
DFO 1986-1993 age 2	0.210	0.070	33%	0.010	5%
DFO 1986-1993 age 3	0.403	0.132	33%	0.014	3%
DFO 1986-1993 age 4	0.385	0.135	35%	0.020	5%
DFO 1986-1993 age 5	0.615	0.212	34%	0.037	6%
DFO 1986-1993 age 6	0.636	0.201	32%	0.032	5%
DFO 1986-1993 age 7	0.734	0.243	33%	0.029	4%
DFO 1986-1993 age 8	0.983	0.336	34%	0.047	5%
DFO 1994-2011 age 1	0.011	0.003	25%	0.000	3%
DFO 1994-2011 age 2	0.103	0.023	22%	0.002	2%
DFO 1994-2011 age 3	0.815	0.168	21%	0.021	3%
DFO 1994-2011 age 4	1.881	0.380	20%	0.026	1%
DFO 1994-2011 age 5	2.321	0.474	20%	0.026	1%
DFO 1994-2011 age 6	2.505	0.515	21%	0.057	2%
DFO 1994-2011 age 7	2.317	0.519	22%	0.078	3%
DFO 1994-2011 age 8	2.468	0.552	22%	0.063	3%
NMFS Spring Y41 1978-1981 age 1	0.017	0.009	54%	0.002	12%
NMFS Spring Y41 1978-1981 age 2	0.193	0.120	62%	0.026	14%
NMFS Spring Y41 1978-1981 age 3	0.216	0.110	51%	0.021	10%
NMFS Spring Y41 1978-1981 age 4	0.209	0.101	48%	0.022	11%
NMFS Spring Y41 1978-1981 age 5	0.309	0.155	50%	0.028	9%
NMFS Spring Y41 1978-1981 age 6	0.296	0.145	49%	0.021	7%
NMFS Spring Y41 1978-1981 age 7	0.380	0.184	48%	0.029	8%
NMFS Spring Y41 1978-1981 age 8	0.332	0.161	48%	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	0.035	27%	0.005	4%
NMFS Spring Y36 1982-1993 age 3	0.254	0.065	26%	0.007	3%
NMFS Spring Y36 1982-1993 age 4	0.307	0.081	26%	0.008	3%
NMFS Spring Y36 1982-1993 age 5	0.371	0.102	27%	0.012	3%
NMFS Spring Y36 1982-1993 age 6	0.393	0.108	27%	0.016	4%
NMFS Spring Y36 1982-1993 age 7	0.336	0.088	26%	0.008	2%
NMFS Spring Y36 1982-1993 age 8	0.369	0.098	26%	0.012	3%
NMFS Spring Y36 1994-2011 age 1	0.030	0.008	27%	0.001	5%
NMFS Spring Y36 1994-2011 age 2	0.120	0.026	22%	0.002	2%
NMFS Spring Y36 1994-2011 age 3	0.467	0.098	21%	0.006	1%
NMFS Spring Y36 1994-2011 age 4	0.985	0.206	21%	0.015	1%
NMFS Spring Y36 1994-2011 age 5	1.092	0.230	21%	0.035	3%
NMFS Spring Y36 1994-2011 age 6	0.876	0.193	22%	0.027	3%
NMFS Spring Y36 1994-2011 age 7	0.964	0.220	23%	0.023	2%
NMFS Spring Y36 1994-2011 age 8	0.912	0.249	27%	0.051	6%
NMFS Fall 1978-1993 age 1	0.070	0.016	22%	0.002	3%
NMFS Fall 1978-1993 age 2	0.066	0.015	23%	0.002	3%
NMFS Fall 1978-1993 age 3	0.095	0.021	22%	0.003	3%
NMFS Fall 1978-1993 age 4	0.054	0.014	25%	0.001	2%
NMFS Fall 1978-1993 age 5	0.044	0.012	27%	0.001	2%
NMFS Fall 1994-2010 age 1	0.050	0.012	23%	0.001	3%
NMFS Fall 1994-2010 age 2	0.136	0.029	21%	0.002	1%
NMFS Fall 1994-2010 age 3	0.230	0.048	21%	0.005	2%
NMFS Fall 1994-2010 age 4	0.212	0.046	22%	0.006	3%
NMFS Fall 1994-2010 age 5	0.210	0.047	22%	0.006	3%

Table 19. Mohn's rho calculations for the "split M 0.2" and the "split M 0.5" models, the numbers highlighted with yellow are the highest retrospective bias among the 7 years peels.

Peel (Assessment Year)	Age 1	3+ Biomass	F	Age 1	3+ Biomass	F
1(2011)	-0.183	0.225	-0.234	-0.167	0.209	-0.215
2(2010)	0.205	0.831	-0.523	0.238	0.657	-0.406
3(2009)	0.068	0.963	-0.486	0.094	0.633	-0.310
4(2008)	-0.279	1.576	-0.542	-0.250	1.041	-0.403
5(2007)	1.438	1.583	-0.481	1.721	1.090	-0.473
6(2006)	0.636	1.562	-0.403	0.587	1.174	-0.400
7(2005)	3.764	0.524	-0.464	2.611	0.543	-0.456
Mohn's Rho	**0.807**	**1.038**	**-0.448**	**0.690**	**0.764**	**-0.380**

Table 20. 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	1391	2961	17453	14211	7104	4458	5332	946	1134	1463	56453	52102
1979	1173	8838	4589	16578	10119	3740	4217	4262	729	2098	56341	46330
1980	2774	6026	14265	4177	16606	8334	2524	2621	3129	2288	62745	53944
1981	1649	7001	11159	15667	4756	11829	6289	3328	2429	4178	68286	59635
1982	523	12378	13203	10155	10852	3428	7942	4118	1380	4901	68880	55979
1983	1134	5244	15911	7023	4979	7135	2132	3888	2555	4249	54250	47872
1984	715	2400	6041	11503	3728	3285	3622	976	2108	4131	38509	35395
1985	445	7494	6106	5793	9980	3745	2777	2509	768	3758	43374	35435
1986	3099	3215	12056	4301	4368	7274	2110	1442	1172	2973	42010	35697
1987	1140	16309	5124	9761	3227	3143	4765	1140	894	3208	48711	31261
1988	2030	5774	21602	5153	8113	2000	1900	3186	1279	3219	54254	46450
1989	640	9063	8217	16972	3394	5331	1104	629	1546	2698	49596	39892
1990	1349	2878	15308	9320	14226	2646	2965	650	410	2721	52474	48248
1991	775	4598	4553	12702	7221	7055	1739	1469	448	2036	42598	37225
1992	297	6066	6706	2814	6524	3606	3595	813	573	1576	32571	26208
1993	213	1770	6531	4220	1869	2894	1413	1045	348	1388	21691	19708
1994	281	1623	1533	3178	1511	563	627	412	266	1005	11000	9095
1995	234	1274	2948	998	1013	350	148	127	149	880	8122	6614
1996	203	876	1959	3395	1092	884	242	142	113	820	9727	8649
1997	690	1352	1388	1790	2297	978	399	238	65	742	9939	7897
1998	110	1928	1954	1098	1072	1196	319	152	67	615	8511	6473
1999	392	1153	3156	1957	754	686	633	203	36	521	9491	7946
2000	84	2588	1386	3439	1340	491	436	239	88	434	10526	7854
2001	9	877	3263	1589	3135	1039	391	263	132	321	11020	10134
2002	25	369	1022	3172	1111	1564	432	152	131	302	8281	7886
2003	7	572	685	1083	2269	538	784	225	53	280	6496	5917
2004	61	101	1494	854	885	1021	255	292	113	236	5312	5149
2005	28	1343	323	1257	449	261	319	131	72	204	4388	3017
2006	27	123	2060	277	1073	241	159	157	27	201	4346	4196
2007	75	452	330	2200	202	677	120	85	96	164	4400	3873
2008	40	659	758	360	1645	120	244	57	37	174	4095	3396
2009	98	516	1315	734	245	1116	68	102	19	146	4359	3745
2010	79	455	823	1186	391	136	551	23	41	120	3804	3271
2011	151	392	646	662	672	122	69	372	5	133	3222	2679
2012		1659	733	799	531	379	24	29	237	113	4504	2845

Table 21. 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	100	33489
1979	10440	10187	2637	5535	2217	721	438	392	66	143	32776
1980	10039	8534	7538	1500	3167	1327	426	292	266	156	33245
1981	17435	8213	6111	4688	957	1724	768	262	216	285	40659
1982	5680	14243	5949	3329	2638	533	985	466	128	335	34287
1983	5065	4637	8502	3104	1589	1187	261	449	243	290	25328
1984	14179	4127	3092	4708	1381	797	615	109	205	282	29495
1985	5108	11594	3171	1808	2639	642	317	254	54	257	25844
1986	23619	4174	6921	1337	888	1277	284	160	110	203	38973
1987	7603	19300	3011	3635	569	420	637	171	88	219	35654
1988	13332	6205	12100	1706	1946	319	225	365	104	220	36522
1989	4501	10895	4820	6152	788	829	145	81	137	184	28531
1990	6285	3655	8306	3215	3261	441	345	68	30	186	25793
1991	8828	5128	2333	4011	1702	1441	231	146	45	139	24003
1992	2342	7169	3279	1008	1567	588	515	95	58	108	16729
1993	3030	1854	3541	1452	414	491	202	141	38	95	11258
1994	1966	2472	1070	1209	382	75	86	48	30	69	7405
1995	1278	1604	1858	445	292	74	22	16	13	60	5661
1996	2312	1045	1262	1308	279	145	44	12	10	56	6473
1997	3630	1887	819	822	714	158	64	24	6	51	8176
1998	1411	2966	1414	486	353	265	55	19	8	42	7020
1999	3537	1152	2338	875	254	148	97	25	4	36	8465
2000	1397	2890	874	1478	414	110	67	29	8	30	7297
2001	915	1137	2302	615	870	204	57	35	13	28	6176
2002	1585	747	842	1398	314	357	74	18	13	26	5373
2003	430	1297	601	576	745	160	153	34	7	24	4025
2004	2809	352	1028	349	256	250	59	46	11	20	5180
2005	490	2280	277	710	151	79	81	17	11	17	4115
2006	886	400	1789	176	410	76	35	34	5	17	3826
2007	1398	723	308	1247	77	165	21	12	12	14	3977
2008	872	1143	523	176	657	35	59	7	4	15	3491
2009	855	713	895	296	91	316	15	18	2	13	3214
2010	993	693	522	535	122	39	139	4	6	10	3064
2011	3963	812	541	325	248	34	19	83	1	11	6037
2012		3239	621	375	184	100	5	5	61	10	4599

Table 22. 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	0.001	0.036	0.464	0.387	0.399	0.288	0.257	0.262	0.257	0.113	0.363
1979	0.002	0.101	0.364	0.358	0.313	0.325	0.205	0.186	0.196	0.050	0.330
1980	0.001	0.134	0.275	0.249	0.408	0.346	0.288	0.103	0.213	0.157	0.335
1981	0.002	0.123	0.407	0.375	0.385	0.359	0.299	0.515	0.354	0.103	0.370
1982	0.003	0.316	0.451	0.539	0.599	0.513	0.585	0.453	0.543	0.178	0.558
1983	0.005	0.205	0.391	0.610	0.490	0.458	0.677	0.584	0.618	0.305	0.557
1984	0.001	0.064	0.337	0.379	0.566	0.724	0.683	0.493	0.654	0.310	0.480
1985	0.002	0.316	0.664	0.511	0.526	0.617	0.480	0.641	0.552	0.169	0.534
1986	0.002	0.127	0.444	0.654	0.549	0.495	0.305	0.395	0.338	0.070	0.538
1987	0.003	0.267	0.368	0.425	0.378	0.423	0.356	0.301	0.345	0.062	0.407
1988	0.002	0.053	0.476	0.572	0.653	0.589	0.828	0.783	0.800	0.209	0.641
1989	0.008	0.071	0.205	0.435	0.381	0.676	0.552	0.776	0.632	0.176	0.463
1990	0.003	0.249	0.528	0.436	0.617	0.448	0.660	0.220	0.587	0.195	0.526
1991	0.008	0.247	0.640	0.740	0.862	0.829	0.686	0.727	0.702	0.241	0.782
1992	0.033	0.505	0.615	0.689	0.960	0.870	1.092	0.729	1.036	0.122	0.888
1993	0.004	0.350	0.875	1.135	1.503	1.548	1.246	1.350	1.289	0.255	1.286
1994	0.003	0.086	0.678	1.222	1.435	1.024	1.474	1.130	1.351	0.044	1.270
1995	0.001	0.040	0.151	0.264	0.501	0.317	0.430	0.323	0.385	0.004	0.356
1996	0.003	0.043	0.228	0.405	0.372	0.610	0.404	0.414	0.406	0.008	0.416
1997	0.002	0.088	0.322	0.645	0.792	0.858	0.996	0.892	0.967	0.037	0.739
1998	0.003	0.038	0.281	0.451	0.669	0.803	0.598	1.332	0.790	0.055	0.618
1999	0.002	0.077	0.258	0.547	0.635	0.592	1.005	0.967	0.997	0.025	0.608
2000	0.006	0.027	0.151	0.330	0.507	0.464	0.455	0.620	0.505	0.023	0.380
2001	0.004	0.100	0.299	0.472	0.692	0.818	0.948	0.782	0.885	0.042	0.642
2002	0.001	0.018	0.181	0.429	0.474	0.647	0.588	0.763	0.623	0.148	0.481
2003	0.000	0.032	0.343	0.608	0.893	0.795	0.998	0.945	0.988	0.082	0.797
2004	0.008	0.040	0.169	0.638	0.974	0.925	1.038	1.226	1.120	0.124	0.858
2005	0.003	0.042	0.254	0.351	0.490	0.631	0.682	1.086	0.753	0.097	0.434
2006	0.004	0.060	0.160	0.627	0.708	1.098	0.820	0.831	0.825	0.134	0.740
2007	0.002	0.123	0.356	0.437	0.595	0.837	0.851	1.012	0.911	0.048	0.502
2008	0.001	0.044	0.371	0.466	0.520	0.623	0.960	0.982	0.962	0.073	0.546
2009	0.010	0.108	0.310	0.681	0.634	0.584	1.082	0.919	0.996	0.060	0.649
2010	0.001	0.044	0.262	0.553	1.071	0.511	0.270	1.193	0.295	0.038	0.582
2011	0.001	0.061	0.154	0.337	0.633	1.602	0.997	0.075	0.242	0.023	0.489

Table 23. 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	17454	14212	7104	4459	5333	946	1135	1463	56457	52105
1979	1173	8839	4589	16580	10120	3740	4217	4262	729	2098	56347	46335
1980	2775	6027	14267	4178	16608	8335	2524	2621	3130	2289	62754	53952
1981	1650	7003	11161	15670	4757	11831	6290	3328	2429	4178	68299	59646
1982	523	12385	13207	10158	10855	3429	7944	4120	1381	4902	68902	55995
1983	1136	5246	15923	7027	4981	7138	2133	3890	2556	4250	54280	47898
1984	715	2404	6045	11515	3731	3288	3624	977	2110	4133	38543	35423
1985	448	7502	6116	5797	9995	3750	2782	2513	769	3762	43435	35484
1986	3110	3235	12075	4315	4374	7293	2116	1446	1175	2977	42116	35771
1987	1159	16370	5160	9785	3247	3150	4784	1144	897	3215	48913	31383
1988	2053	5870	21707	5206	8143	2018	1906	3205	1285	3229	54621	46698
1989	660	9169	8361	17105	3456	5369	1122	634	1566	2712	50154	40326
1990	1398	2967	15499	9521	14397	2717	3006	669	416	2754	53344	48979
1991	795	4767	4734	12970	7461	7211	1811	1508	464	2069	43789	38227
1992	332	6224	7021	3024	6809	3886	3775	879	604	1622	34176	27620
1993	241	1985	6811	4584	2145	3219	1672	1198	407	1462	23724	21498
1994	331	1842	1797	3501	1909	925	948	669	413	1140	13474	11302
1995	272	1499	3381	1334	1355	728	279	261	292	849	10249	8479
1996	232	1019	2319	3975	1571	1375	436	239	201	690	12056	10805
1997	794	1547	1625	2202	2884	1599	562	374	94	531	12213	9871
1998	127	2222	2262	1356	1540	1865	545	210	109	346	10582	8232
1999	436	1336	3656	2364	1032	1270	972	326	55	259	11705	9933
2000	94	2882	1623	4143	1820	831	781	393	154	179	12900	9924
2001	10	974	3645	1905	4026	1656	584	421	202	151	13574	12590
2002	31	412	1148	3671	1465	2447	693	230	207	161	10463	10021
2003	8	697	765	1242	2817	812	1130	328	76	166	8041	7336
2004	95	118	1832	994	1122	1616	370	424	163	121	6855	6643
2005	34	2099	378	1594	587	445	533	196	118	106	6090	3957
2006	29	149	3269	337	1480	362	259	254	44	133	6317	6139
2007	89	488	406	3717	283	1195	198	140	158	96	6770	6193
2008	47	783	826	478	3406	208	466	99	70	135	6518	5688
2009	118	613	1574	828	372	3143	113	238	38	104	7141	6410
2010	95	550	995	1504	490	271	1736	45	131	77	5892	5247
2011	184	471	786	844	990	212	131	1072	15	157	4862	4207
2012		2023	892	1005	743	740	82	79	540	112	6215	4192

Table 24. 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	12453	3341	10750	3987	1312	714	618	105	111	100	33492
1979	10442	10188	2637	5535	2217	721	438	392	66	143	32780
1980	10041	8536	7539	1500	3167	1327	426	292	266	156	33251
1981	17444	8216	6112	4689	957	1724	769	262	216	286	40673
1982	5683	14251	5951	3330	2638	533	985	467	128	335	34301
1983	5073	4639	8508	3105	1590	1187	262	450	243	290	25347
1984	14195	4134	3093	4713	1382	798	615	109	205	282	29527
1985	5140	11607	3176	1809	2643	643	317	255	54	257	25902
1986	23707	4200	6932	1341	889	1280	284	161	110	203	39109
1987	7729	19372	3033	3644	573	421	640	172	89	220	35891
1988	13487	6308	12159	1724	1953	322	226	367	104	221	36871
1989	4639	11021	4904	6200	803	835	147	81	138	185	28954
1990	6514	3768	8410	3284	3300	453	350	70	31	188	26368
1991	9055	5316	2426	4095	1758	1473	240	150	47	141	24701
1992	2617	7355	3432	1083	1636	634	541	103	61	111	17573
1993	3436	2080	3693	1577	475	547	239	162	44	100	12352
1994	2311	2804	1254	1332	483	124	129	77	47	78	8639
1995	1487	1887	2130	594	390	155	42	33	25	58	6801
1996	2644	1216	1493	1531	402	225	80	20	17	47	7675
1997	4182	2159	959	1012	896	258	91	38	9	36	9640
1998	1634	3418	1637	601	508	413	93	27	13	24	8367
1999	3939	1334	2708	1057	347	274	149	40	7	18	9872
2000	1551	3218	1023	1781	563	186	120	48	13	12	8516
2001	1020	1263	2571	738	1118	325	85	56	20	13	7208
2002	1931	832	945	1618	414	558	118	27	21	14	6479
2003	500	1580	671	660	925	242	221	49	10	14	4870
2004	4376	409	1260	406	325	396	86	67	16	10	7351
2005	595	3564	324	900	198	135	135	26	18	9	5904
2006	956	486	2840	214	565	114	56	54	8	11	5304
2007	1661	780	378	2107	108	292	34	21	20	8	5409
2008	1035	1358	570	234	1360	60	112	12	7	12	4760
2009	1031	847	1071	334	138	891	25	43	4	9	4392
2010	1194	837	631	679	153	77	438	8	18	7	4043
2011	4830	976	659	414	365	59	36	239	3	13	7596
2012		3949	755	472	257	196	16	12	139	10	5807

Table 25. 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	0.001	0.036	0.464	0.387	0.399	0.288	0.257	0.262	0.257	0.113	0.363
1979	0.002	0.101	0.364	0.358	0.313	0.325	0.205	0.186	0.196	0.050	0.330
1980	0.001	0.134	0.275	0.249	0.408	0.346	0.288	0.103	0.213	0.157	0.335
1981	0.002	0.122	0.407	0.375	0.384	0.359	0.299	0.515	0.354	0.103	0.370
1982	0.003	0.316	0.450	0.539	0.598	0.512	0.585	0.453	0.543	0.178	0.557
1983	0.005	0.205	0.391	0.609	0.489	0.457	0.676	0.584	0.618	0.305	0.556
1984	0.001	0.063	0.336	0.378	0.566	0.723	0.682	0.493	0.654	0.310	0.479
1985	0.002	0.315	0.662	0.510	0.525	0.615	0.479	0.640	0.550	0.169	0.533
1986	0.002	0.126	0.443	0.651	0.548	0.494	0.304	0.394	0.337	0.070	0.536
1987	0.003	0.266	0.365	0.424	0.375	0.422	0.355	0.300	0.343	0.062	0.405
1988	0.002	0.052	0.474	0.565	0.650	0.582	0.824	0.776	0.794	0.208	0.635
1989	0.008	0.070	0.201	0.431	0.373	0.669	0.541	0.767	0.621	0.175	0.458
1990	0.003	0.240	0.520	0.425	0.607	0.434	0.648	0.213	0.575	0.192	0.515
1991	0.008	0.237	0.607	0.718	0.820	0.802	0.648	0.700	0.668	0.237	0.754
1992	0.030	0.489	0.578	0.623	0.896	0.777	1.004	0.653	0.948	0.119	0.814
1993	0.003	0.306	0.820	0.984	1.143	1.242	0.929	1.047	0.977	0.240	1.054
1994	0.003	0.075	0.547	1.028	0.936	0.590	0.869	0.647	0.786	0.045	0.955
1995	0.001	0.034	0.130	0.191	0.350	0.163	0.240	0.168	0.208	0.005	0.239
1996	0.003	0.037	0.189	0.335	0.244	0.409	0.238	0.262	0.243	0.011	0.322
1997	0.002	0.077	0.268	0.490	0.575	0.516	0.711	0.560	0.667	0.060	0.536
1998	0.002	0.033	0.238	0.349	0.417	0.518	0.360	0.921	0.486	0.115	0.423
1999	0.002	0.066	0.219	0.430	0.423	0.325	0.637	0.582	0.626	0.060	0.434
2000	0.005	0.025	0.127	0.266	0.348	0.290	0.267	0.389	0.302	0.066	0.287
2001	0.003	0.090	0.263	0.378	0.495	0.512	0.630	0.491	0.575	0.106	0.466
2002	0.001	0.016	0.159	0.359	0.338	0.428	0.382	0.513	0.407	0.350	0.373
2003	0.000	0.026	0.301	0.507	0.649	0.535	0.690	0.649	0.682	0.165	0.596
2004	0.005	0.034	0.136	0.520	0.679	0.571	0.708	0.804	0.750	0.300	0.606
2005	0.003	0.027	0.213	0.266	0.352	0.378	0.414	0.703	0.460	0.228	0.313
2006	0.003	0.049	0.097	0.484	0.459	0.703	0.500	0.508	0.504	0.245	0.497
2007	0.001	0.114	0.277	0.233	0.386	0.455	0.504	0.576	0.531	0.096	0.273
2008	0.001	0.037	0.333	0.325	0.215	0.366	0.456	0.531	0.464	0.109	0.253
2009	0.008	0.089	0.250	0.571	0.361	0.199	0.605	0.347	0.443	0.096	0.314
2010	0.001	0.036	0.209	0.403	0.727	0.253	0.097	0.517	0.105	0.068	0.331
2011	0.001	0.051	0.124	0.252	0.382	0.689	0.465	0.036	0.095	0.021	0.278

Table 26. 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)										
2012-2013	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)										
2012-2013	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)										
2012-2013	0.01	0.1	0.5	0.9	1	1	1	1	1	0.1
Fishery Partial Recruitment("split M 0.5" model)										
2012-2013	0.01	0.2	0.8	1	1	1	1	1	1	0.3
Fishery Weight at Age										
2012	0.43	1.22	1.90	2.75	3.54	4.08	5.03	6.32	6.91	11.65
2013	0.43	1.22	1.90	2.75	3.54	4.08	5.03	6.32	9.68	11.65
Population Beginning of Year Weight at Age										
2013	0.05	0.55	1.32	2.13	2.93	3.62	4.25	5.40	5.89	11.65
2014	0.05	0.55	1.32	2.13	2.93	3.62	4.25	5.40	5.89	11.65

Table 27. Deterministic projection results for eastern Georges Bank cod from benchmark model formulations. Shaded values show the 2010 year class (in purple) and the projected catch and 3+ biomass (in orange). The numbers in red show the year classes with assumed recruitments.

a. "split M 0.2" model

	Age Group										
	1	2	3	4	5	6	7	8	9	10+	1+	3+
Fishing Mortality												
2012	0.002	0.023	0.116	0.21	0.233	0.233	0.233	0.233	0.233	0.023		
2013	0.002	0.018	0.09	0.162	0.18	0.18	0.18	0.18	0.18	0.018		
Projected Population Numbers												
2012	1326	3241	633	379	180	99	5	5	63	10		
2013	1326	1083	2592	461	252	116	64	3	3	49		
2014	1326	1084	871	1940	321	172	80	44	2	41		
Projected Population Biomass												
2012	40	1653	746	808	519	372	26	30	333	114	4641	2949
2013	66	596	3422	982	738	422	272	18	18	567	7100	6438
2014	66	596	1150	4132	940	624	338	236	13	480	8576	7913
Projected Catch Numbers												
2012	3	68	63	65	34	19	1	1	12	0		
2013	2	18	203	63	38	17	10	0	0	1		
Projected Catch Biomass												
2012	1	83	120	180	120	76	5	6	82	2	675	
2013	1	21	385	172	134	71	48	3	4	9	850	

b. "split M 0.5" model

	Age Group										
	1	2	3	4	5	6	7	8	9	10+	1+	3+
Fishing Mortality												
2012	0.001	0.026	0.104	0.13	0.13	0.13	0.13	0.13	0.13	0.039		
2013	0.002	0.036	0.144	0.18	0.18	0.18	0.18	0.18	0.18	0.054		
Projected Population Numbers												
2012	1592	3973	743	473	261	194	17	13	136	9		
2013	1592	1302	3169	548	340	187	103	9	7	78		
2014	1592	1301	1028	2247	375	232	95	52	4	48		
Projected Population Biomass												
2012	48	2026	877	1007	753	732	84	81	722	109	6441	4366
2013	80	716	4183	1168	996	678	439	47	40	909	9257	8461
2014	80	716	1357	4786	1099	842	403	283	26	563	10153	9358
Projected Catch Numbers												
2012	2	93	67	53	29	19	2	1	13	0		
2013	3	42	386	82	51	24	13	1	1	3		
Projected Catch Biomass												
2012	1	113	127	144	102	77	8	8	91	3	675	
2013	1	51	734	226	180	100	68	7	9	38	1414	

Table 28. Projection and risk analysis result for eastern Georges Bank cod from benchmark model formulations and Mohn's rho adjustment.

a. The probability of exceeding F_{ref} =0.18.

Probability of exceeding F_{ref} in 2013	**0.25**	**0.5**	**0.75**
"Split M 0.2"	750 mt	875 mt	1,025mt
"Split M 0.5"	1,175 mt	1,400 mt	1,625 mt
"Split M 0.2": Mohn's rho adjusted	325 mt	400 mt	475 mt
"Split M 0.5": Mohn's rho adjusted	625 mt	775 mt	875 mt

b. Changes in adult biomass from 2013 to 2014.

Neutral risk (50%) that biomass will not increase by:	**0%**	**10%**	**20%**
"Split M 0.2"	2,475 mt	1,775 mt	1,050 mt
"Split M 0.5"	2,475 mt	1,525 mt	575 mt
"Split M 0.2": Mohn's rho adjusted	1,175 mt	900 mt	575 mt
"Split M 0.5": Mohn's rho adjusted	1,450 mt	900 mt	400 mt

Table 29. Mohn's role adjusted deterministic projection results for eastern Georges Bank cod from benchmark model formulations. Shaded values show the 2010 year class (in purple) and the projected catch and 3+ biomass (in orange). The numbers in red show the year classes with assumed recruitments.

a. "split M 0.2" model

	Age Group											
	1	2	3	4	5	6	7	8	9	10+	1+	3+
Fishing Mortality												
2012	0.005	0.053	0.263	0.474	0.526	0.526	0.526	0.526	0.526	0.053		
2013	0.002	0.018	0.09	0.162	0.18	0.18	0.18	0.18	0.18	0.018		
Projected Population Numbers												
2012	650	1588	310	186	88	48	2	2	31	5		
2013	650	529	1233	195	95	43	23	1	1	19		
2014	650	531	426	923	136	65	29	16	1	16		
Projected Population Biomass												
2012	19	810	366	396	254	182	13	15	163	56	2274	1445
2013	33	291	1628	415	278	154	99	7	7	217	3129	2805
2014	33	292	562	1966	398	235	124	86	5	183	3883	3559
Projected Catch Numbers												
2012	3	74	65	64	33	18	1	1	12	0		
2013	1	9	96	27	14	6	4	0	0	0		
Projected Catch Biomass												
2012	1	90	124	176	117	74	5	5	80	3	675	
2013	0	10	183	73	50	26	18	1	2	4	367	

b. "split M 0.5" model

	Age Group											
	1	2	3	4	5	6	7	8	9	10+	1+	3+
Fishing Mortality												
2012	0.002	0.048	0.191	0.238	0.238	0.238	0.238	0.238	0.238	0.071		
2013	0.002	0.036	0.144	0.18	0.18	0.18	0.18	0.18	0.18	0.054		
Projected Population Numbers												
2012	907	2265	424	270	149	111	9	7	78	5		
2013	907	741	1768	287	174	96	53	4	3	40		
2014	907	741	585	1253	196	119	49	27	2	25		
Projected Population Biomass												
2012	27	1155	500	574	429	417	48	46	411	62	3671	2489
2013	45	408	2334	611	510	347	225	24	21	468	4991	4538
2014	45	408	773	2670	574	431	206	145	13	289	5554	5101
Projected Catch Numbers												
2012	2	96	67	52	29	19	2	1	13	0		
2013	1	24	215	43	26	13	7	1	0	2		
Projected Catch Biomass												
2012	1	117	127	143	101	76	8	8	90	3	675	
2013	1	29	410	118	92	51	35	4	4	19	763	

Table 30. 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 – 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% Now 0.58 or 0.33; Age 3+ biomass decreased 18%/20% from 10-11
2010[4]	2011	(1) 1,000 – 1,400 mt (2) 1,850 – 1,350 mt	(1) Neutral risk of exceeding Fref (2) Neutral risk of stock decline from 2011 - 2012	1,050 mt	Low risk of exceeding Fref, and biomass growth of up to 10%.	1,037 mt	F = 0.49 or 0.28 Age 3+ biomass increased 6%/stable
2011	2012	(1) 600 – 925 mt (2) 1,350 – 900 mt	(1) Neutral risk of exceeding Fref (2) Neutral risk of stock decline from 2012 – 2013	675 mt	Low risk of exceeding Fref, and low to neutral risk of biomass decline		

(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

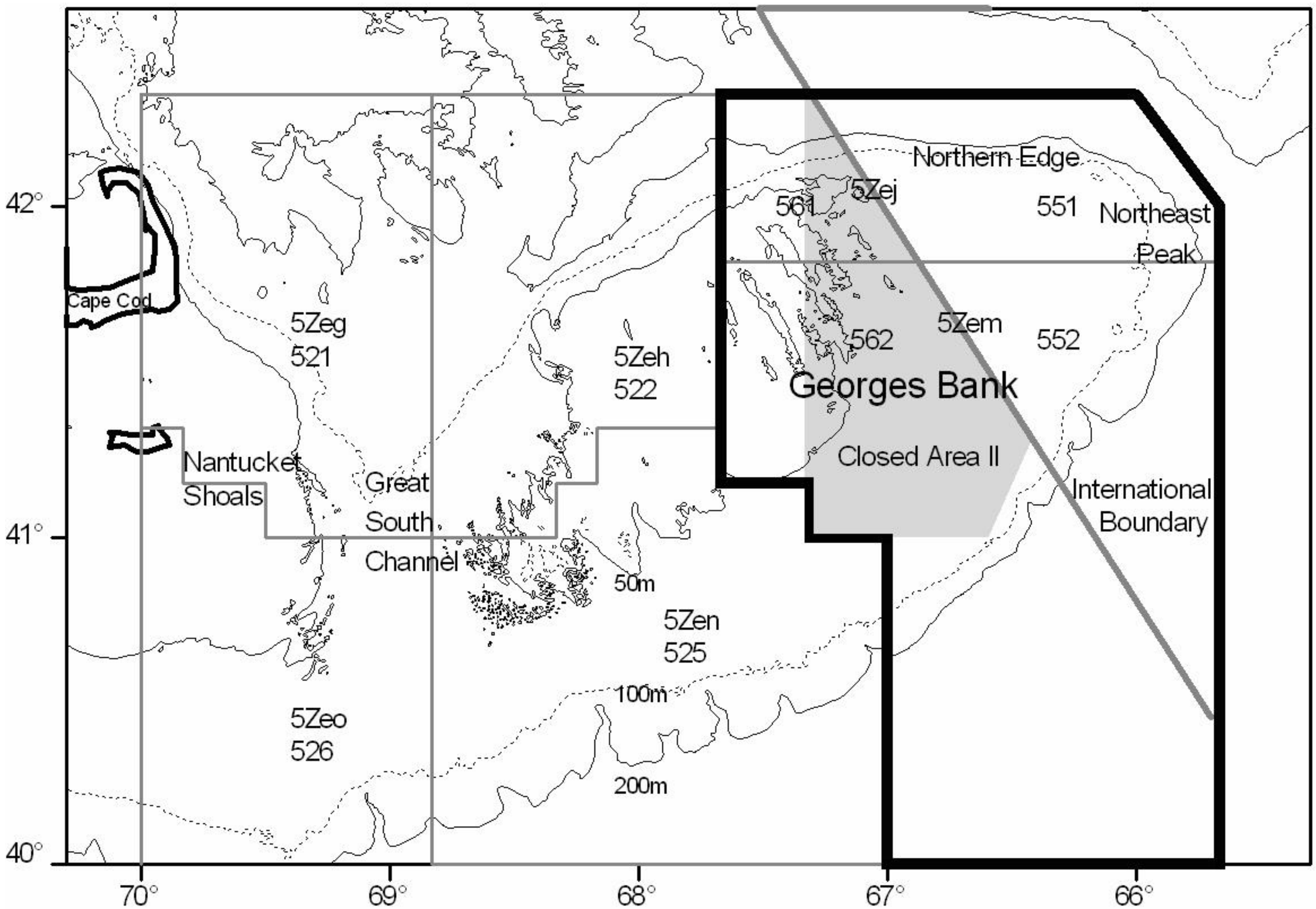


Figure 1. Fisheries statistical unit areas in NAFO Subdivision 5Ze. The eastern Georges Bank management unit is outlined by a heavy black line.

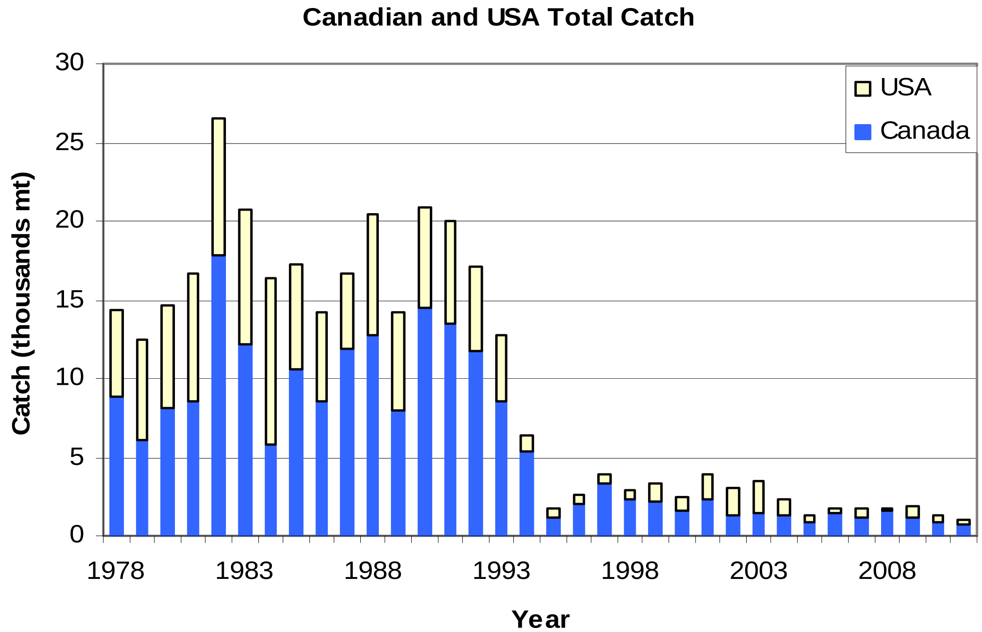
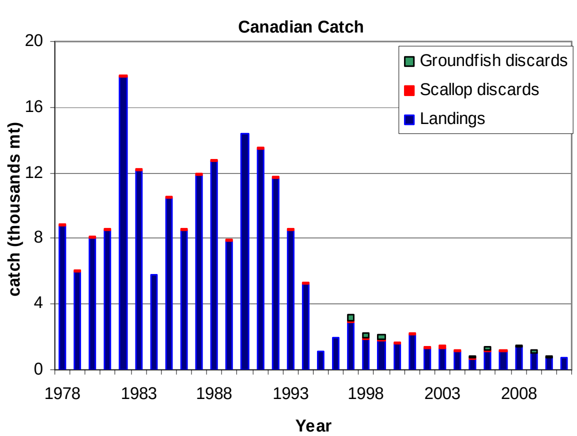


Figure 2. Catches of cod from eastern Georges Bank, 1978 to 2011.



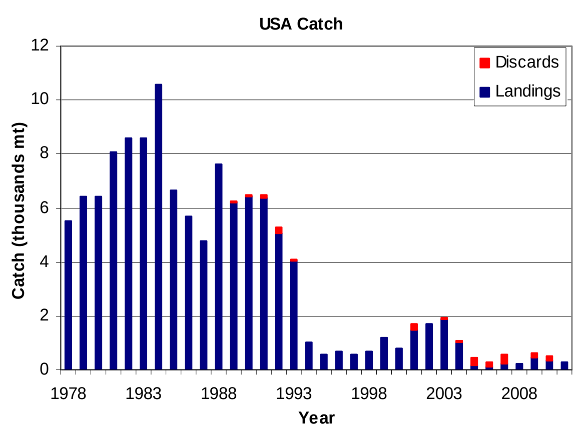


Figure 3. Canadian and USA landings and discards of cod from eastern Georges Bank, 1978 to 2011.

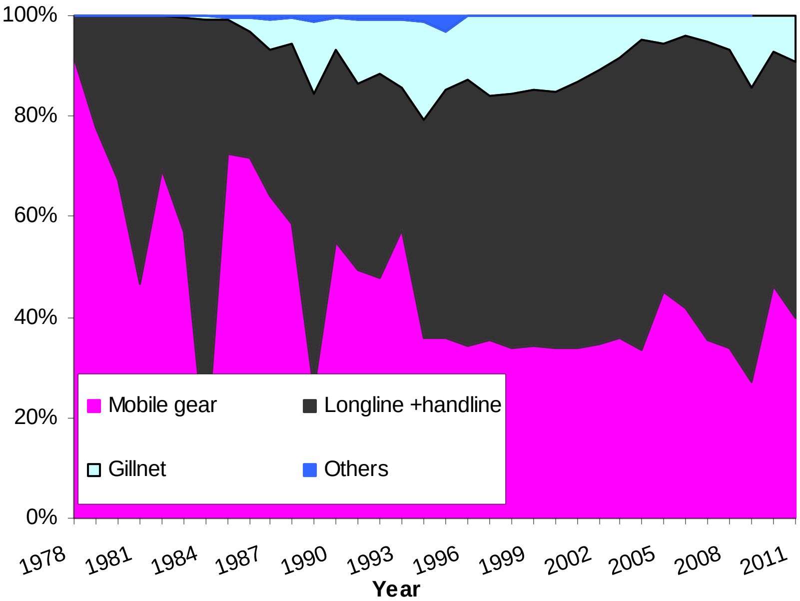


Figure 4. Proportion of Canadian gear specific landings of cod from eastern Georges Bank for 1978 to 2011.

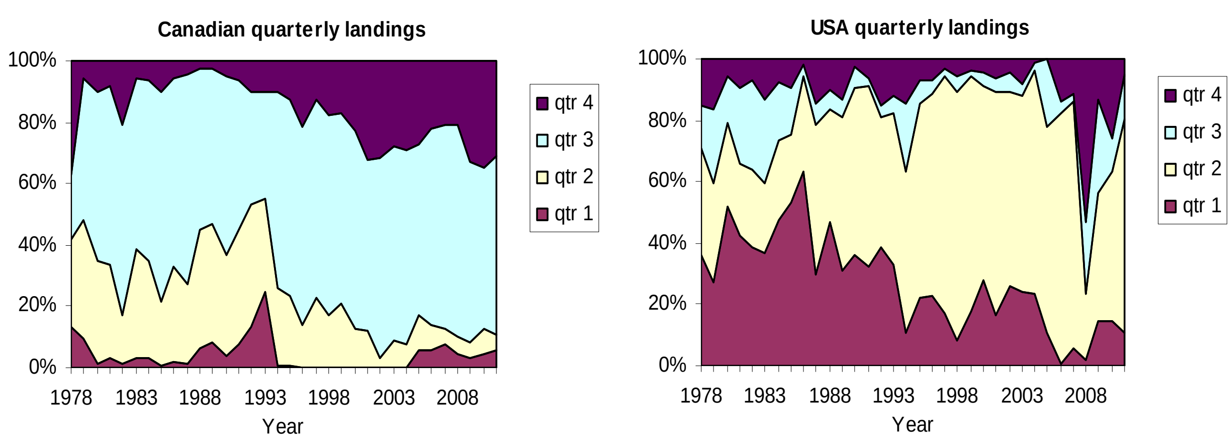


Figure 5. Proportion of Canadian and USA quarterly landings of cod from eastern Georges Bank, 1978 to 2011.

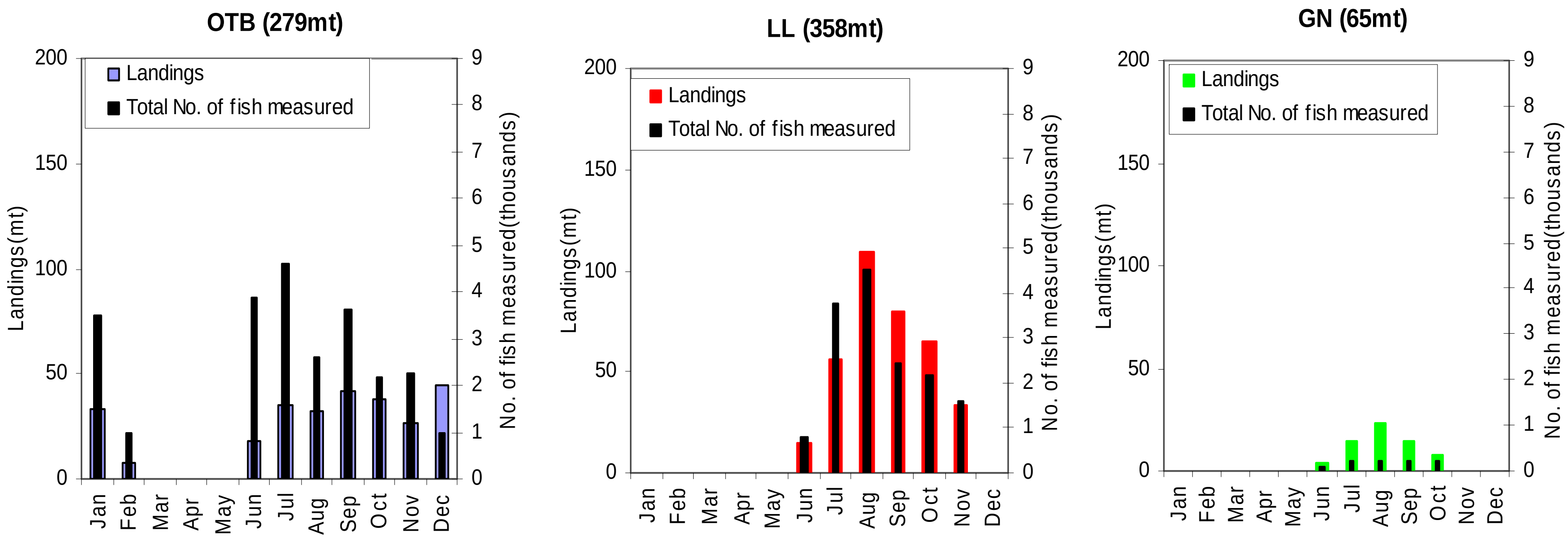


Figure 6. Landings (wide bars) and sampling (narrow dark bars) of cod by gear and month from the 2011 Canadian bottom trawl (OTB), longline (LL) and gillnet (GN) fisheries on eastern Georges Bank.

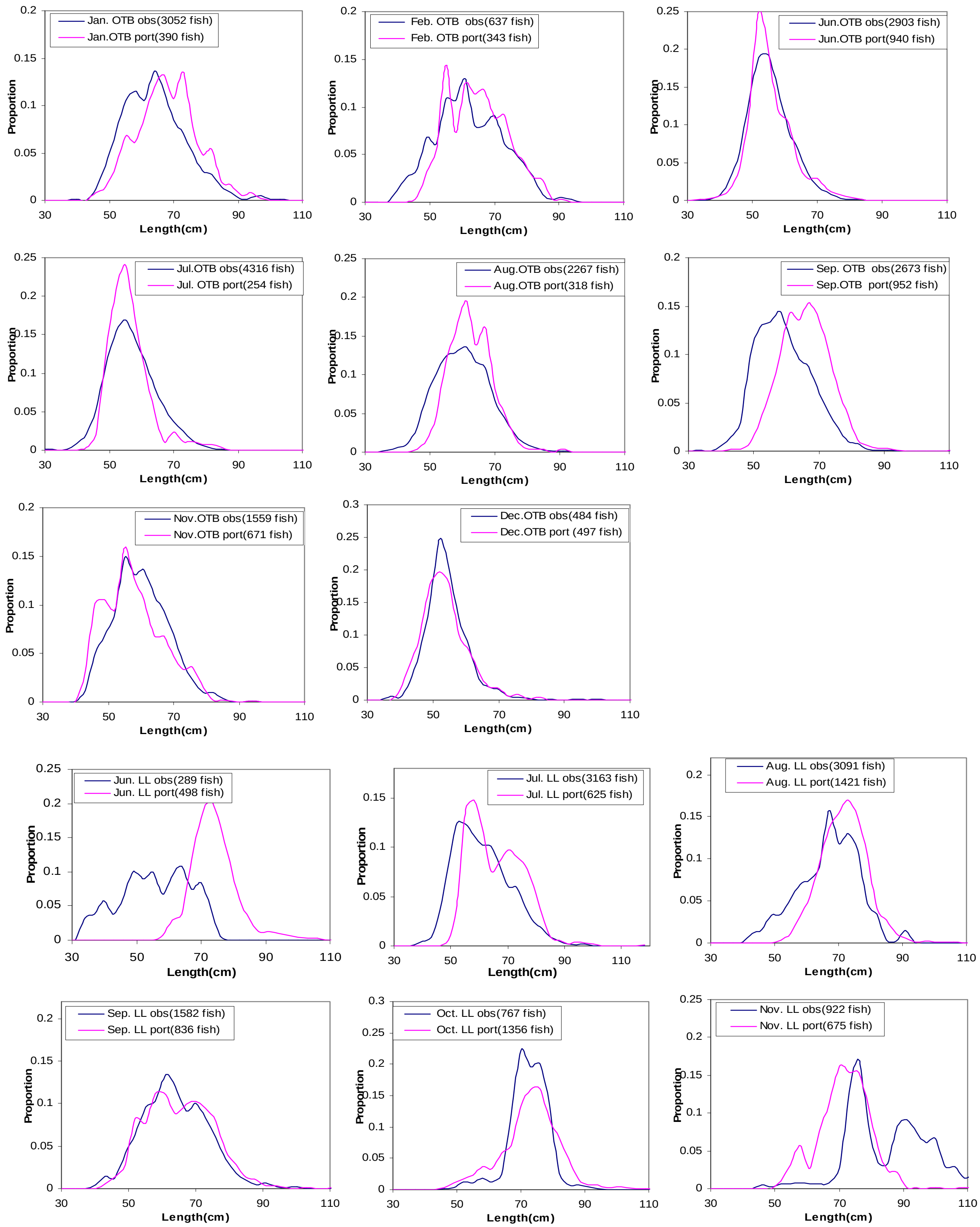


Figure 7. Comparison of cod length frequency composition from port and at sea observer sampling of the 2011 Canadian bottom trawl (OTB) and longline (LL) fisheries on eastern Georges Bank.

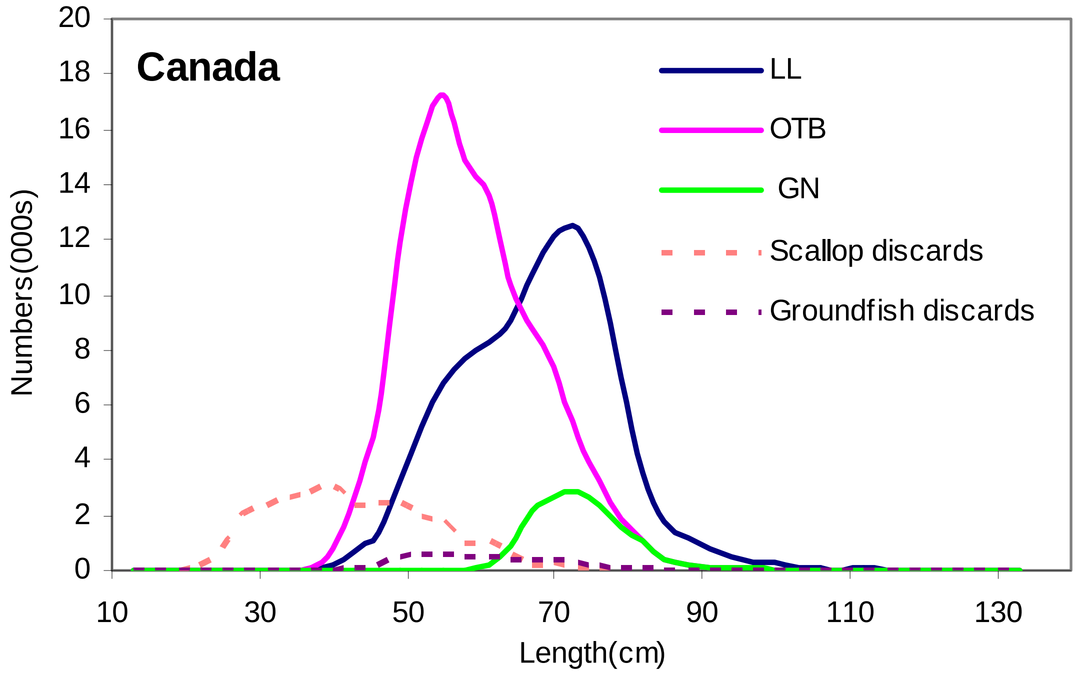


Figure 8. Cod catches at length by gear from the 2011 Canadian fisheries on eastern Georges Bank.

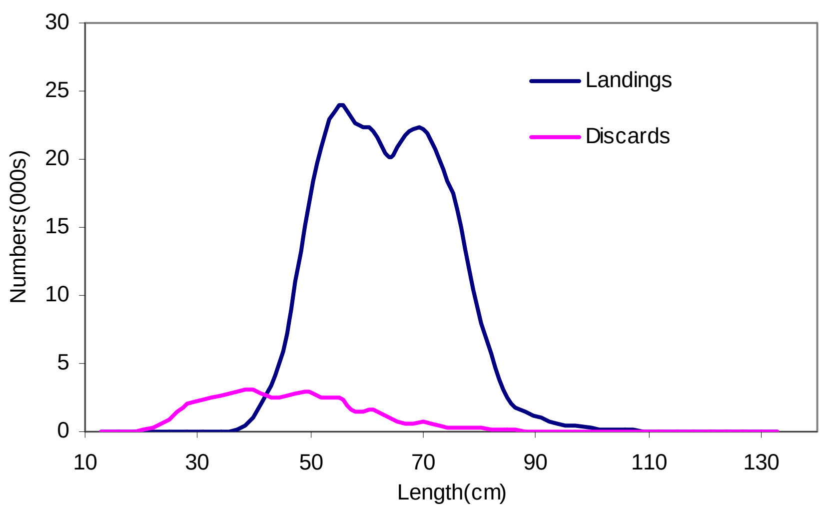


Figure 9. Cod landings and discards at length from the 2011 Canadian fisheries on eastern Georges Bank.

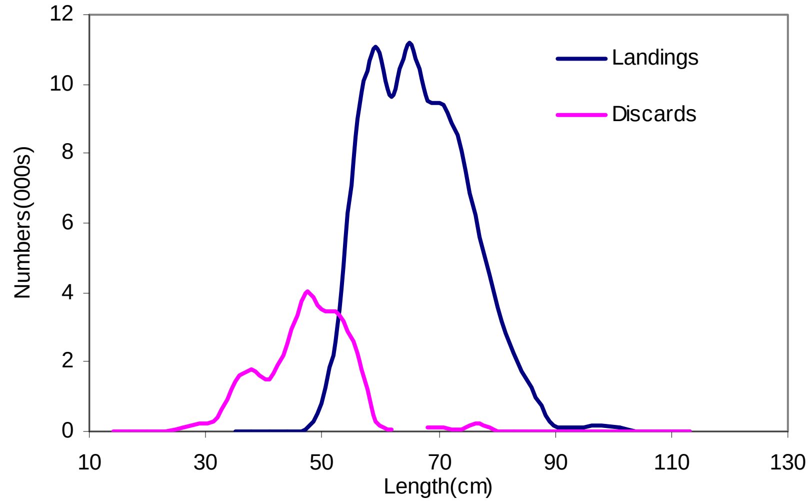


Figure 10. Cod landings and discards at length from the 2011 USA fisheries on eastern Georges Bank.

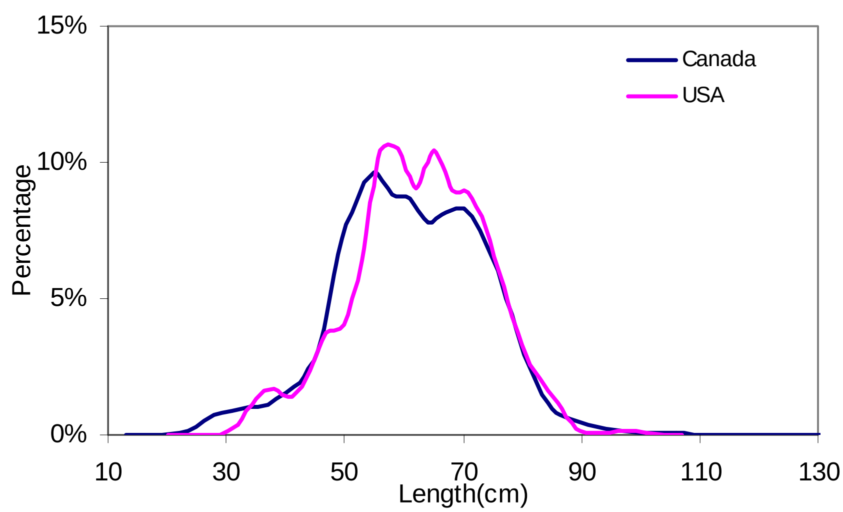


Figure 11. Catch length frequency composition from the 2011 Canadian and USA fisheries on eastern Georges Bank.

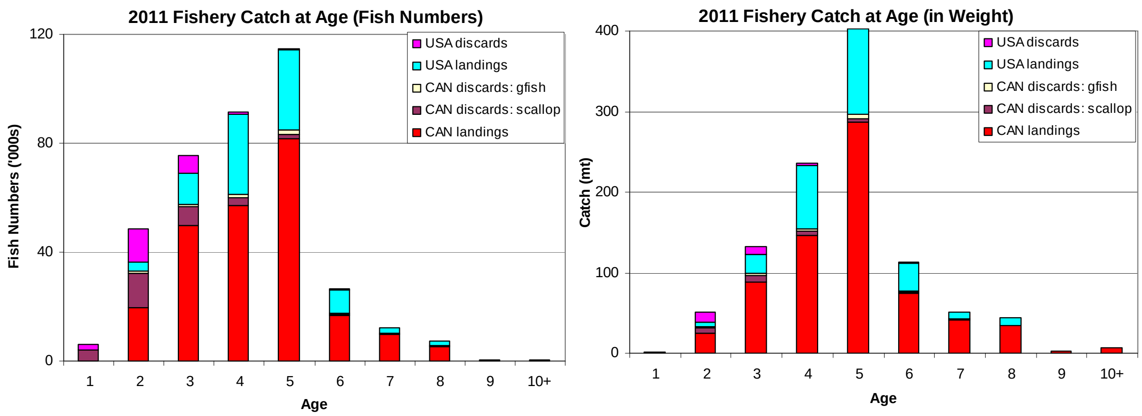


Figure 12. Catch at age in numbers (left) and weight (right) for landings and discards of cod from the 2011 eastern Georges Bank fisheries.

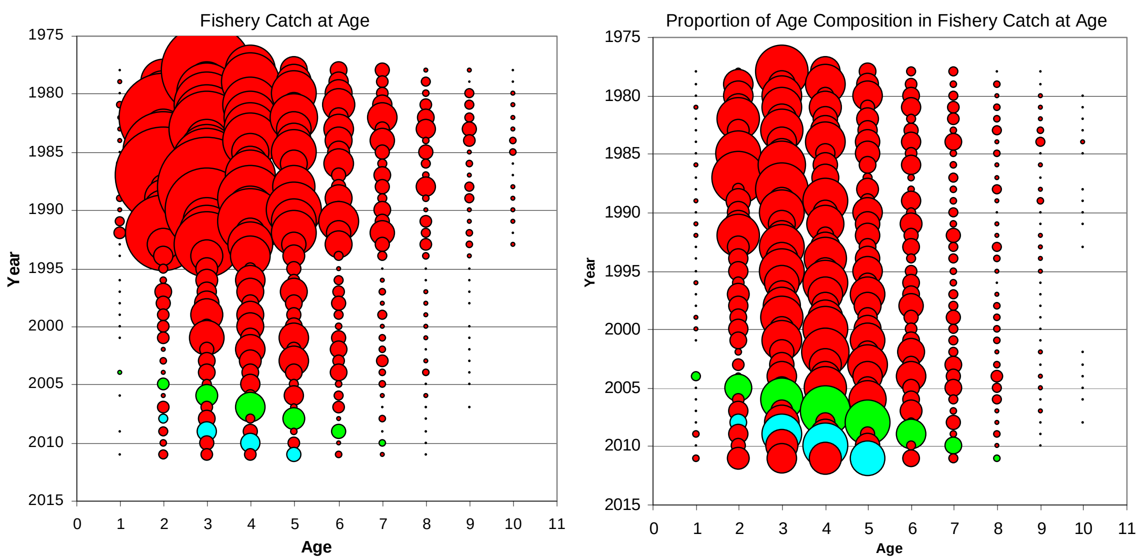


Figure 13. Total catch at age (numbers) of cod (left) and proportion of catch at age from eastern Georges Bank for 1978 to 2011. The bubble area is proportional to the magnitude. The light green circles are the 2003 year class and the light blue circles are the 2006 year class.

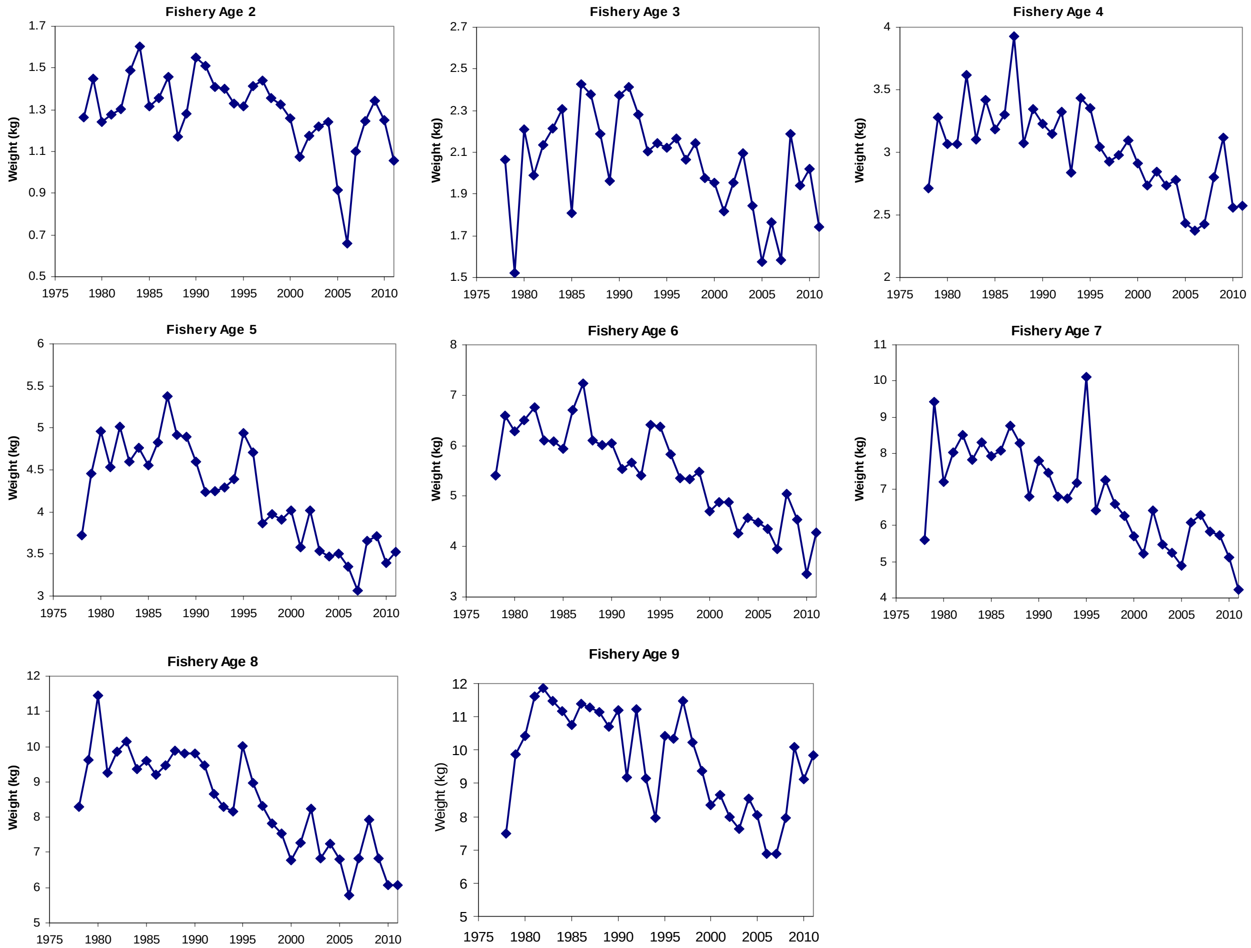


Figure 14. Average weights at ages 2 to 9 of cod from the eastern Georges Bank fishery, 1978 to 2011.

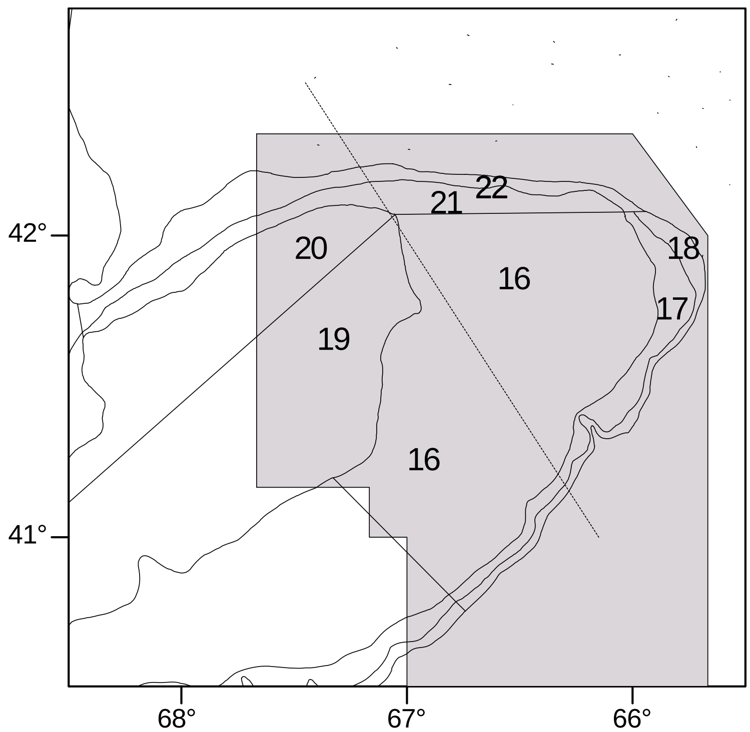


Figure 15. Stratification used for the NMFS surveys. The eastern Georges Bank management unit is indicated by shading.

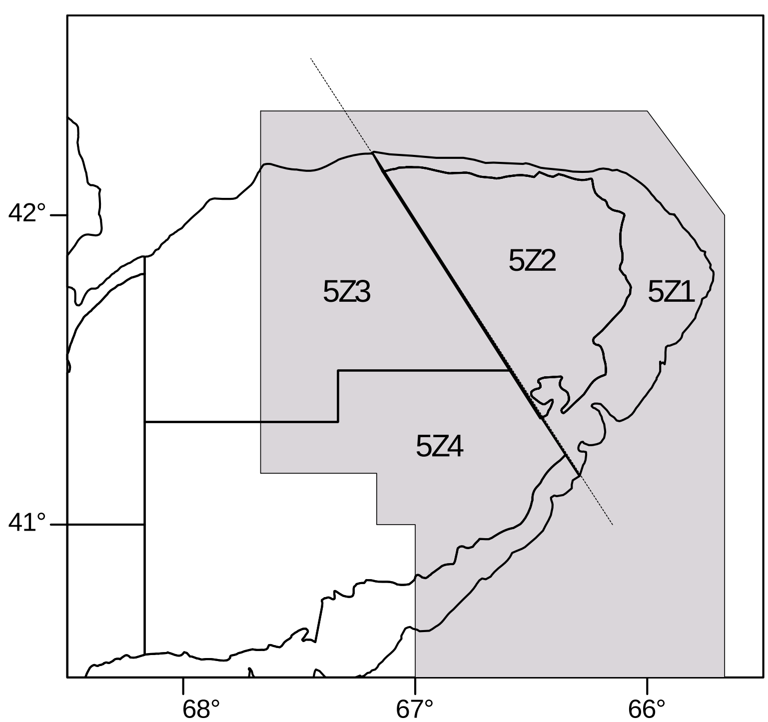


Figure 16. Stratification used for the DFO survey. The eastern Georges Bank management unit is indicated by shading.

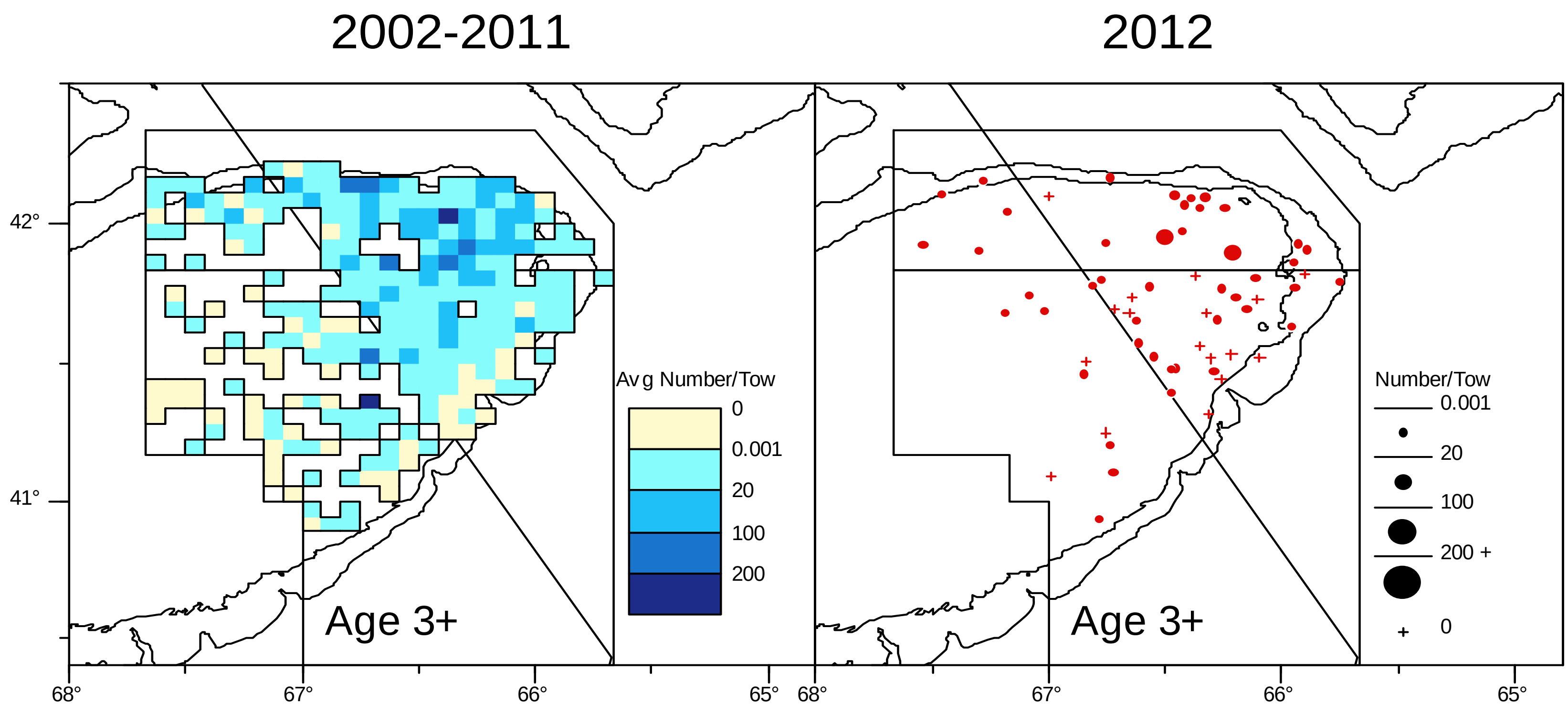


Figure 17. Spatial distribution of age 3+ cod on eastern Georges Bank from the DFO survey for 2012 (right panel) compared to the average for 2002 to 2011 (left panel).

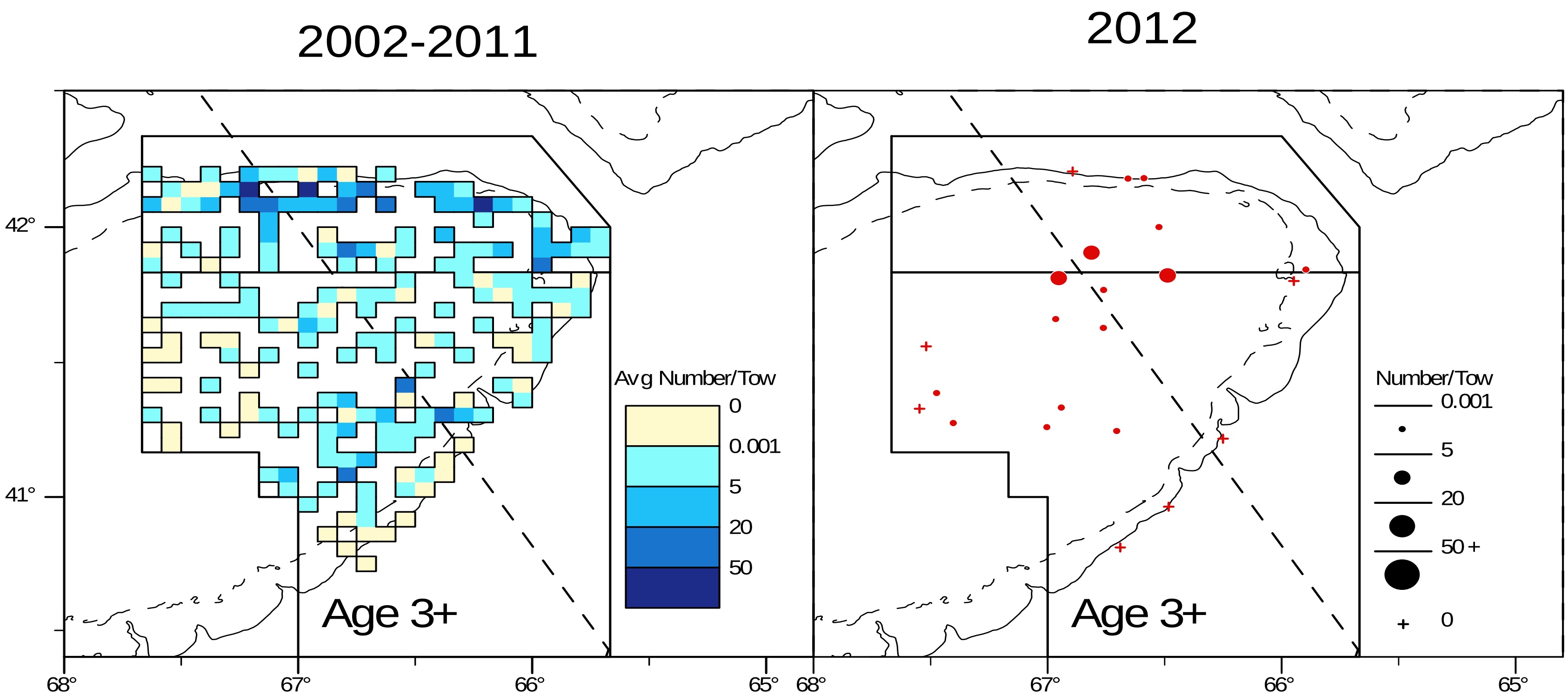


Figure 18. Spatial distribution of age 3+ cod on eastern Georges Bank from the NMFS spring survey for 2012 (right panel) compared to the average for 2002-2011 (left panel).

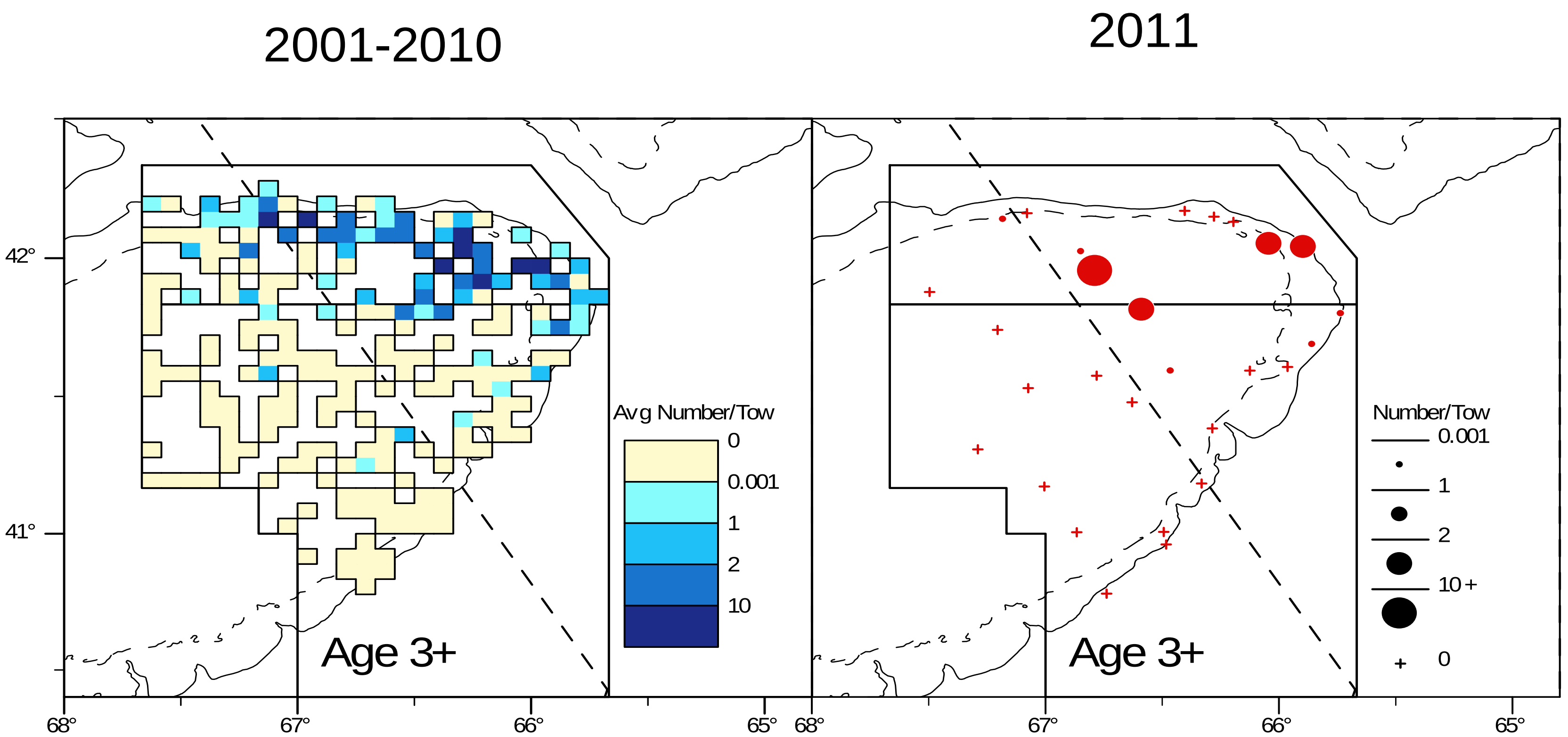


Figure 19. Spatial distribution of age 3+ cod on eastern Georges Bank from the NMFS fall survey for 2011 (right panel) compared to the average for 2001-2010 (left panel).

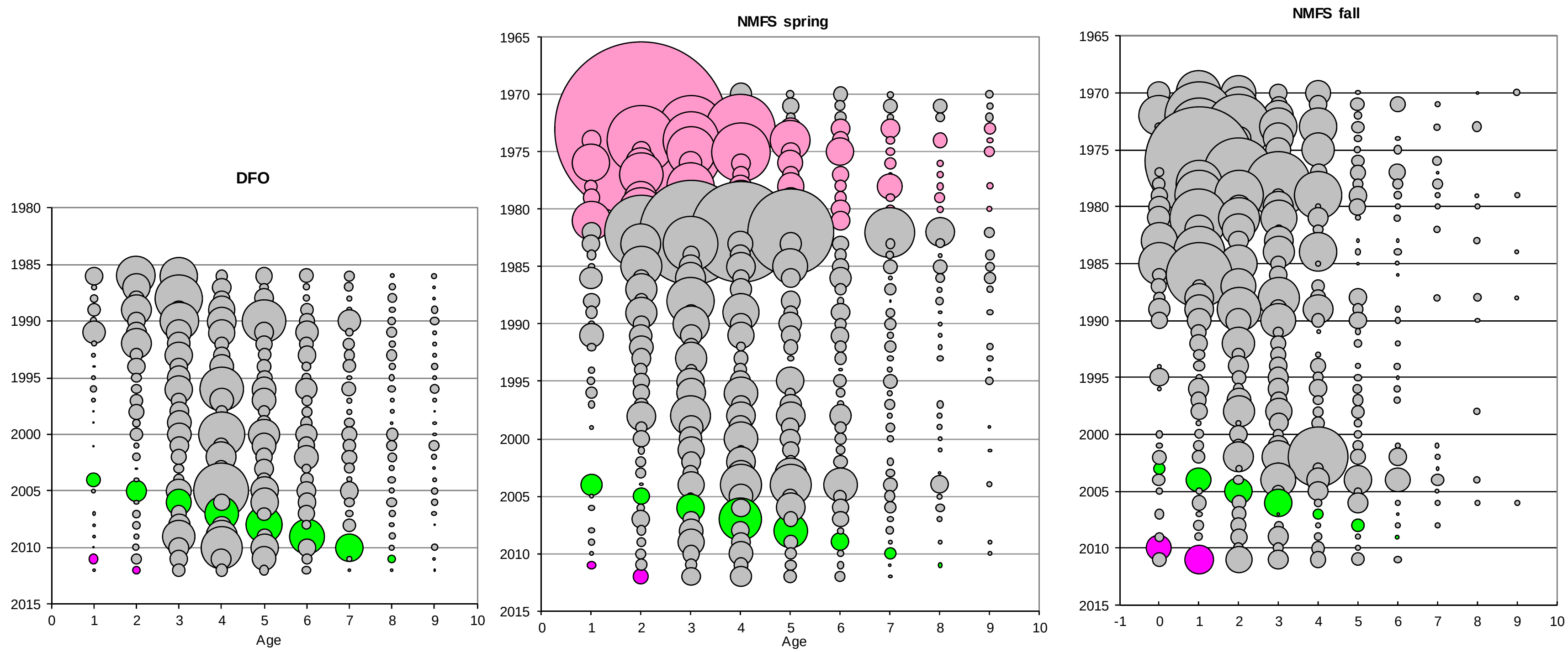
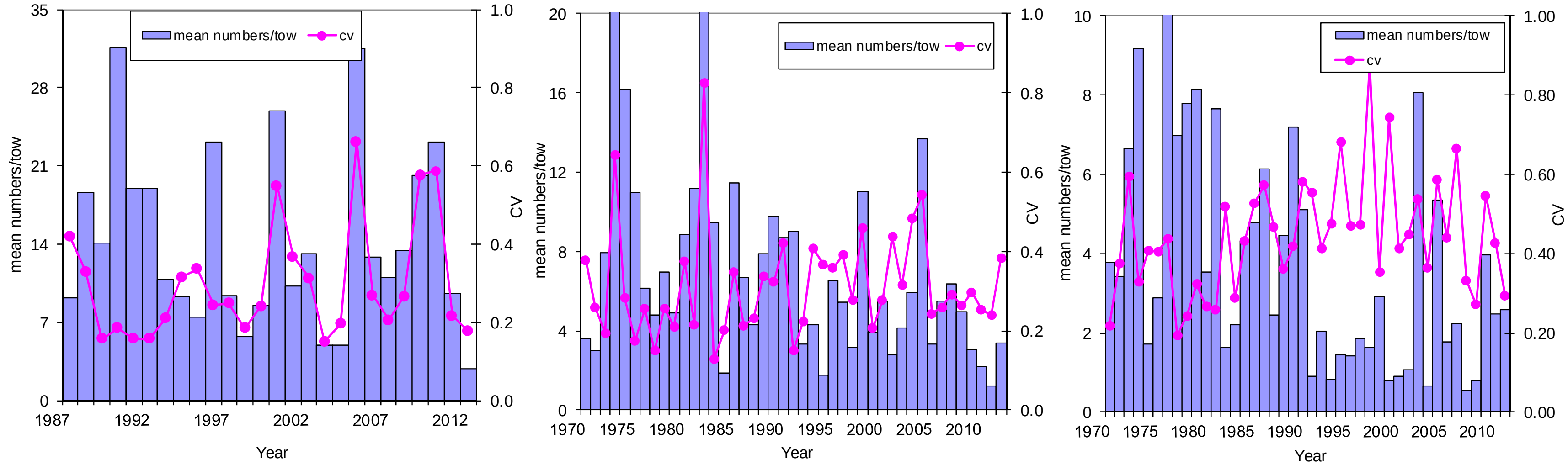
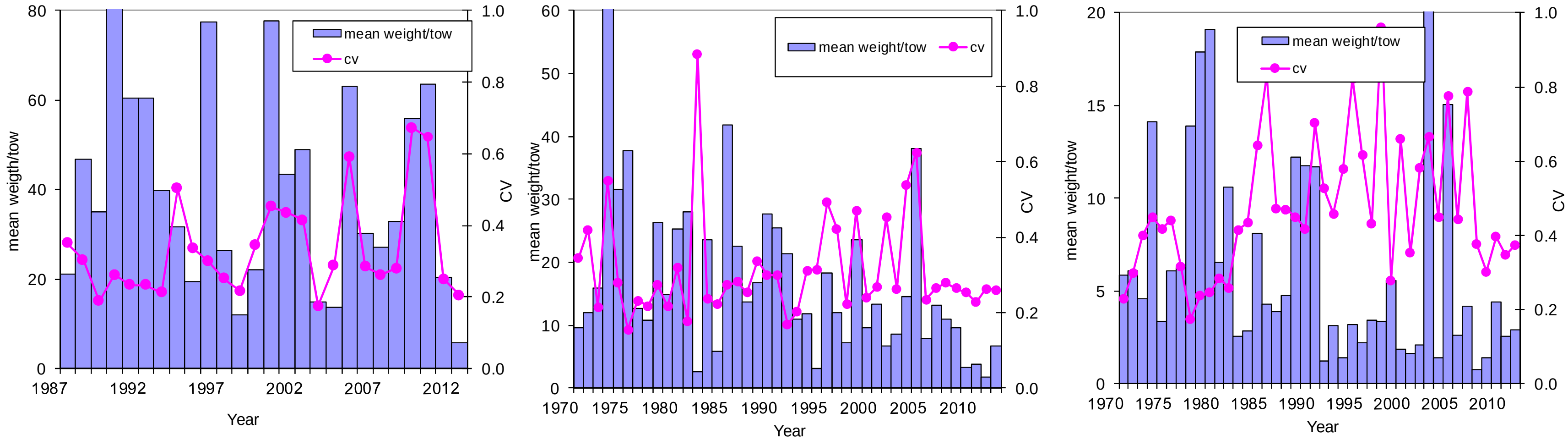


Figure 20. Survey abundance at age (numbers) of eastern Georges Bank cod. The bubble area is proportional to magnitude within each survey. Conversion factors to account for changes in door type, net and survey vessel were applied to the NMFS surveys. The NMFS spring survey was conducted using a modified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



DFO **NMFS spring** **NMFS fall**

Figure 21. Mean number/tow and coefficient of variation (CV) for DFO, NMFS spring and fall survey catch of EGB cod.



DFO **NMFS spring** **NMFS fall**

Figure 22. Mean weight/tow and coefficient of Variation (CV) for DFO, NMFS spring and fall survey catch of EGB cod.

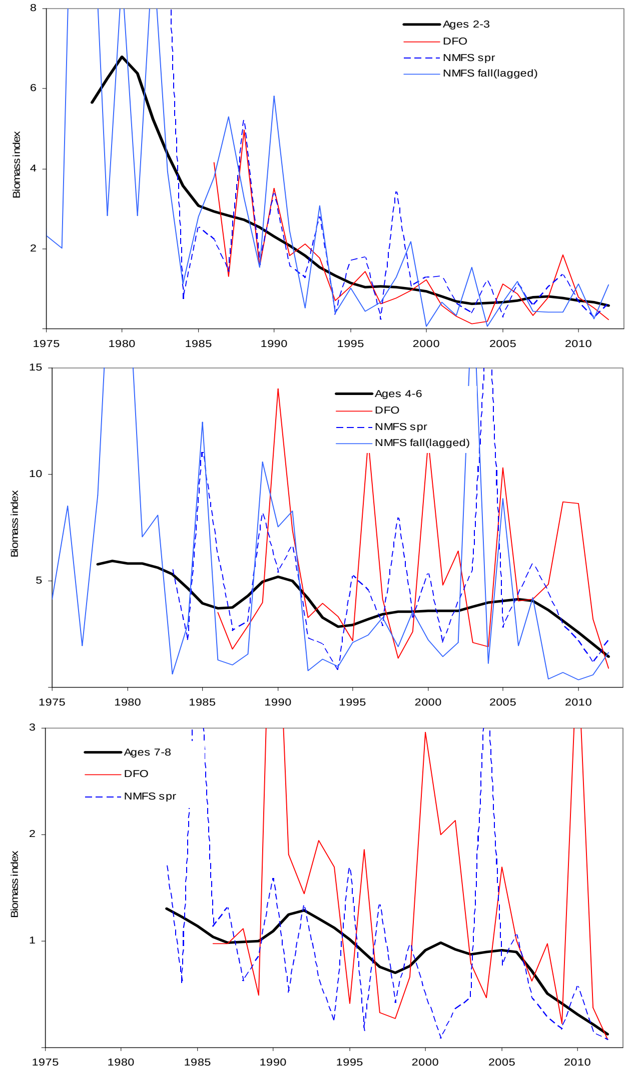


Figure 23. Survey biomass indices for ages 2-3, ages 4-6, and ages 7-8 for the DFO spring and NMFS spring and fall surveys, 1975-2012. The black line represents the smoothed trends for different age groups of eastern Georges Bank cod.

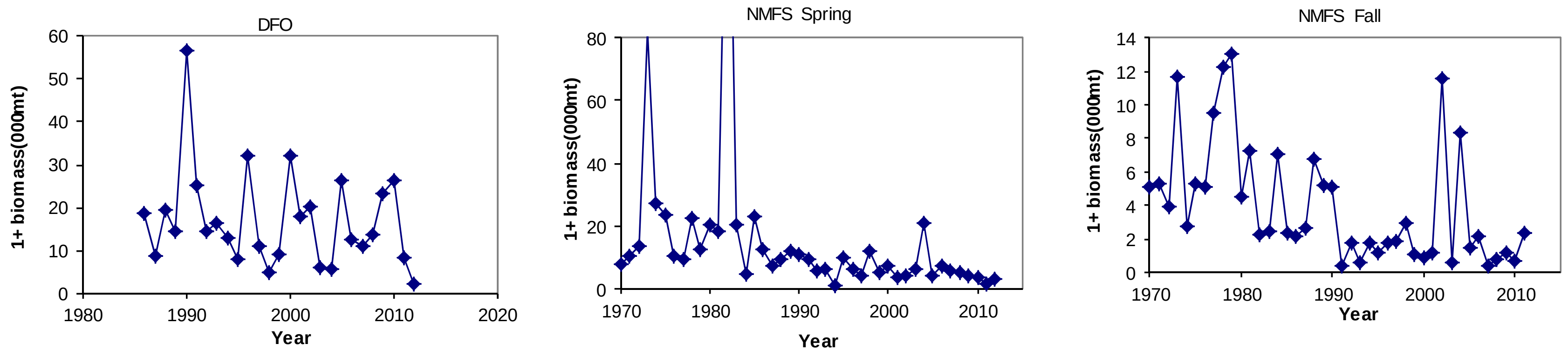


Figure 24. Survey biomass indices (ages 1+) for eastern Georges Bank cod from the DFO spring and NMFS spring and fall surveys, 1978-2012.

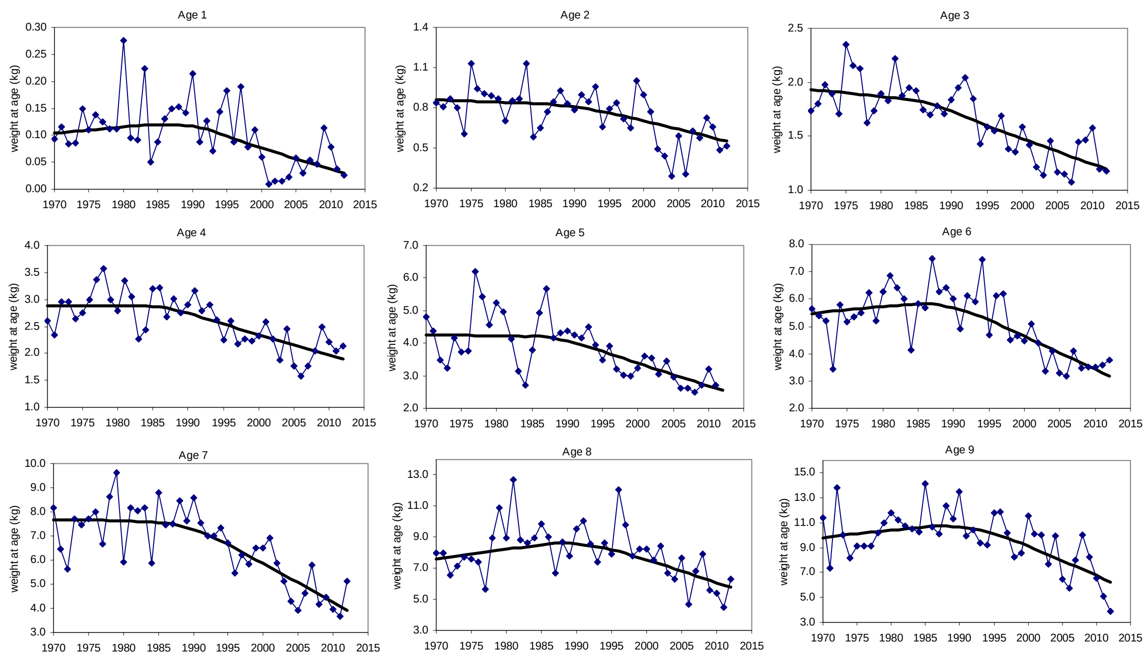


Figure 25. Beginning of year weight at age of eastern Georges Bank cod from DFO and NMFS spring surveys. The lines show the smoothed values using LOESS method.

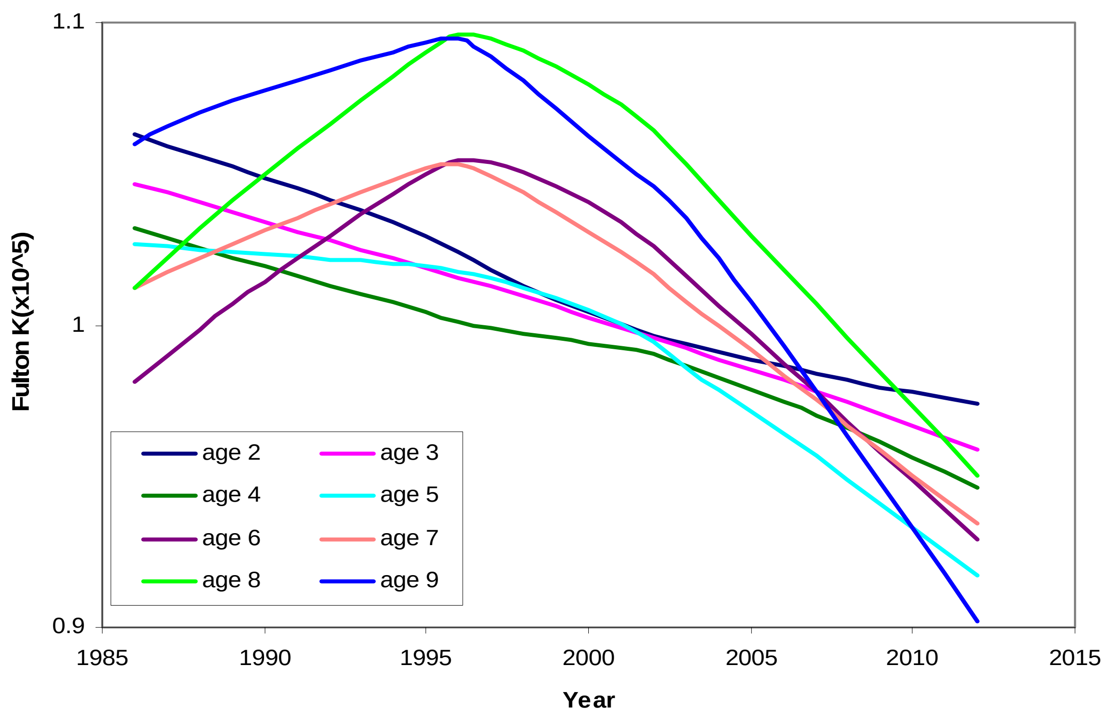


Figure 26. Smoothed **c**ondition factor (Fulton's K by age) for eastern Georges Bank cod from the DFO survey.

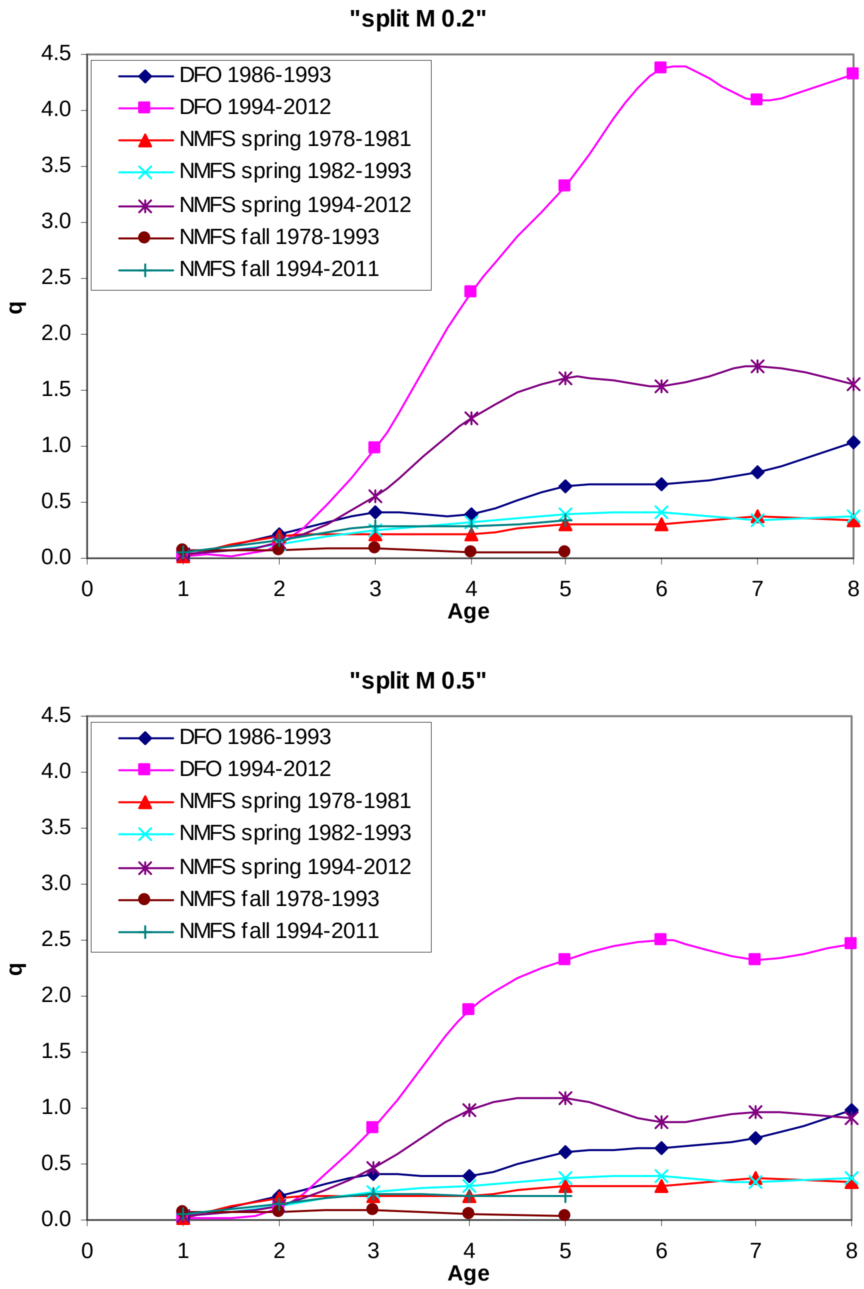
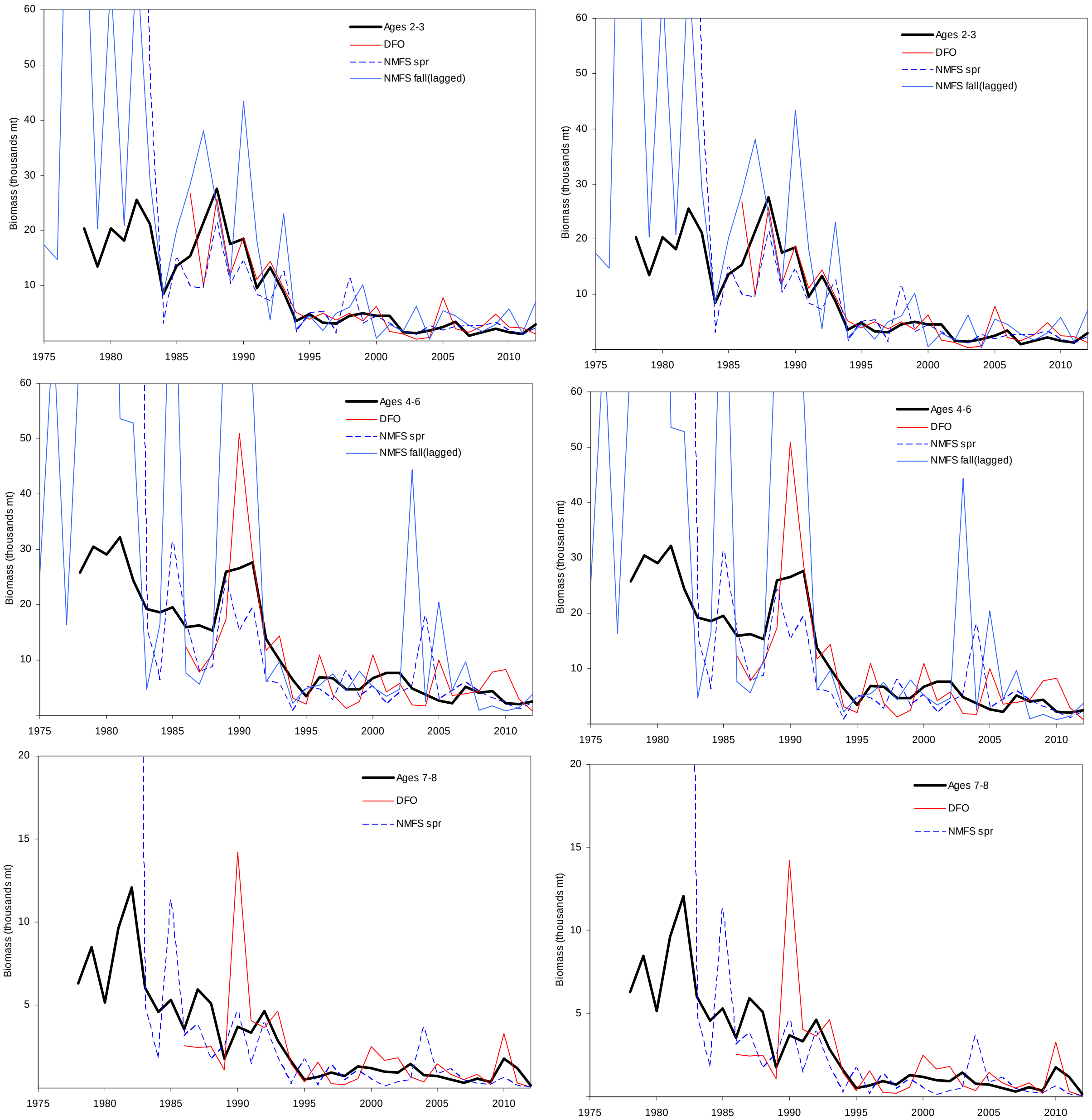


Figure 27. Survey catchability (q) for the DFO, NMFS spring and NMFS fall surveys from the “split M 0.2” and “split M 0.5” model formulations.



"split M 0.2" "split M 0.5"

Figure 28. Assessment biomass trends comparison with DFO, NMFS spring and NMFS fall surveys.

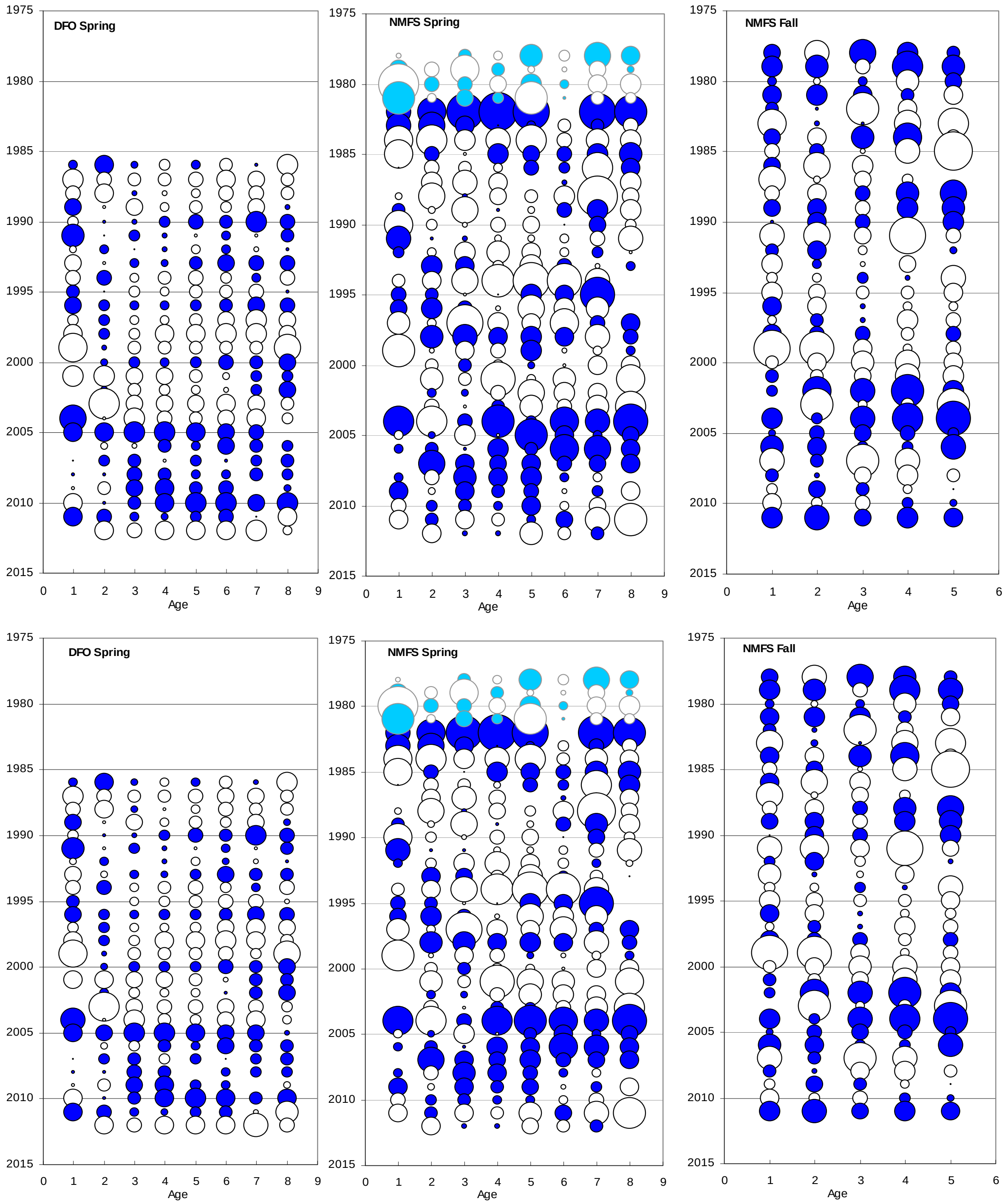
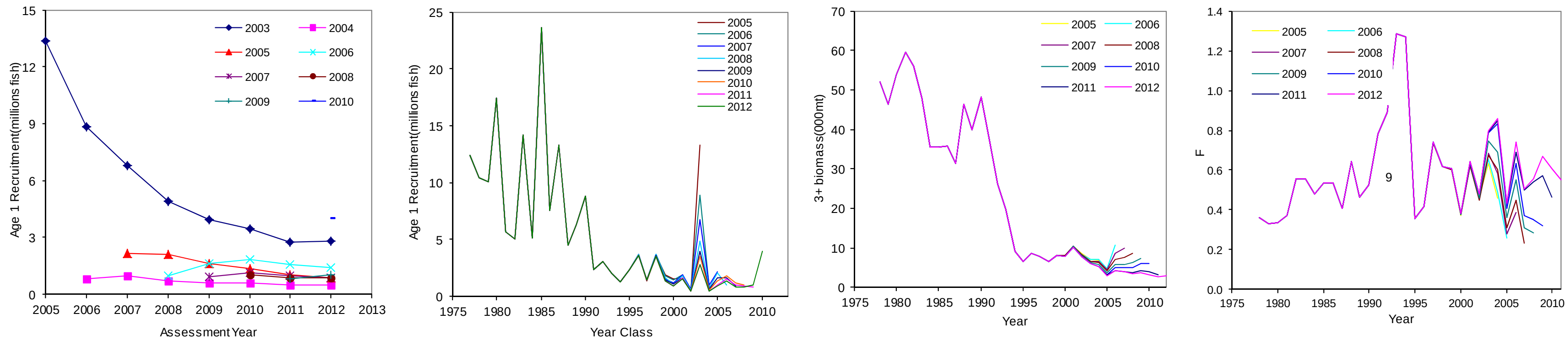
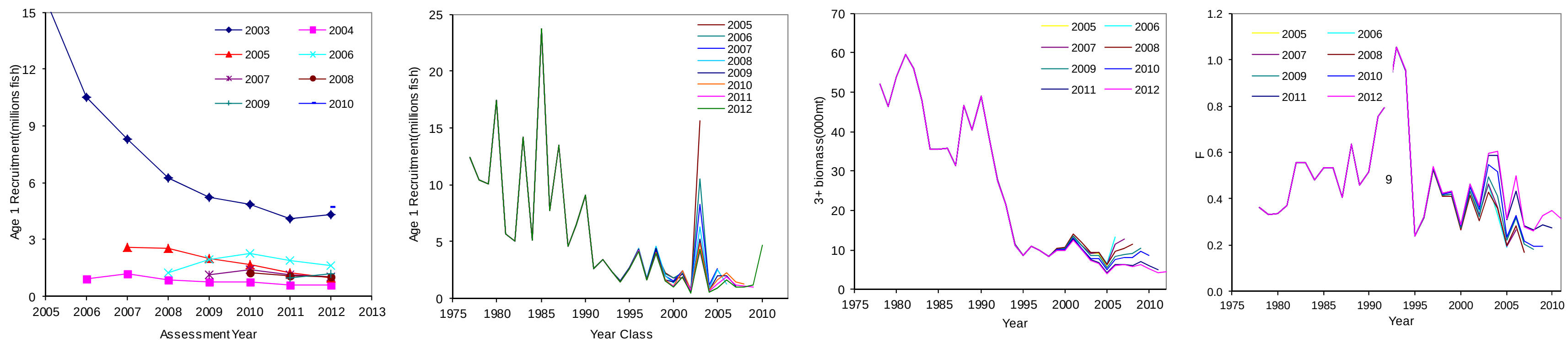


Figure 29. Residuals by year and age group from survey indices for eastern Georges Bank cod. Solid bubbles indicate positive values, open bubbles indicate negative values and the bubble area is proportional to magnitude. The NMFS spring survey was conducted using a modified Yankee 41 from 1978 to 1981 (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.

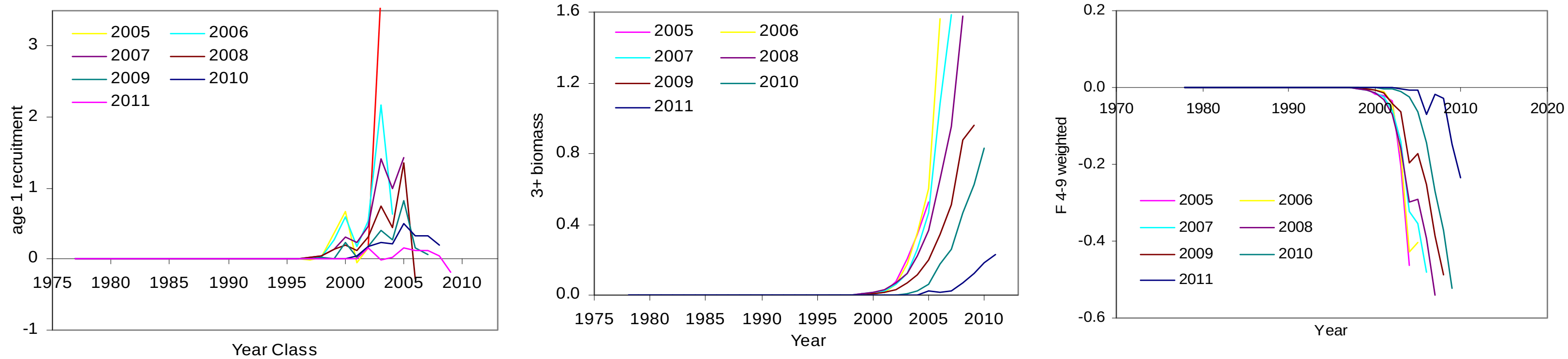


“split M 0.2”

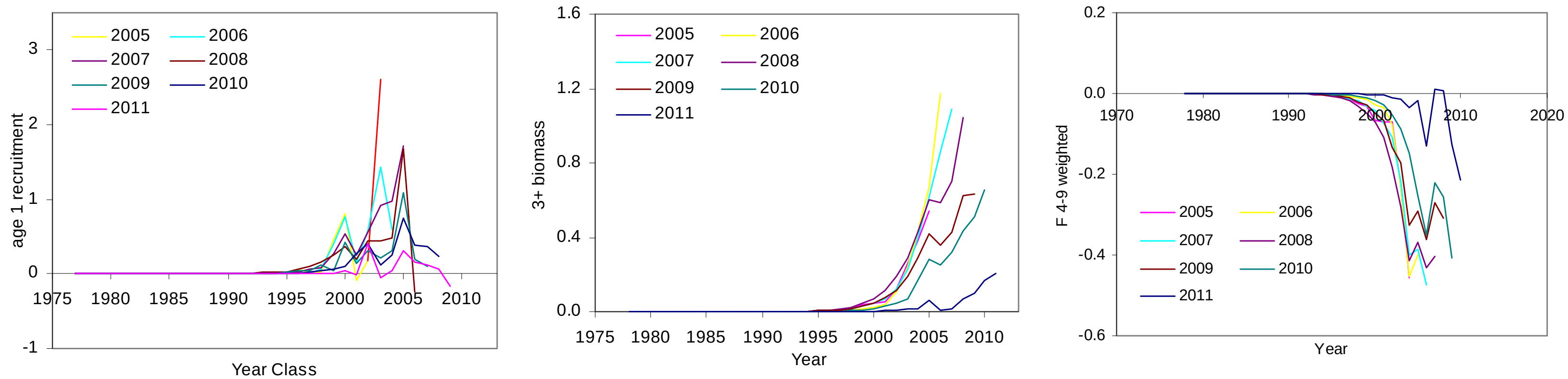


“split M 0.5”

Figure 30. 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 31. 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.

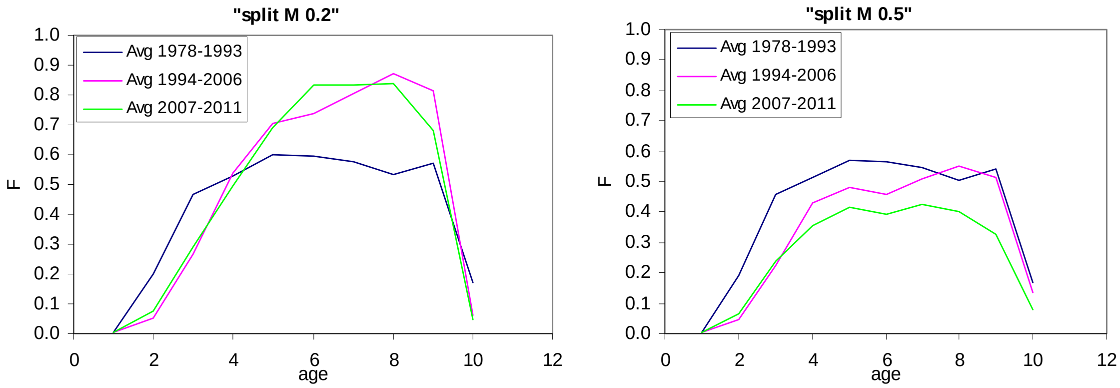


Figure 32. Average fishing mortality (F) for eastern Georges Bank cod in three time series blocks (1978-1993, 1994-2006, 2007-2011) from the “split M 0.2” (left) and “split M 0.5 (right) model formulations.

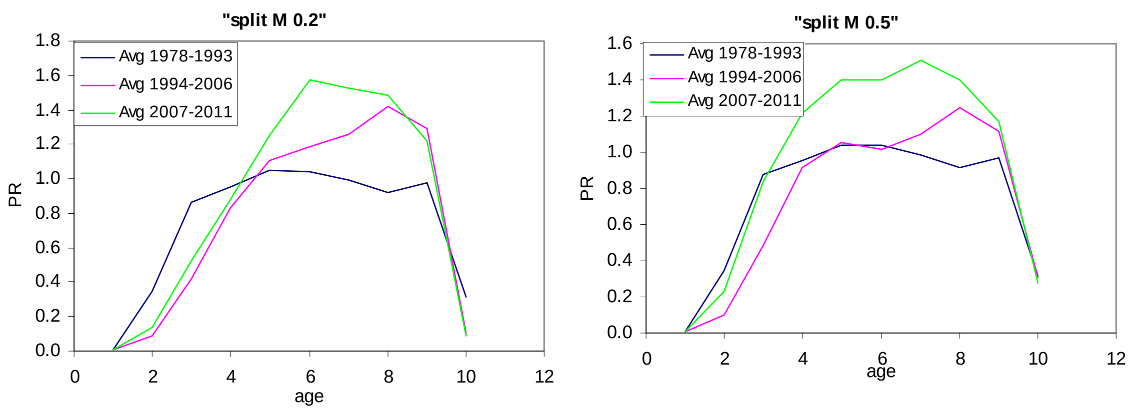


Figure 33. The fishing partial recruitment (PR) for eastern Georges Bank cod in three time series blocks (1978-1993, 1994-2006, 2007-2011) from the “split M 0.2” (left) and “split M 0.5 (right) model formulations.

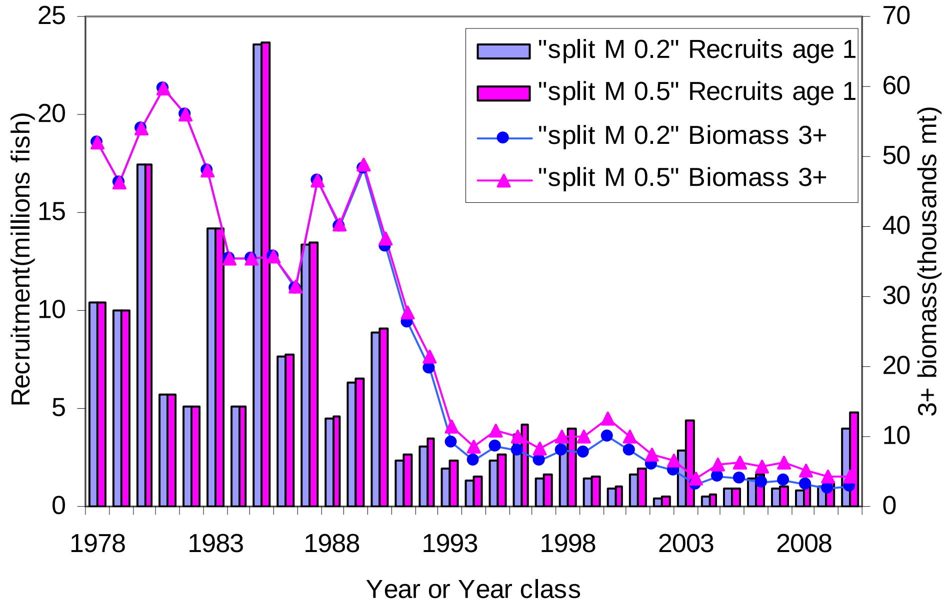
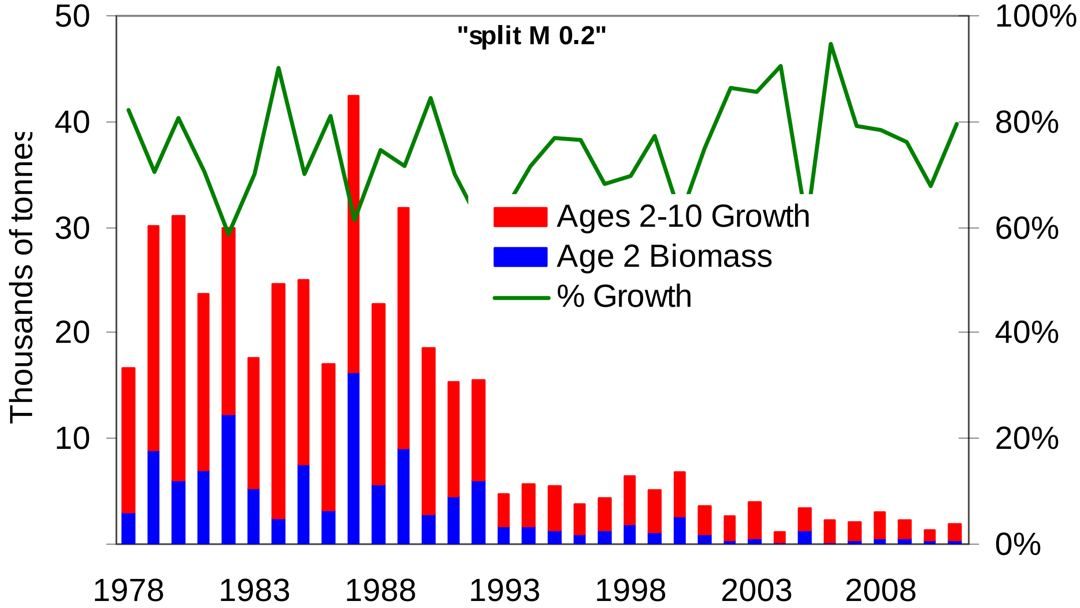


Figure 34. Adult biomass (ages 3+) and year class abundance at age 1 for eastern Georges Bank cod.



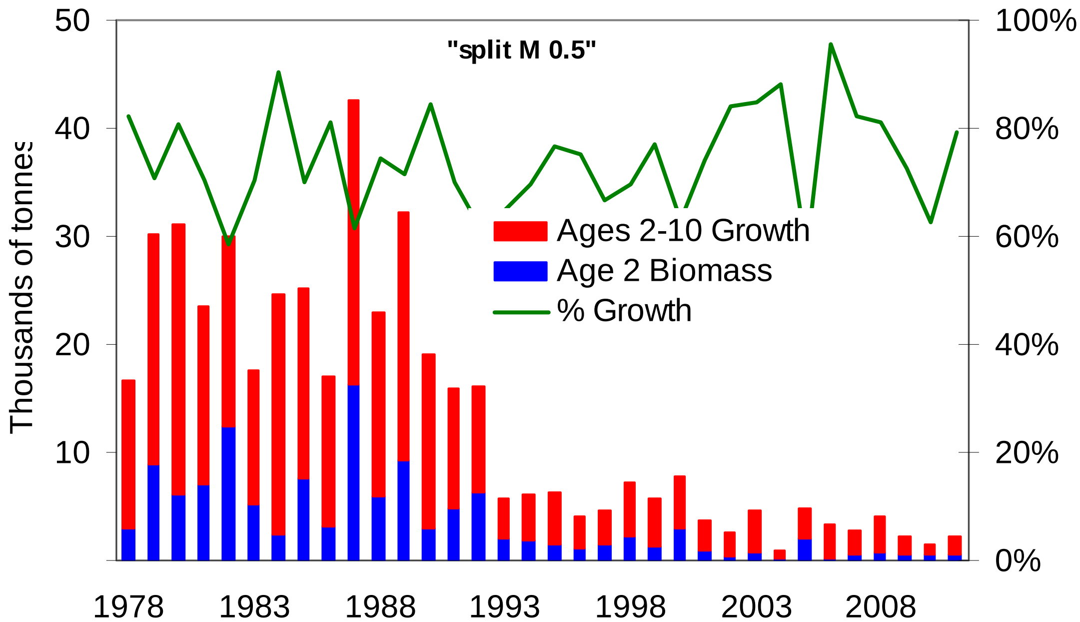


Figure 35. Components of annual production for eastern Georges Bank cod attributable to growth of ages 2 to 10 and to the amount contributed by incoming year classes at age 2.

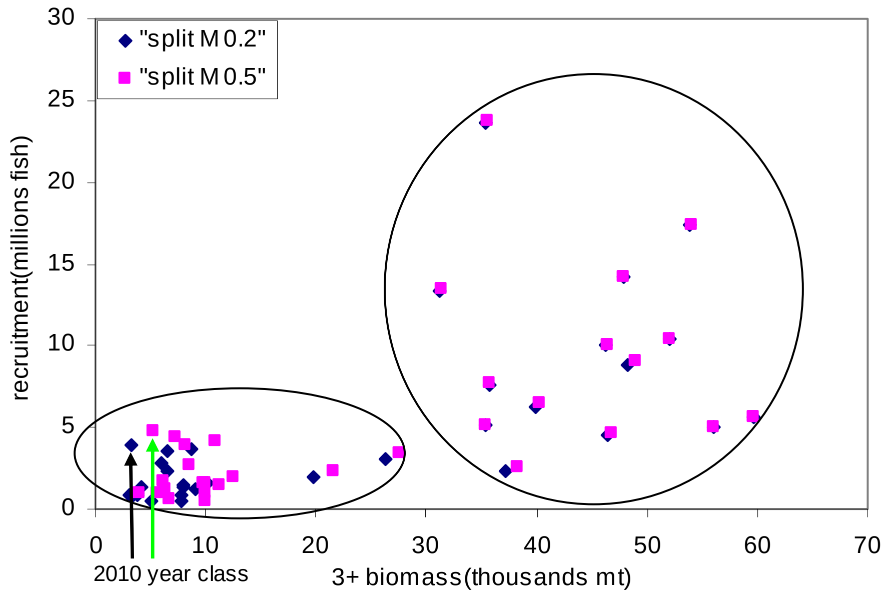


Figure 36. Relationship between adult biomass (ages 3+) and recruits at age 1 for eastern Georges Bank cod. The green and red arrows indicate the 2010 year class at age 1 from the "split M 0.2" and "split M 0.5" model, respectively.

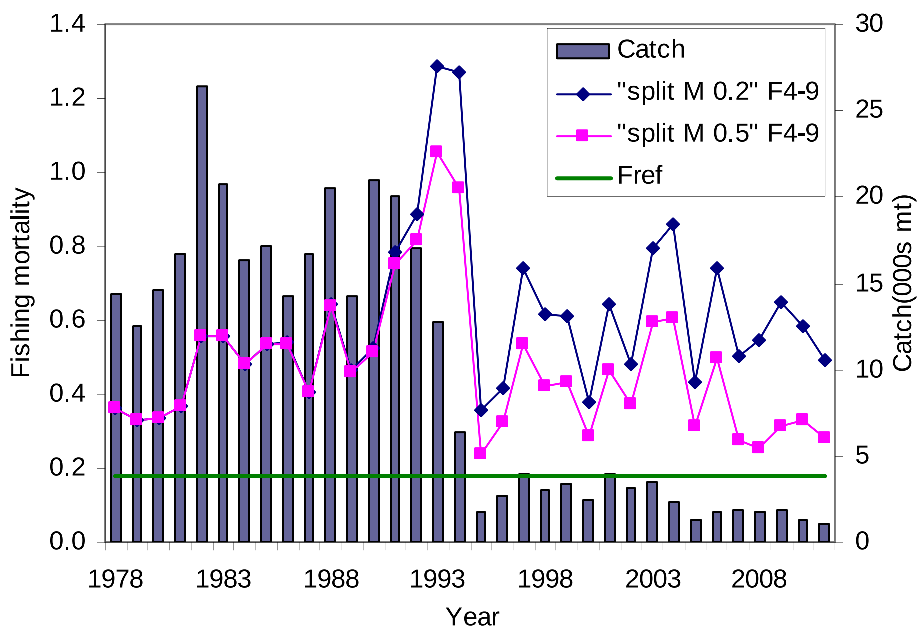


Figure 37. Average fishing mortality rate at ages 4 to 9 and catches for eastern Georges Bank cod. The established fishing mortality threshold reference, F_{ref}=0.18, is indicated.

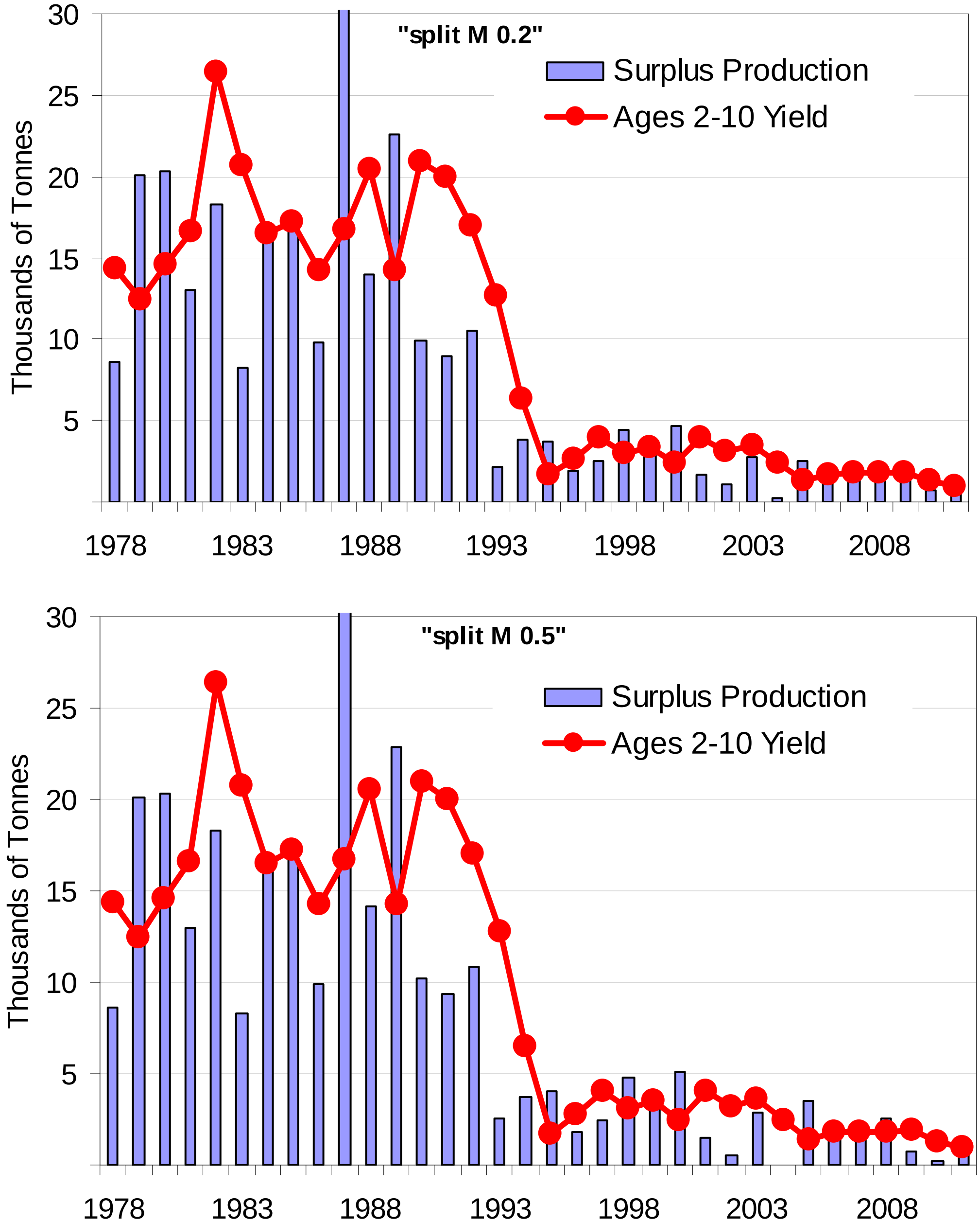


Figure 38. Surplus production of eastern Georges Bank cod compared to harvested yield.

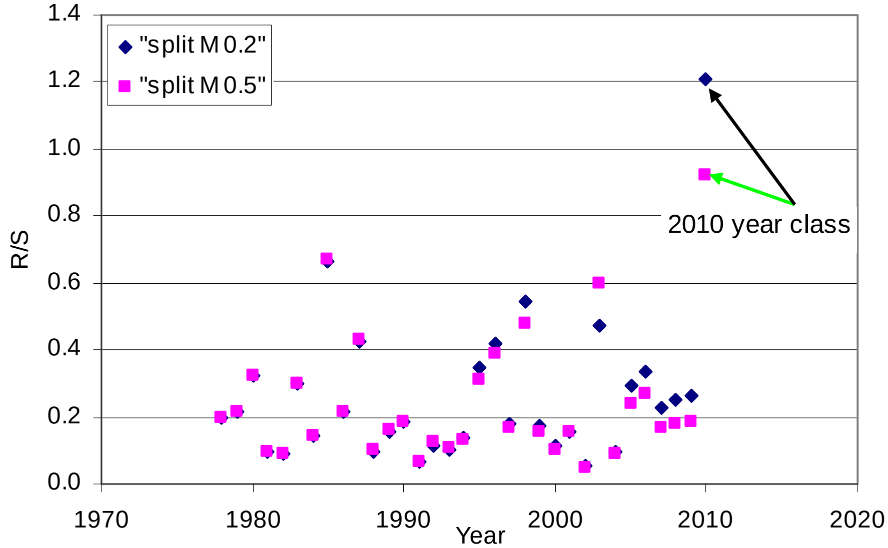


Figure 39. Recruitment rate (R/3+biomass) for eastern Georges Bank cod.

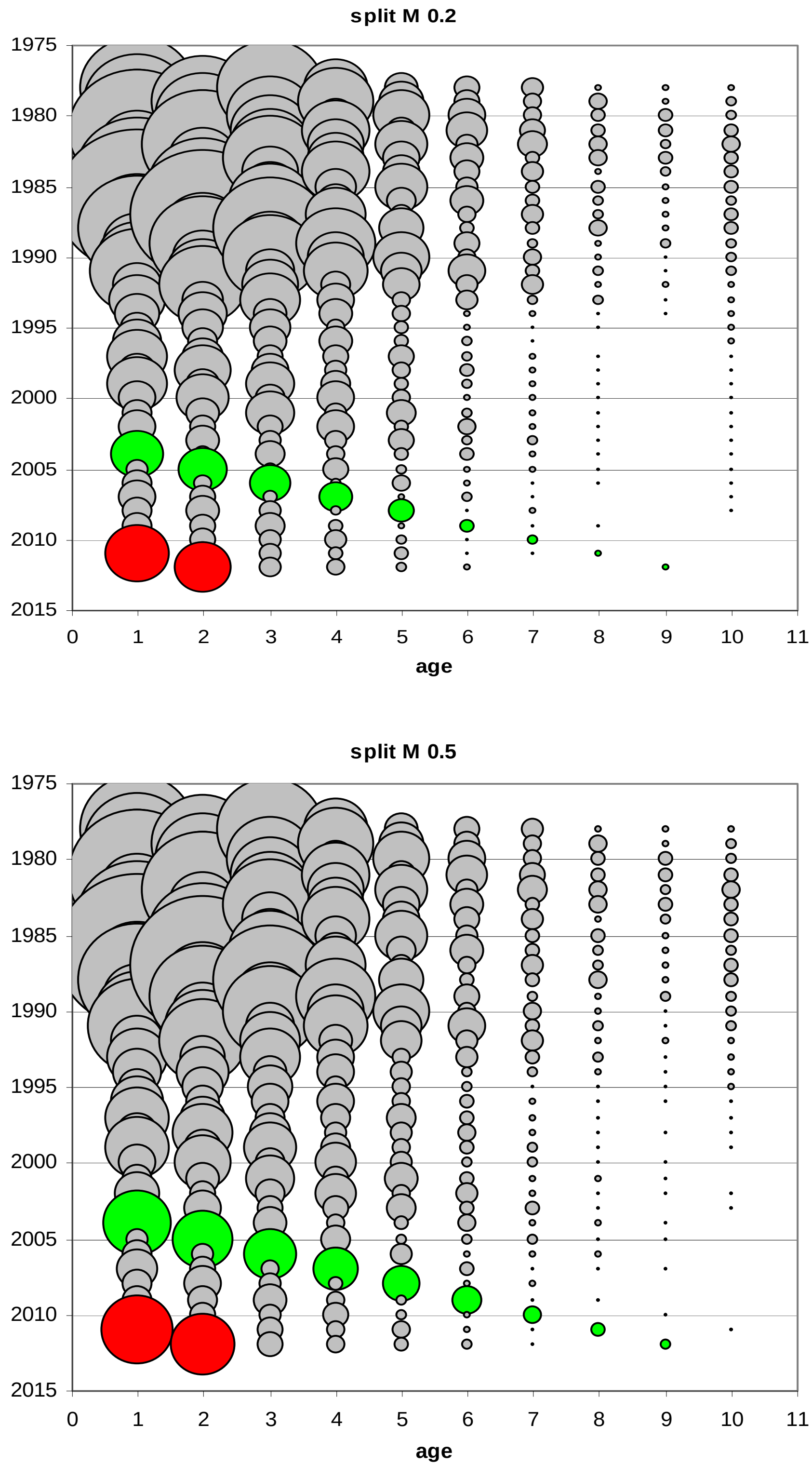


Figure 40. Population numbers from the 2012 assessment of eastern Georges Bank cod. Bubble sizes are proportional to population numbers. Light green bubbles are the 2003 year class and red bubbles for the 2006 year class.

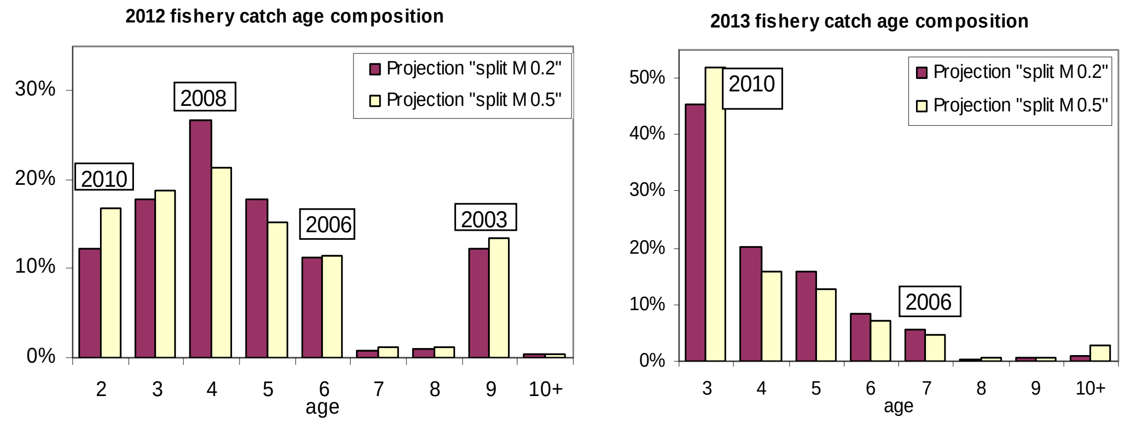


Figure 41. Projected fishery catch age composition of eastern Georges Bank in 2012 and 2013 if the catch is 675 mt in 2012 and F_{2013}=0.18, the year label represents the year class.

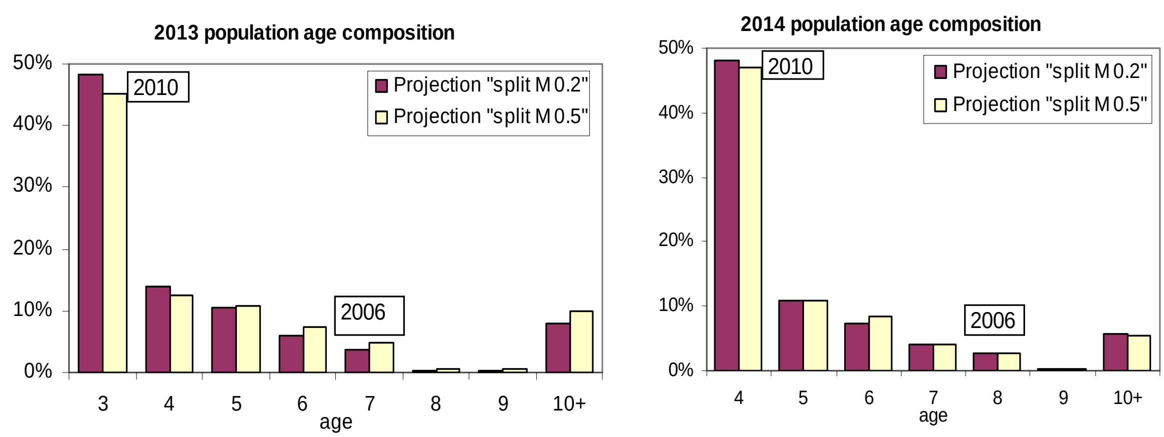


Figure 42. Projected fish population age composition of eastern Georges Bank in 2013 and 2014 if the catch is 675 mt in 2011 and F_{2012}=0.18, the year label represents the year class.

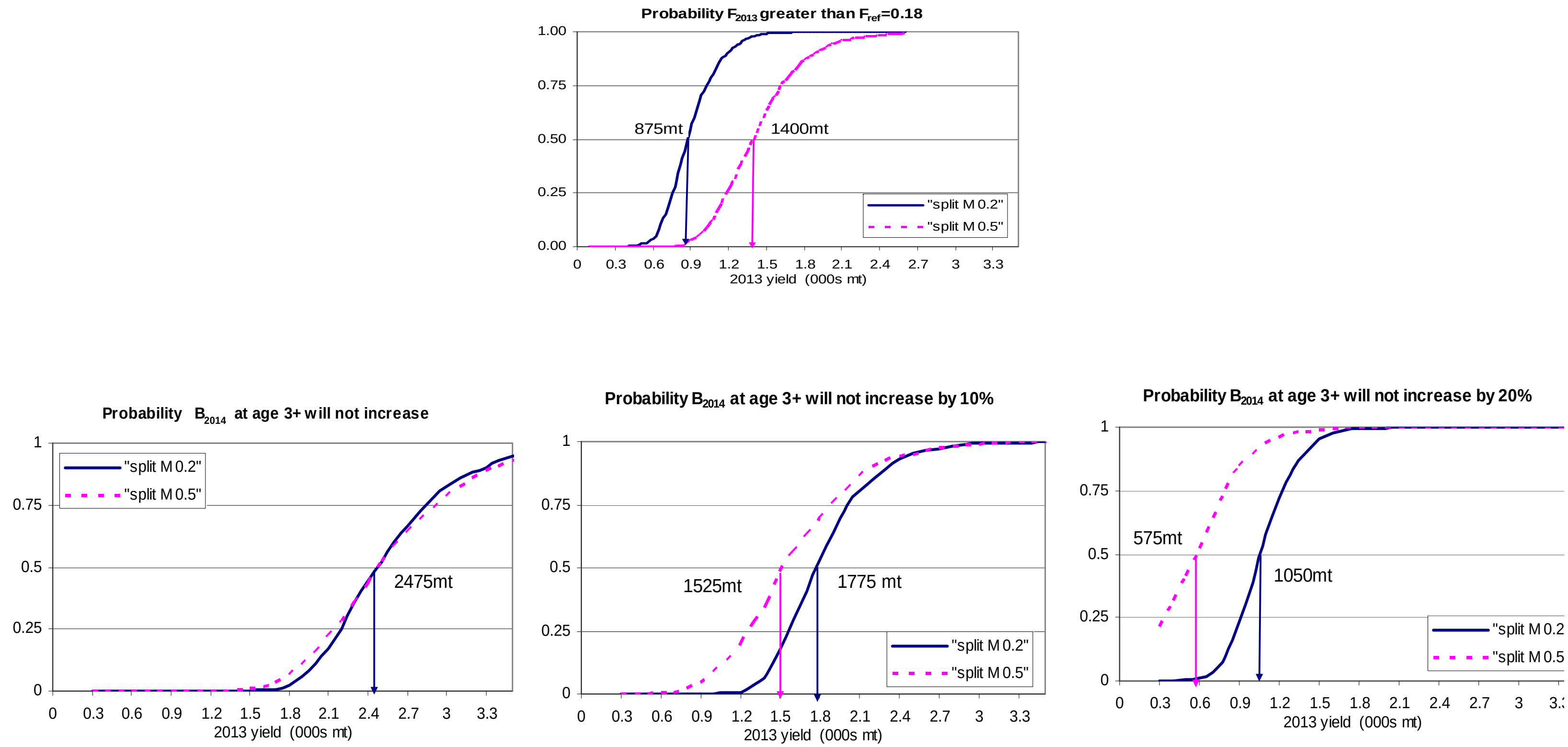


Figure 43. Risk of 2013 fishing mortality exceeding F_{ref} = 0.18 and 2014 biomass not increasing, and 2013 biomass not increasing by 10% or 20% from 2013 for alternative total yields of eastern Georges Bank cod.

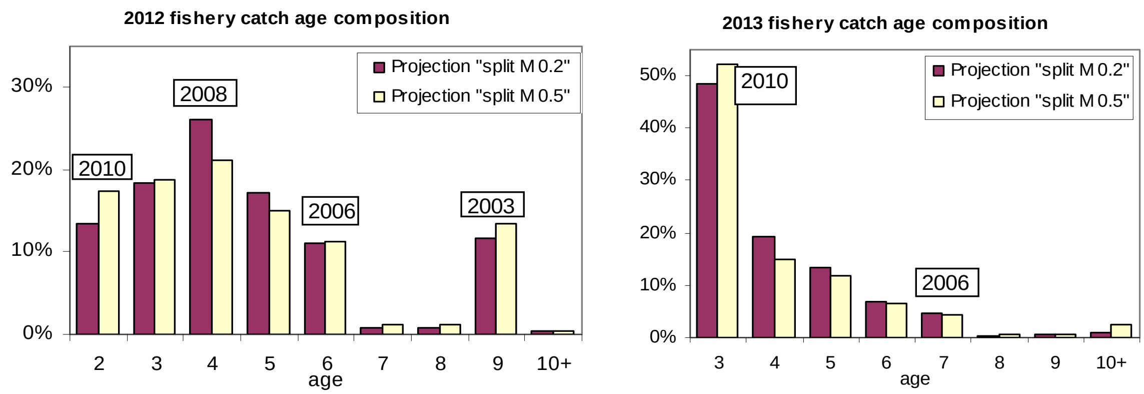


Figure 44. Mohn's rho adjusted projected fishery catch age composition of eastern Georges Bank in 2012 and 2013 if the catch is 675 mt in 2012 and F_{2013}=0.18, the year label represents the year class.

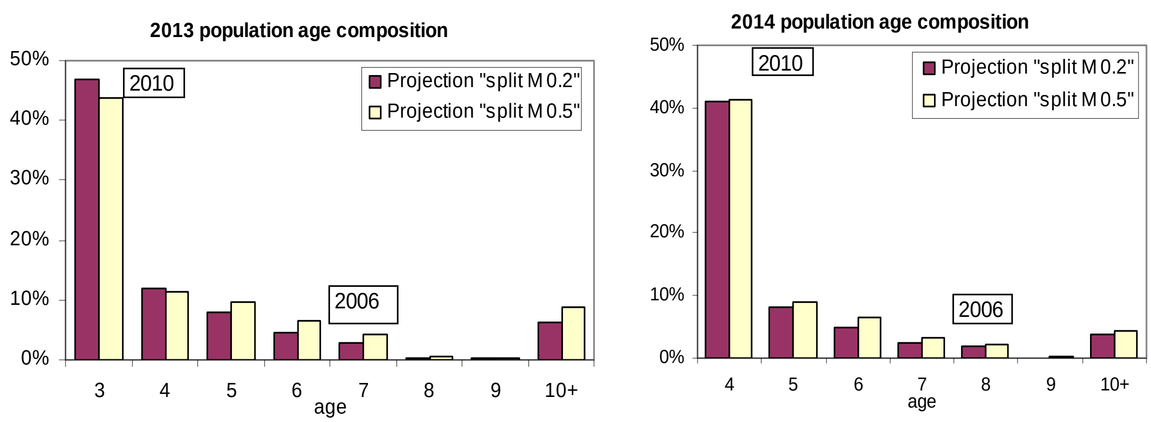


Figure 45. Mohn's rho adjusted projected fish population age composition of eastern Georges Bank in 2013 and 2014 if the catch is 675 mt in 2011 and F_{2012}=0.18, the year label represents the year class.

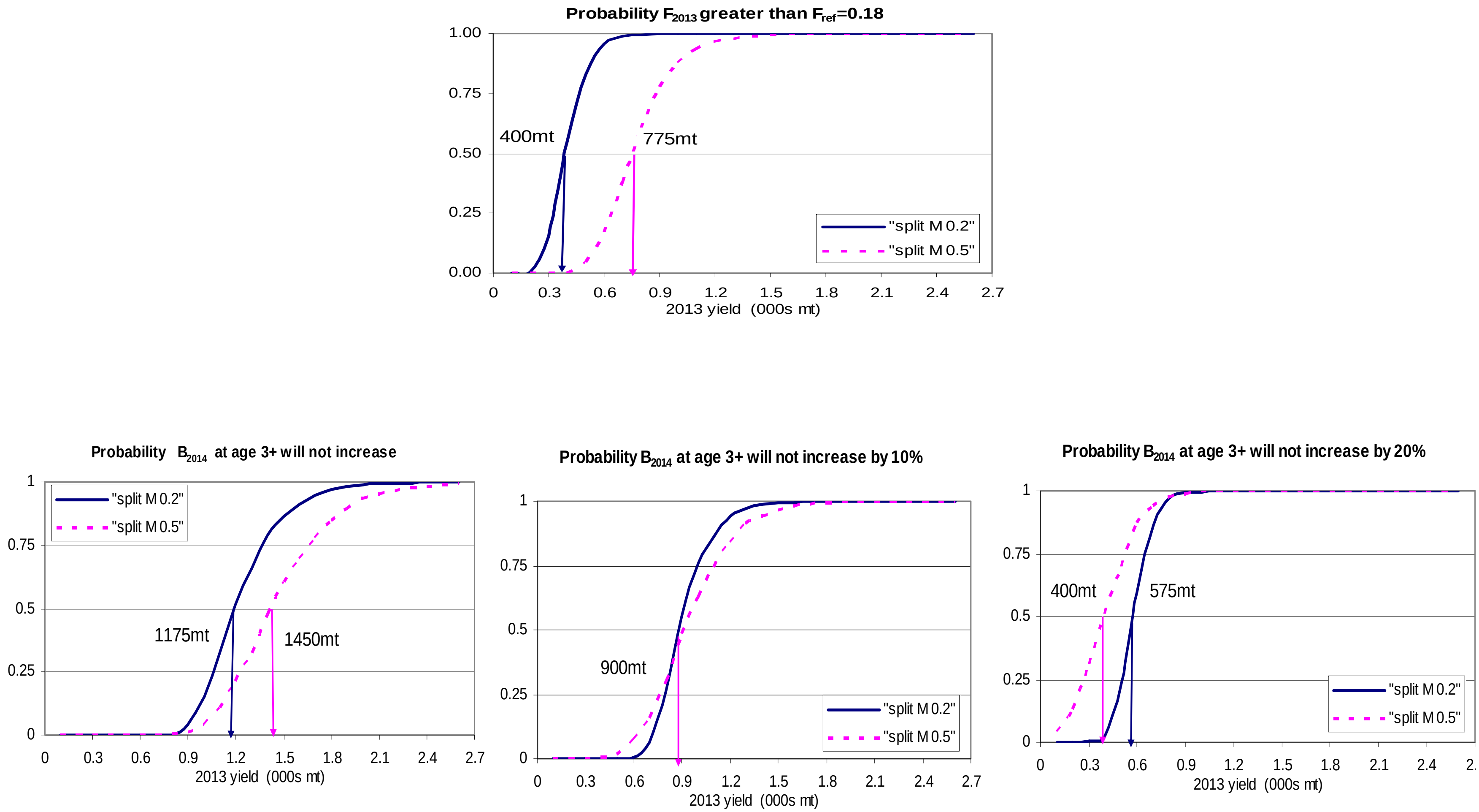


Figure 46. Mohn's rho adjusted risk of 2013 fishing mortality exceeding F_{ref} = 0.18 and 2014 biomass not increasing, and 2013 biomass not increasing by 10% or 20% from 2013 for alternative total yields of eastern Georges Bank cod.