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Assessment of Eastern Georges Bank Atlantic Cod for 2009

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ABSTRACT

Combined Canada/USA catches averaged 17,508 mt between 1978 and 1992. They peaked at 26,463 mt in 1982, declined to 1,684 mt in 1995, fluctuated around 3,000 mt until 2004 and subsequently declined again. Catches in 2008 were 1,782 mt, including 161 mt of discards. Canadian catches increased to 1,529 mt in 2008 from 1,222 mt in 2007. USA catches decreased to 253 mt in 2008 from 557 mt in 2007.

Two consensus Virtual Population model formulations were established during the benchmark review in 2009. These are referred to as the "split M 0.2" and "split M 0.5" models.

Adult population biomass (ages 3+) declined from about 50,000 mt in 1990 to below 10,000 mt in 1995. Biomass subsequently fluctuated between 6,000 and 13,000 mt before decreasing in 2005 to about 3,800 mt in the "split M 0.2" model and 6,000 mt in the "split M 0.5" model. It increased at the beginning of 2009 to 8,700 mt in the "split M 0.2" model and 12,000 mt in the "split M 0.5" model.

Recruitment at age 1 of the 2003 year-class (4.4 million from the "split M 0.2" model and 5.8 million from the "split M 0.5" model) is the highest since the 1990 year-class but is still lower than the pre-1990 average (10 million from both models). The 2002 and 2004 year-classes are the lowest on record. The 2005 and 2006 year-classes are close to the post-1990 average. Initial indications are that the 2007 year-class is weak.

Fishing mortality (F) for ages 4-9 was higher prior to 1994. Due to restrictive management measures, it declined in 1995 to F=0.36 for the "split M 0.2" model and 0.24 for the "split M 0.5" model and then fluctuated until 2004. F was estimated to be 0.25 from the "split M 0.2" model and 0.17 from the "split M 0.5" model in 2008. Both models show recent reductions in F since 2005; however, F has been above the F_{ref}=0.18 in the past.

Assuming a 2009 catch equal to the 1,700 mt total quota, a combined Canada/USA catch of about 1,300 mt ("split M 0.2" model) and 1,700 mt ("split M 0.5" model) in 2010 will result in a neutral risk (50%) that the fishing mortality rate in 2010 will exceed F_{ref}. A catch of 1,800 mt ("split M 0.2" model) and 900 mt ("split M 0.5" model) will result in a neutral risk (50%) that the 2011 adult biomass (ages 4+) will be lower than 2010. A catch of about 1,000 mt ("split M 0.2" model) will result in a neutral risk (50%) and 500 mt ("split M 0.5" model) will have high risk (75%) of adult biomass in 2011 will not increase by 10% from 2010.

RÉSUMÉ

Les captures combinées du Canada et des États-Unis ont été en moyenne de 17 508 tm entre 1978 et 1992. Elles ont culminé à 26 463 tm en 1982, sont tombées à 1 684 tm en 1995, puis ont fluctué alentour de 3 000 tm jusqu'en 2004, et ont diminué de nouveau ensuite. En 2008, elles se sont chiffrées à 1 782 tm, dont 161 tm de rejets. Les captures canadiennes ont augmenté à 1 529 tm en 2008, par rapport aux 1 222 tm de 2007. Celles des États-Unis ont diminué, passant de 557 tm en 2007 à 253 tm en 2008.

Deux formules de modèle de population virtuelle ont recueilli un consensus à l'examen des points de référence de 2009. On les appelle modèle « fractionnement + M = 0,2 » et modèle « fractionnement + M = 0,5 ».

La biomasse des adultes (âges 3 +) a diminué, passant d'environ 50 000 tm en 1990 à moins de 10 000 tm en 1995. Elle a fluctué par la suite entre 6 000 et 13 000 tm, puis a diminué en 2005, à environ 3 800 tm d'après le modèle « fractionnement + M = 0,2 » et 6 000 tm d'après le modèle « fractionnement + M = 0,5 ». Elle a augmenté au début de 2009, se chiffrant à 8 700 tm d'après le modèle « fractionnement + M = 0,2 » et 12 000 tm d'après le modèle « fractionnement + M = 0,5 ».

Le recrutement à l'âge 1 de la classe d'âge de 2003 (effectif de 4,4 millions d'après le modèle « fractionnement + M = 0,2 » ou de 5,8 millions d'après le modèle « fractionnement + M = 0,5 ») est le

plus élevé depuis l'arrivée de la classe d'âge de 1990, mais il demeure inférieur à la moyenne d'avant 1990 (10 millions de poissons d'après les deux modèles). Les classes d'âge de 2002 et de 2004 sont les plus basses observées à ce jour. Celles de 2005 et de 2006 s'approchent de la moyenne d'après 1990. Selon les premières indications, la classe d'âge de 2007 est faible.

La mortalité par pêche (F) dans les âges 4-6 était plus forte avant 1994. Elle a diminué en 1995, à 0,36 selon le modèle « fractionnement + M = 0,2 » et à 0,24 selon le modèle « fractionnement + M = 0,5 », en raison de mesures de gestion strictes, puis elle a fluctué jusqu'en 2004. En 2008, F a été estimée à 0,25 d'après le modèle « fractionnement + M = 0,2 » et à 0,17 d'après le modèle « fractionnement + M = 0,5 ». Depuis 2005, les deux modèles dénotent des baisses de F, qui par le passé a été supérieure à $F_{réf.}$ = 0,18.

Dans l'hypothèse où le quota de 1 700 tm serait entièrement pêché en 2009, des captures combinées du Canada et des États-Unis d'environ 1 300 tm (modèle « fractionnement + M = 0,2 ») et 1 700 tm (modèle « fractionnement + M = 0,5») en 2010 se traduiraient par un risque neutre (50 %) que la mortalité par pêche en 2010 dépasse $F_{réf}$. Des captures de 1 800 tm (modèle « fractionnement + M = 0,2 ») et 900 tm (modèle « fractionnement + M = 0,5) équivaudraient à un risque neutre (50 %) que la biomasse des adultes (âges 4+) en 2011 soit inférieure à celle de 2010. Des captures d'environ 1 000 tm (modèle « fractionnement + M = 0,2 ») et 500 tm (modèle fractionnement + M = 0,5 »), se traduiraient, respectivement, par un risque neutre (50 %) et par un risque élevé (75 %) que la biomasse des adultes en 2011 n'augmente pas de 10 % par rapport à 2010.

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 benchmark meeting (O'Brien and Worcester, 2009). For the purpose 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 and all of USA Closed Area II; Figure 1; DFO 2002). The USA has a requirement for management advice on cod west of eastern Georges Bank. 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 benchmark assessment has been applied to eastern Georges Bank cod assessment during 2002-2008. In recent assessments the results exhibited a domed catchability pattern by age in both the Fisheries and Oceans Canada (DFO) and National Marine Fisheries Services (NMFS) spring surveys, and the descending limb of the fishery partial recruitment became increasingly steeper for older ages. The resulting assessment generated appreciable 'cryptic' biomass that could not be observed by either the fishery or the surveys. Further 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. A benchmark assessment to address these concerns was conducted in 2009 and the details of the model formulations that were agreed upon are documented in Wang *et al.* (2009).

This assessment applied the 2009 benchmark formulations using Canadian and USA fishery information updated to 2008 including commercial landings and discards, DFO survey updated to 2009, and NMFS spring and fall surveys updated to 2008.

FISHERY

Commercial Fishery Catches

All the catch data were updated at the 2009 benchmark meeting, and only a minor revision was made for this assessment. Combined Canada/USA catches averaged 17,508 mt between 1978 and 1992. Catches peaked at 26,463 mt in 1982, and then declined to 1,684 mt in 1995. Catches fluctuated around 3,000 mt until 2004 and subsequently declined again. Catches in 2008 were 1,782 mt, including 161 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 introduction of the cod separator panel for bottom trawls in 1999 (Table 2). From 1995-2007, Canadian catches fluctuated between 859 mt and 3,405 mt (Table 1). Landings in 2008 were 1,390 mt, taken primarily between June and December by otter trawl and longline (Table 3, Figure 4 and 5). All 2008 landings were subject to dockside

monitoring and at sea observers monitored close to 38% by weight of the mobile gear fleet landings and 21% by weight of the fixed gear landings.

Canadian regulations prohibit the discarding of undersized fish. Discards from the Canadian groundfish fishery were estimated for 1997-1999 (Van Eeckhaute and Gavaris, 2004) and for 2005 and 2006 (Gavaris *et al.*, 2006, 2007a, 2007b) (Table 1). In 2007, no discards were attributed to the mobile gear fleet because of the high observer coverage (99%) and discards for the fixed gear fleet could not be calculated because of the low observer coverage but were assumed negligible, as discards had not been detected in previous years (Clark *et al.*, 2008). The ratio of sums method applied by Gavaris *et al*. (2006, 2007a) was used to estimate discards of cod from the 2008 Canadian groundfish fishery (Appendix). Cod discards from the 2008 Canadian groundfish fishery were estimated at 6 mt from the mobile gear fleet and 97 mt from the fixed gear fleet (Table 1).

Since 1996 the Canadian scallop fishery has not been permitted to land cod. Landings until 1995 include those catches reported by the scallop fishery. Estimated discards of cod by the Canadian scallop fishery ranged up to 200 mt annually since 1978 (Van Eeckhaute *et al.,* 2005). Estimated discards of cod by the Canadian scallop fishery were 36 mt in 2008 (Gavaris *et al.,* 2009; Table 1).

USA catches increased from 5,502 mt in 1978 to 10,550 mt in 1984, then declined and fluctuated around 6,000 mt between 1985 and 1993 (Table 1, Figure 3). Since December 1994, a year-round closure of Area II (Figure 1) has been in effect, with the exception of a Special Access Program in 2004. Minimum mesh size limits were increased in 1994, 1999 and in 2002. Limits on sea days, as well as trip limits, have also been implemented (Table 2). USA catches during 1994-2000 ranged between 544 mt to 1,208 mt and increased to 1,959 mt in 2003. Quotas were introduced in May 2004. USA landings have since decreased with a total catch of 253 mt in 2008. USA landings are usually taken in the first and second quarter (Figure 5). Because of the seasonal restrictions on eastern Georges Bank in 2008 (Table 2), the majority of the 231 mt of landed cod was harvested in the fourth quarter (Figure 5).

Discards are permitted by USA groundfish fleets because of trip and size limit. In 2008, the 'Ruhle trawl', which is effective in reducing by-catch of cod, was authorized for use on EGB. The estimated discards of cod in the groundfish fishery for 2008 declined to 22 mt. Otter trawl gear accounted for 96% of the discards with scallop gear accounting for the remainder (Table 1, Figure 2).

Size and Age Composition

The size and age compositions of the 2008 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 are representative samples over the months for all the fishing gears. Comparison of port and at-sea length frequencies did not indicate any discrepancies for otter trawlers. However, some fixed gear observer samples tended to have more smaller fish than the port samples (Figure 7). At-sea samples were pooled with port samples to derive catch at length and age. Landings peaked at 58 cm (23 in) for bottom trawlers (Figure 8) while longliners displayed a broader peak between 67 cm and 76 cm (28 to 30 in). Gill-netters caught fewer cod but these fish were larger, peaking at 76 cm (30 in).

The size composition of cod discards from the 2008 Canadian scallop fishery was derived from at-sea sampling. Cod discards from the scallop fishery peaked at 46 cm (18 in), appreciably

smaller than cod caught in the groundfish fishery. The size composition of cod discards from longliners was derived using only the at-sea observer length samples because of the difference between port and observer samples. The gear combined landings peaked at 61-67cm (24-26 in), with discards peaking at 64cm (25 in) (Figure 9).

The size and age compositions of the 2008 USA fishery landings on eastern Georges Bank were derived using port samples from all principal gears and seasons by market category (Table 4). Landings peaked at 72 cm (28 in), and discards peaked at 53cm (21in) (Figure 10).

The catch composition, combined landings and discards, for Canada and USA are shown in Figure 11. Canadian and USA catches peaked at similar length (Canada: 64 cm (25 in); USA: 62 cm (24 in)), but Canadian catches contained more large fish than USA catches.

Otoliths taken from port and at sea observer samples are used for age reading. Comparisons 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 2008 DFO survey, conducted in February, was used to augment the first quarter key. The age composition of the USA landings was estimated, by market category, from length frequency and age samples pooled by calendar quarter. Discards at age from the USA groundfish and scallop fisheries (1989-2008), the Canadian groundfish fishery (1995-2008) and the Canadian scallop fishery (1978-2008) were included in the assessment when identified.

The combined Canada/USA 2008 fishery age composition was dominated by the 2003 year-class at age 5 (47% by number), followed by the 2005 year-classes at age 3 (23% by number) and 2004 year-class at age 4 (11% by number) (Figure 12). The 2001 year-class at age 7 still contributes to the catch (6% by number). The contribution of fish older than age 7 to the catch continues to be smaller in recent years (Table 6, Figure 13).

Fishery weights at age show a declining trend starting in the early 1990s (Table 7, Figure 14). Except for age 7, weights at age improved slightly in 2008.

ABUNDANCE INDICES

Surveys

Surveys of Georges Bank have been conducted by DFO each year (February/March) since 1986 and by NMFS each autumn (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 *CCG Alfred Needler*. A sister ship, the *CCG Wilfred Templeman*, conducted the survey in 1993, 2004, 2007 and 2008 and another vessel, the *CCG 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 (436) in other years, but no net conversion factors are available for cod.

The spatial distribution of ages 3 and older cod caught during the 2009 DFO survey was similar to those observed from surveys over the previous decade (Figure 17) with some of the highest densities observed on the northern part of the bank, but only 2 fish were caught on the USA side. Total catch in numbers in the 2009 DFO survey increased slightly from 2007 and 2008. The 2003 year-class at age 5 remained strong, while the 2005 year-class at age 4 and 2006 year-class at age 3 looked promising from this survey, although not consistent with previous years survey results (Table 9, Figure 19).

A new vessel and net were used for the 2009 NMFS spring survey. Since conversion factors were not available before the 2009 TRAC meeting, these data are not applied in this assessment (Table 10). The 2008 NMFS autumn survey caught very few cod (32 in total) (Table 11). The limited catches were in locations similar to the pattern observed during the previous decade (Figure 18), but no fish were caught on the USA side

With the exception of the 2003 year-class, the survey abundance at age (Tables 9-11, Figure 19) shows poor recruitment since the 1990 year-class. The 2003 year-class appears strong over several ages while the 2005 and 2006 year-classes appear promising, but results are not consistent at all ages. Compared with pre-1990s, the proportion of the age composition for ages 4-6 increased during the 2000s.

Biomass indices at age were calculated by applying weights at age to the abundance indices at age. Survey biomass indices fluctuate without a clear trend in recent years. The biomass indices slightly increased for ages 2-3 and ages 4-6 in recent years, but the older fish at ages 7-8 are still decreasing (Figure 20).

The average weights at age derived from the DFO survey and NMFS spring survey are used as population weights at age for the beginning of the year. All the weights at age display a declining trend since the early 1990s, but there is some improvement in 2009 for some ages (Table 12, Figure 21). Cod condition, derived from the DFO survey and measured as average weight at length at 3 representative length groupings, did not show any notable trends (Figure 22).

HARVEST STRATEGY

The Transboundary Management Guidance Committee has adopted a strategy to maintain a low to neutral risk of exceeding the fishing mortality limit reference, $F_{ref} = 0.18$. When stock conditions are poor, fishing mortality rates should be further reduced to promote rebuilding.

ESTIMATION AND DIAGNOSTICS

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 2008 (including discards). The VPA was calibrated to trends in abundance from three 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.*, 2009). These model formulations will be referred to as the "split M 0.2" and "split M 0.5" method 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 2008, 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… 2008.17, 2009.00
$I_{3,a,t}$ = 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… 2007.28, 2008.28
$I_{6,a,t}$ = NMFS autumn survey, ages a = 1 to 5 and time t = 1978.79, 1979.79… 1992.79, 1993.79
$I_{7,a,t}$ = NMFS autumn survey, ages a = 1 to 5 and time t = 1994.79, 1995.79… 2007.79, 2008.79.

The population was calculated to the beginning of 2009.00; therefore, the DFO spring survey indices for 2009 were designated as occurring at the beginning of the year, i.e. 2009.00. 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. The survey time series are split in 1993-1994. The annual natural mortality rate, M, was assumed constant and equal to 0.2 for all ages in all years for the "split M 0.2" model formulation. For the "split M 0.5" model formulation, M was assumed equal to 0.5 for ages 6+ during 1994-2008 and equal to 0.2 for other ages and years. Fishing mortality on age 9 for 1978 to 2008 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:

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

The estimated model parameters were:
$\nu_{a,t}$ = $lnN_{a,t}$ = ln population abundance for a = 2 to 9 at time t = 2009
$\kappa_{1,a}$ = ln DFO survey catchability for a = 1 to 8 at time t=1986 to 1993
$\kappa_{2,a}$ = ln DFO survey catchability for a = 1 to 8 at time t =1994 to 2009
$\kappa_{3,a}$ = ln NMFS spring survey (Yankee 41) catchability for ages a = 1 to 8 at time t=1978 to 1981
$\kappa_{4,a}$ = ln NMFS spring survey (Yankee 36) catchability for ages a = 1 to 8 at time t=1982 to 1993
$\kappa_{5,a}$ = ln NMFS spring survey (Yankee 36) catchability for ages a = 1 to 8 at time t=1993 to 2008
$\kappa_{6,a}$ = ln NMFS autumn survey catchability for ages a = 1 to 5 at time t= 1978-1993
$\kappa_{7,a}$ = ln NMFS autumn survey catchability for ages a = 1 to 5 at time t=1994-2008.

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 at age 2 at the beginning of 2009 exhibited the largest relative bias of 13%, while that for other ages/times ranged between 4% and 8%. The relative error ranged between 37% and 58% (Table 13). Survey catchability (q) at age progressively increased until about age 6 for DFO 1994-2009 and age 5 for NMFS spring Y36 1994-2008 survey (Figure 23). Compared with the survey catchability prior to 1994, both DFO and NMFS spring survey have abruptly increased by about three-fold starting at about age 3. Survey catchability at age for the NMFS autumn survey was very low (Figure 23).

B. "split M 0.5" Model

The population abundance estimate at age 2 at the beginning of 2009 exhibited the largest relative bias of about 10%, while that for other ages/times ranged between 4% and 8%. The relative error ranged between 31% and 50% (Table 14). 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 DFO 1994-2009 survey and NMFS spring Y36 1994-2008 survey, remaining flat shaped at older ages. Compared with the survey catchability prior to 1994, both DFO and NMFS spring survey have increased by about two-fold starting at about age 3. Survey catchability at age for the NMFS autumn survey was very low (Figure 23).

Comparisons

The overall fit of model estimated biomass to the DFO, NMFS spring and NMFS fall surveys was good and generally consistent with the survey trends after 1994. However, VPA estimates at younger ages tended to be lower than survey observations in 2009, while VPA estimates at older ages were higher than survey observations for the most recent 3 years (Figure 24). There are still residual patterns for both models, which suggest some year effects (Figure 25).

Retrospective analyses were used to detect any patterns of consistently overestimating or underestimating fishing mortality, biomass and recruitment relative to the terminal year estimates. There was no persistent retrospective pattern, but there was a tendency to initially overestimate 3+ biomass in some recent years (Figures 26-27). The "split M 0.5" model generally displays less retrospective pattern than the "split M 0.2" model.

F from the "split M 0.5" model is more consistent with perception about changes in effort associated with the management measures that were imposed (Figure 28). Recent management measures and observed catch better matched expectations of model output. Both models indicate flat fishing partial recruitment except for the 10+ group (Figure 29).

STATE OF RESOURCE

Adult population biomass (ages 3+) declined substantially from about 50,000 mt in 1990 to below 10,000 mt in 1995, the lowest observed (Table 17 and 20, Figure 31), regardless of model formulation. From the "split M 0.2" model, biomass subsequently fluctuated between 5,900 mt and 10,200 mt before decreasing to 3,800 mt in 2005 and increasing again to 8,700 mt (80% confidence interval: 7,595 mt-11,279 mt) at the beginning of 2009. From the "split M 0.5" model, biomass subsequently fluctuated between 8,400 mt and 13,500 mt before decreasing to 6,000 mt in 2005 and increasing again to 12,000 mt (80% confidence interval: 10,417 mt-15,245 mt) at the beginning of 2009. The increase in 2006 was largely due to recruitment of the

2003 year-class, and the increases in 2007, 2008 and 2009 were due to growth of the 2003 year-class (Figure 30). Lower weights-at-age in the population in recent years and generally poor recruitment have contributed to the lack of sustained rebuilding, although improvement in size at some ages has been seen in 2008 fishery and 2009 DFO survey.

Recruitment at age 1 of the 2003 year-class (4.4 million from the "split M 0.2" model and 5.8 million from the "split M 0.5" model) is the highest since the 1990 year-class but is still lower than the pre-1990 average level (10 million for both models) (Table 15 and 18, Figure 31). The 2002 and 2004 year-classes are the lowest on record. The 2005 and 2006 year-classes are close to post-1990 average level (2 million from the "split M 0.2" model and 2.4 million from the "split M 0.5" model). Initial indications are that the 2007 year-class is weak.

Fishing mortality (population weighted average) for ages 4-9 was higher prior to 1994 (Table 16 and 19, Figure 32). 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 0.25 and 0.74 for the "split M0.2" model and 0.18 and 0.53 for the "split M 0.5" model. F in 2008 was estimated to be 0.25 from the "split M 0.2" model and 0.17 from the "split M 0.5" model. Both models show recent reductions in F; however, F has been above the F_{ref} =0.18 in the past.

Yield exceeded surplus production during the early 1990s (Figure 33). 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 (Figure 32).

Recruitment, while highly variable, has generally been higher when ages 3+ biomass exceeded 30,000 mt (Figure 34). The current biomass is below 30,000 mt. The recruits per spawner has not increased when the biomass has been low (Figure 35). This lack of compensation hampers stock rebuilding.

PRODUCTIVITY

Recruitment, age structure, fish growth and spatial distribution reflect changes in the productive potential. In both absolute numbers and percent composition, the population age structure since 1995 displays a very low proportion of 7+ older age groups compared to the 1980s (Figure 36). Average weight at length, used to reflect condition, has been stable, but declines in length and weights at age have hampered biomass rebuilding. There is some improvement in size at age in the 2008 fishery and the 2009 DFO survey for some ages. The spatial distribution patterns observed during the most recent bottom trawl surveys showed that adult cod were distributed in a similar manner to the average over the past decade. Resource productivity is currently 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 2010 (Gavaris and Sinclair, 1998; Rivard and Gavaris, 2003b). Uncertainty about standing stock generates uncertainty in forecast results which is expressed here as the risk of exceeding F_{ref} =0.18. The risk calculations assist in evaluating the consequences of alternative catch quotas by providing a general measure of the uncertainties.

However, they are dependent on the data and model assumptions and do not include uncertainty due to variations in weights at age, partial recruitment to the fishery, natural mortality, systematic errors in data reporting or the possibility that the model may not reflect stock dynamics closely enough.

For projections, the 2006-2008 average values were assumed for the fishery weights at age, the 2004-2008 average values were assumed for the partial recruitment pattern in 2009-2010, and the 2007-2009 survey average values were assumed for beginning of year population weights at age in 2010-2011 (Table 21). Catch in 2009 was assumed to be equal to the 1,700 mt quota. Projections are provided from each of the model results.

A. "split M 0.2" Model

A combined Canada/USA catch of about 1,300 mt in 2010 will result in a neutral risk (50%) that the fishing mortality rate in 2010 will exceed F_{ref} whereas a catch of 1,800 mt will result in a neutral risk (50%) that the 2011 adult biomass (4+) will be lower than the 2010 adult biomass (Figure 37). A catch of about 1,000 mt will result in a neutral risk (50%) that 2011 adult biomass will not increase by 10%.

B. "split M 0.5" Model

A combined Canada/USA catch of about 1,700 mt in 2010 will result in a neutral risk (50%) that the fishing mortality rate in 2010 will exceed F_{ref} whereas a catch of 900 mt will result in a neutral risk (50%) that the 2011 adult biomass will be lower than the 2010 adult biomass (Figure 37). A catch of about 500 mt will have a high risk (75%) that 2011 adult biomass will not increase by 10%.

While management measures have resulted in decreased exploitation rate since 1995, adult biomass has fluctuated without any appreciable rebuilding. The continuing poor recruitment since the early 1990s is an important factor for this lower productivity. The 2003 year-class made a substantial contribution to the fishery and population biomass, and it is projected to continue to be an important component in the fishery catch biomass in 2009-2010 (around one third of the catch) and population biomass in 2010-2011 (Figures 38-39, Table 22). With the passing of the 2003 year-class through the population, rebuilding will not occur without improved recruitment.

SPECIAL CONSIDERATIONS

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. 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. Possible differences in vertical structure of cod aggregations in relation to changes in abundance could cause changes in catchability. 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.

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Table 1. Catches (mt) of cod from eastern Georges Bank, 1978-2008.

	Canada				USA			Total
Year	Landings	Discards Scallop	Discards Grndfish	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	104	6,286	14,257
1990	14,364	70		14,434	6,414	95	6,509	20,943
1991	13,467	65		13,532	6,353	149	6,501	20,034
1992	11,667	71		11,738	5,080	179	5,259	16,997
1993	8,526	63		8,589	4,019	67	4,087	12,676
1994	5,277	63		5,340	998	6	1,005	6,344
1995	1,102	38		1,140	544	0	544	1,684
1996	1,924	56		1,980	676	2	677	2,658
1997	2,919	58	428	3,405	549	8	557	3,962
1998	1,907	92	273	2,272	679	7	686	2,959
1999	1,818	85	253	2,156	1,195	14	1,208	3,365
2000	1,572	69		1,641	772	26	798	2,439
2001	2,143	143		2,286	1,487	220	1,708	3,993
2002	1,278	94		1,372	1,680	12	1,692	3,064
2003	1,328	200		1,528	1,854	105	1,959	3,486
2004	1,112	145		1,257	1,007	70	1,077	2,334
2005	630	84	144	859	174	249	423	1,281
2006	1,096	112	237	1,445	134	128	262	1,707
2007	1,108	114		1,222	216	341	557	1,779
2008	1,390	36	103	1,529	231	22	253	1,782
Minimum	630	36	103	859	134	0	253	1,281
Maximum	17,827	200	428	17,898	10,550	341	10,550	26,463
Average	6,229	85	240	6,360	3,843	90	3,901	10,261

Table 2. Canadian and USA fishery management history of cod on eastern Georges Bank, 1978-2008.

2a. Canadian

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=1,633t; Winter fishery from Jan.1 to Feb. 8; 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.

2b. USA

USA Regulations	
1982-1985	The "Interim Plan" for Atlantic groundfish; eliminated all catch controls, retained closed area and mesh size regulations, implemented minimum landings sizes.
1983	Mesh size increased to 5½“ diamond
1984	October: The 'Hague' line established separate fishing zones for the USA and Canada in the Gulf of Maine and on Georges Bank
1986	September: FMP for the Northeast Multispecies Fishery Effective; Areas 1 and 2 closed during February 1 - May 31. Mesh size increased to 5 ½" (yr 1+ 2), 6 “(yr 3); Minimum size landed - commercial 17 “(yr 1), 19 “(yr 2+) , Recreational 15" (yr 1),17" (yr 2+3), 19" (yr 4+).
1989	January : Minimum size in recreational = commercial = 19 inches.
1993	Area 2 closure in effect from Jan 1-June 30.
1994	January: Amendment 5: 50% reduction in effort (5-7 years), Expanded Area 2 closure. Days at sea (DAS) monitoring; mandatory logbooks. December: Year round closure of Area II.
1996	October: Sustainable Fisheries Act (SFA) effective. May:Recreational minimum size increases to 20". July 1: Amendment 7 effective. Establishes target TACs, rebuilding target of $F_{0.1}$
1997	May: Recreational minimum size increases to 21".
1999	May: Minimum mesh size increase to 6 ½” square, remains at 6" diamond. November: Amendment 9 effective; Redefines over fishing definitions to comply with SFA. August: Bottom trawl trip limit: 2000 lb/day, 20,000 lb/trip with trigger at 75% of TAC. Hook fishermen: 4000 lb/day trip limit.
2002	May: Interim rule as a result of FW 33 lawsuit settlement agreement. Continuation of most measures from previous frameworks. DAS: 15 hour minimum charged for all trips over 3 hours,Vessels limited to 25% of allocation May 1 through July 31, 2002 (only). Prohibition on front-loading DAS. Minimum size: Cod 22”. Gear: GOM Regulated Mesh Area (RMA): 6.5 in. diamond or square codend minimum, 6.5” mesh for trip gillnets, 6.5 inch mesh standup (roundfish) or 7” mesh tiedown (flatfish) for day gillnets. All areas:day gillnets limited to 50 standup/100 tiedown nets. *Hook gear*: de-hooking devices with spacing of less than 6” prohibited. Recreational: Cod minimum size 23”. All areas- private recreational limited to 10 cod. Possession limits: Remain the same. June: Revised interim rule:Minimum size: Cod 19”, Gear: *Hook*: Requirement for 6” spacing for de-hooking gear removed. Aug: Emergency rule implementing FW 33 lawsuit settlement agreement: DAS: DAS allocation for each permit reduced 20 percent from maximum used \ FY 1996-2000 (est 71,218 allocated, including carry-over). DAS counted by the minute, except for day gillnet vessels (15 hour minimum). (This change reverted to DAS counting in effect in FY 2001). Prohibition on front-loading DAS clock. Minimum size: Cod 22”. Gear: *Trawl:* GOM/GB RMAs: 6.5” diamond or square codend minimum; *Hook*: GB: 3,600 rigged hooks Closures: Add GB seasonal closure areas, May – Blocks 80, 81, 118, 119, 120 (south of 42-20N). Recreational: Cod/haddock: 23” minimum size. Party/charter: GOM RMA: April-November, 10 cod/haddock combined per person, Dec-Mar – 10 cod/haddock combined, no more than 5 cod per person per trip. Private: GOM RMA: December-March – 10 cod/haddock combined, no more than 5 cod. Commercial minimum size increased to 22" (55.9 cm)
2003	July: Final emergency rule implementing FW 33 lawsuit settlement agreement. Recreational: Other areas (including GB):10 cod/haddock combined.
2004	May: Implementation of Amendment 13. Measures based on emergency rule and measures in effect prior to interim rule. Special Management Programs: *US/Canada Area*: hard TAC on cod, Cod possession limit: 500 lbs-DAS/5,000 lbs-trip, not more than 5 percent of catch. No DAS charged to/from SAs 561, 562. VMS required in U.S/Canada Management Area ; only Category A DAS Daily catch report via VMS (catch&discard) ;Haddock separator trawl; flatfish net. October: Closure of SAs 561 and 562 to all fishing on a multispecies DAS. November: Framework Adjustment 40A. *Eastern US/CA Area Haddock SAP Pilot Program* Access to northern corner of CAII and adjacent area to target haddock using separator trawl. Season: May 1 through December 31. Authorized use of Category B DAS.
2005	January: Eastern US/CA reopened, Cod trip limit of 5,000 lbs./trip in Eastern US/CA area. Vessels fishing in Eastern US/CA area must use haddock separator trawl. April: Eastern US/CA area closed until April 30, 2005. May: Eastern US/CA Area reopens at beginning of fishing year. Measures revert to those implemented May 1, 2004. July: NE multispecies DAS vessels are limited to one trip per month in the Eastern US/CA area. Multispecies DAS vessels are prohibited from fishing in the Category B (regular) DAS program in the GB cod stock area through July 31. NE multispecies trawl vessels are required to use haddock separator trawl when fishing in the Eastern US/CA area. August : Eastern US/CA area is closed to all limited access multispecies DAS vessels because 90 percent of the GB cod TAC for the area is projected to be harvested.
2006	Implementation of an emergency rule to reduce fishing mortality on groundfish stocks while FW 42 is reviewed. Special Management Programs: *Eastern US/Canada haddock SAP*: Opening delayed until August 1. Category B (regular) DAS Program: Renewed, with vessels restricted to the US/CA Area, required to use a haddock separator trawl, limited to 500 days May-June, 1,000 days in other quarters, low trip limits on stocks of concern. Other: Vessels allowed to fish inside and outside the eastern US/CA area on the same trip. June: All trawl vessels fishing in the eastern US/CA area required to use a haddock separator trawl. November: Implementation of FW 42 - Major regulatory changes: Special Management

	Programs: *US/Canada Area*: Opening delayed until August 1. Prohibition on discarding legal sized fish. Category B (regular) DAS Program: Renewed for all areas. Trawl vessels required to use a haddock separator trawl, limited to 500 days May-June, 1,000 days in other quarters, low trip limits on stocks of concern. Prohibition on discarding legal sized fish. Other: (same as emergency rule) Vessels allowed to fish inside and outside the eastern US/CA area on the same trip.
2007	March: Trawl vessels fishing in the eastern US/CA area allowed to use either a haddock separator trawl or a flounder net. April: Eastern U.S./Canada area closed to limited access multispecies vessels (through April 30, 2007). May: Eastern U.S./Canada area reopens. June: Eastern US/CA area is closed to limited access multispecies DAS vessels due to cod catch.. October: The Eastern US/CA area is opened to limited access multispecies DAS vessels. The GB cod possession limit is 1,000 lb/trip for all vessels declared into the Eastern US/CA Area or the Eastern US/CA Area SAP.
2008	May: Eastern U.S./Canada area opening delayed until August 1, 2008 for vessels fishing with trawl gear. Eastern U.S./Canada area opened to longline gear but with a cod cap of 33.4 mt. August: Eastern U.S./Canada management area opens to all vessels. U.S./Canada Haddock SAP opens. Haddock rope trawl (later called the Ruhle trawl, previously called the eliminator trawl) approved for use in the Category B (regular) DAS program and the U.S./Canada Haddock SAP. September: Ruhle trawl authorized for use in the Eastern U.S./Canada management area. November: Landing limit for Eastern GB cod increased to 1,000 lbs./DAS up to a maximum of 10,000 lbs./trip (applies to cod caught in the Eastern U.S./Canada management area).

Table 3. Nominal landings (mt) of cod from eastern Georges Bank by gear and month for Canada during 1999-2008.

Year	Gear	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1999	Mobile	3					226	156	47	72	59	38	19	619
	Gillnet						59	100	48	15	36	7	6	270
	Longline						95	288	244	152	107	27	17	929
	Total	3					379	544	339	239	201	71	42	1,818
2000	Mobile						102	140	82	73	70	38	30	535
	Gillnet						55	76	28	24	41	9	4	238
	Longline						41	191	177	222	138	15	16	799
	Total						197	407	287	318	248	63	51	1,572
2001	Mobile						160	84	58	104	133	111	72	722
	Gillnet						37	75	48	60	43	21		284
	Longline						62	212	273	282	229	62	16	1,137
	Total						259	371	379	446	406	193	88	2,143
2002	Mobile						38	87	33	83	62	55	86	445
	Gillnet						3	45	51	23	1	9	7	140
	Longline						2	150	199	156	127	31	29	693
	Total						43	282	283	263	190	95	122	1,278
2003	Mobile						87	81	55	65	67	74	45	474
	Gillnet						6	31	31	27	3	14	1	112
	Longline						20	166	252	136	124	30	14	742
	Total						114	277	338	228	194	117	59	1,328
2004	Mobile						78	82	50	47	56	42	16	371
	Gillnet						4	2	14	21		11		52
	Longline						6	85	231	168	89	97	14	689
	Total						88	169	294	236	145	150	30	1,112
2005	Mobile	12	22			3	50	49	31	27	28	31	30	283
	Gillnet						11	18		6				36
	Longline	1					9	44	101	71	52	29	4	311
	Total	13	22			3	70	111	133	105	80	60	34	630
2006	Mobile	41	16				88	73	74	63	39	24	39	458
	Gillnet							27	15					43
	Longline	3					7	126	173	147	91	34	14	595
	Total	44	16				96	226	262	211	130	58	53	1,096
2007	Mobile	68	18				44	84	55	31	49	14	28	393
	Gillnet							4	41	13				58
	Longline						7	116	173	219	102	39		657
	Total	68	18				51	205	268	263	152	53	28	1,108
2008	Mobile	40	21				69	100	55	67	46	43	28	468
	Gillnet						1	22	50	22				94
	Longline						7	190	280	177	136	38		827
	Total	40	21				77	312	384	265	182	81	28	1,390

Table 4. Length and age samples for landings at age calculation for 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 1978-1986 and DFO survey age samples for 1987-2008, the numbers are shown in brackets.

Year	USA		Canada	
	Lengths	Ages	Lengths	Ages
1978	2,294[1]	384	7,684	1,364
1979	2,384	402	3,103	796(205)
1980	2,080[1]	286	2,784	728(192)
1981	1,615	455	3,906	842
1982	4,466[1]	778	4,948	1,054(268)
1983	3,906[1]	903	3,822	754(150)
1984	3,891	1,130	1,889	1,241(858)
1985	2,076	597	7,031	1,309(351)
1986	2,145	643	5,890	987(103)
1987	1,865	524	9,133	1,429(193)
1988	3,229	797	11,350	1,892(510)
1989	1,572	347	8,726	1,499
1990	2,395	552	31,951	2,825(1153)
1991	1,969	442	27,739	1,782
1992	2,048	489	28,825	2,215(359)
1993	2,215	569	31,473	2,146
1994	898	180	27,659	1,268
1995	2645[1]	14	6,633	548
1996	4,895[1]	1,163	25,818	828
1997	1,761[1]	82	31,420	1,216
1998	1,301[1]	338	25,743	1,643
1999	921	228	25,871	1,290(410)
2000	200	121	20,127	1,374
2001	1,434	397	18,627	1,505
2002	1,424	429	15,616	1,252
2003	1,367	416	19,185	1,070
2004	1,547	517	17,856	1,370
2005	249[1]	65	21,942	1,483(697)
2006	446	151	43,259	1,455(648)
2007	406	131	139,816	1,672(456)
2008	1,365[1]	295	63,213	1,729(495)

1 Includes length samples from western Georges Bank.

Table 5. Results of age comparison testing.

Sample Source	Stock	Test Type	Date Completed	Age Reader	Sample Size	CV (%)	Agreement (%)
2007 US Port Samples (Q1-2)	GB	Exchange	Spring 2008	NS vs. BH	99	1.80	88.9
2006 US Fall Survey (200610)	GB	Exchange	Spring 2008	NS vs. BH	60	2.83	88.3
2006-2007 CAN Intra Aging Tests Qtr 1-4	GB	Precision	April 2008	BH	192	.68	95
Feb. 2007 CAN DFO Survey TEM2007685	GB	Exchange	Jan 2009	BH vs. NS	50	.07	82
Dec. 2006 CAN Observer Sample J06-0625	GB	Exchange	Jan 2009	BH vs. NS	23	.02	91
Aug. 2006 CAN Comm. Sample 20060230	GB	Exchange	Jan 2009	BH vs. NS	27	0	100
2007-2008 CAN Intra Aging Tests Qtr 1-4	GB	Precision	April 2009	BH	126	.07	95

*****BH: Bette Hat from DFO

NS: Nina Shepherd from NMFS

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

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	889	734	1519	543	182	74	60	11	3	2	1	0	1	0	0	4035
1980	2	6	973	1651	301	969	354	97	26	46	16	4	1	0	0	0	0	4448
1981	3	35	788	1656	1260	283	530	199	102	61	21	3	1	0	0	0	0	4943
1982	0	15	3516	1971	1269	1087	195	399	155	49	14	22	6	3	4	1	0	8707
1983	10	22	783	2511	1297	563	398	118	182	102	25	28	12	1	4	1	0	6057
1984	0	17	231	805	1354	546	377	279	39	90	38	17	7	2	3	0	1	3806
1985	33	9	2859	1408	660	986	270	110	110	21	27	3	4	1	1	0	0	6504
1986	1	41	451	2266	588	343	456	68	48	29	4	8	1	0	0	0	0	4303
1987	2	22	4116	845	1148	163	132	174	40	24	8	3	1	0	0	0	0	6679
1988	1	23	289	4191	681	856	130	117	182	52	21	13	4	1	0	0	0	6559
1989	1	35	682	811	1978	228	373	56	40	59	15	7	5	0	0	0	0	4290
1990	1	20	734	3117	1038	1374	145	153	12	12	24	3	2	1	0	0	0	6636
1991	0	65	1022	1010	1924	904	746	105	69	21	11	8	4	2	0	1	0	5893
1992	0	65	2555	1377	459	890	314	316	45	34	3	5	2	1	0	0	0	6067
1993	0	10	498	1898	909	299	359	133	97	25	17	2	0	0	0	0	0	4249
1994	1	5	184	483	788	270	45	61	30	21	2	1	0	0	0	0	0	1890
1995	3	1	57	236	94	105	18	7	4	4	0	0	0	0	0	0	0	530
1996	0	7	40	234	397	79	60	13	4	3	0	0	0	0	0	0	0	838
1997	1	7	145	206	358	359	83	37	13	4	1	1	0	0	0	0	0	1214
1998	0	4	100	315	161	158	134	23	13	4	1	0	1	0	0	0	0	914
1999	0	7	77	486	337	109	61	57	14	2	1	0	0	0	0	0	0	1150
2000	1	8	74	112	379	151	37	22	12	3	0	0	0	0	0	0	0	801
2001	1	55	138	499	217	401	105	32	17	7	1	0	0	0	0	0	0	1472
2002	1	1	12	125	438	107	154	30	9	5	2	1	0	0	0	0	0	884
2003	13	0	38	159	240	404	80	89	19	4	1	0	0	0	0	0	0	1047
2004	0	22	13	146	151	147	139	35	30	7	1	1	0	0	0	0	0	691
2005	0	2	85	56	191	54	34	37	11	5	1	0	0	0	0	0	0	476
2006	0	3	21	243	75	191	47	18	17	2	2	0	0	0	0	0	0	620
2007	0	2	74	81	402	30	84	11	7	7	0	0	0	0	0	0	0	699
2008	0	1	41	130	62	261	16	35	4	2	1	0	0	0	0	0	0	555

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	1.98	3.06	4.57	6.52	8.01	9.18	11.42	14.55
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	6.80	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	13.27
1992	0.86	1.42	2.28	3.33	4.25	5.67	6.80	8.66	11.21	14.87
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	7.96	11.44
1995	0.28	1.32	2.12	3.35	4.94	6.38	10.09	10.01	10.43	15.64
1996	0.49	1.42	2.17	3.05	4.70	5.83	6.42	8.96	10.35	10.28
1997	0.72	1.44	2.07	2.93	3.86	5.36	7.26	8.31	11.49	9.88
1998	0.78	1.35	2.15	2.98	3.97	5.33	6.59	7.82	10.23	12.79
1999	0.56	1.33	1.97	3.10	3.91	5.48	6.27	7.54	9.38	13.58
2000	0.65	1.24	1.94	2.91	4.02	4.70	5.72	6.77	8.38	14.05
2001	0.47	0.97	1.88	2.70	3.56	4.87	5.22	7.28	8.65	10.98
2002	0.32	1.18	1.96	2.85	4.02	4.89	6.42	8.23	7.99	10.11
2003		1.23	2.10	2.73	3.54	4.27	5.47	6.84	7.63	8.12
2004	0.24	1.24	1.84	2.78	3.47	4.56	5.24	7.25	8.54	8.62
2005	0.17	0.91	1.57	2.43	3.50	4.48	4.89	6.81	8.05	8.94
2006	0.21	0.66	1.77	2.38	3.35	4.34	6.09	5.79	6.91	7.17
2007	0.47	1.10	1.56	2.42	3.08	3.98	6.29	6.83	6.89	9.29
2008	0.21	1.19	2.09	2.76	3.62	4.91	5.76	7.79	7.93	8.69
Min	0.17	0.66	1.52	2.38	3.08	3.98	4.89	5.79	6.89	7.17
Max	0.90	1.60	2.43	3.93	5.38	7.23	10.09	11.46	11.86	15.64
Avg.[1]	0.26	1.02	1.77	2.55	3.40	4.46	5.65	6.89	7.66	8.54

[1]for 2004-2008

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

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. 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

Table 10. 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

Table 11. 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

Table 12. Beginning of year population weights at age 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	7.99	11.427	14.635
1971	0.116	0.811	1.798	2.347	4.372	5.377	6.45	7.99	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	1.89	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	9.15	14.635
1976	0.138	0.946	2.156	2.999	3.753	5.342	8.011	7.384	9.15	14.635
1977	0.124	0.905	2.13	3.365	6.182	5.503	6.667	5.664	9.15	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	1.74	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	3.05	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	0.05	0.582	1.954	2.443	2.699	4.121	5.89	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	0.77	1.742	3.217	4.92	5.698	7.439	8.988	10.684	14.635
1987	0.15	0.845	1.701	2.686	5.672	7.487	7.48	6.659	10.1	14.635
1988	0.152	0.931	1.785	3.02	4.169	6.268	8.438	8.724	12.33	14.635
1989	0.142	0.832	1.705	2.759	4.306	6.432	7.615	7.813	11.32	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	9.906	14.635
1993	0.07	0.955	1.845	2.907	4.513	5.889	6.999	7.383	9.279	14.635
1994	0.143	0.657	1.433	2.629	3.954	7.458	7.33	8.661	8.871	14.635
1995	0.183	0.794	1.587	2.245	3.474	4.697	6.692	7.92	11.886	14.635
1996	0.088	0.838	1.553	2.597	3.908	6.112	5.458	12.028	11.92	14.635
1997	0.19	0.717	1.694	2.176	3.218	6.2	6.204	9.796	10.174	14.635
1998	0.078	0.65	1.382	2.258	3.034	4.516	5.831	7.787	8.211	14.635
1999	0.111	1.001	1.35	2.237	2.973	4.635	6.513	8.25	8.448	14.635
2000	0.06	0.896	1.587	2.326	3.234	4.461	6.501	8.211	11.523	14.635
2001	0.01	0.771	1.418	2.584	3.602	5.089	6.909	7.552	10.254	10.687
2002	0.016	0.495	1.214	2.269	3.538	4.385	5.856	8.436	10.001	10.687
2003	0.016	0.441	1.141	1.882	3.046	3.361	5.12	6.702	7.661	10.687
2004	0.022	0.288	1.454	2.447	3.449	4.086	4.312	6.32	10.535	10.687
2005	0.058	0.589	1.167	1.77	2.972	3.297	3.936	7.655	6.448	10.687
2006	0.031	0.307	1.151	1.574	2.621	3.182	4.615	4.684	5.729	10.687
2007	0.054	0.625	1.073	1.764	2.622	4.098	5.789	6.81	7.981	10.687
2008	0.046	0.577	1.45	2.041	2.504	3.465	4.165	7.931	10.05	10.687
2009[1]	0.041	0.75	1.499	2.64	2.798	3.712	4.977	5.594	9.015	10.687
Average	0.104	0.768	1.689	2.629	3.874	5.251	6.808	8.198	10.098	13.825
Minimum	0.010	0.288	1.073	1.574	2.504	3.182	3.936	4.684	5.729	10.687
Maximum	0.276	1.132	2.354	3.564	6.182	7.487	9.629	12.712	14.114	14.635

1: from 2009 DFO survey, weights for age 7 and 9 are from the average of 2007 and 2008.

Table 13. Statistical properties of estimates for population abundance (numbers in thousands) and survey calibration constants 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[2009 2]	918	533	0.581	122.44	0.133
N[2009 3]	1066	441	0.414	66.37	0.062
N[2009 4]	855	316	0.370	40.72	0.048
N[2009 5]	170	64	0.377	9.79	0.057
N[2009 6]	930	322	0.346	41.91	0.045
N[2009 7]	57	29	0.503	4.23	0.074
N[2009 8]	74	38	0.520	5.55	0.075
N[2009 9]	46	20.16	0.437	2.27	0.049
DFO 1986-1993 age 1	0.024	0.008	0.351	0.001	0.051
DFO 1986-1993 age 2	0.217	0.068	0.311	0.006	0.027
DFO 1986-1993 age 3	0.413	0.134	0.324	0.018	0.043
DFO 1986-1993 age 4	0.398	0.129	0.324	0.019	0.048
DFO 1986-1993 age 5	0.642	0.225	0.351	0.040	0.062
DFO 1986-1993 age 6	0.663	0.222	0.335	0.042	0.063
DFO 1986-1993 age 7	0.770	0.264	0.343	0.042	0.054
DFO 1986-1993 age 8	1.029	0.372	0.361	0.041	0.040
DFO 1994-2009 age 1	0.010	0.003	0.280	0.000	0.031
DFO 1994-2009 age 2	0.103	0.023	0.228	0.001	0.014
DFO 1994-2009 age 3	0.805	0.189	0.235	0.015	0.019
DFO 1994-2009 age 4	1.875	0.403	0.215	0.024	0.013
DFO 1994-2009 age 5	2.546	0.600	0.235	0.082	0.032
DFO 1994-2009 age 6	3.169	0.768	0.242	0.095	0.030
DFO 1994-2009 age 7	3.286	0.827	0.252	0.129	0.039
DFO 1994-2009 age 8	3.038	0.735	0.242	0.081	0.027
NMFS Spring Y41 1978-1981 age 1	0.017	0.008	0.480	0.001	0.077
NMFS Spring Y41 1978-1981 age 2	0.197	0.115	0.586	0.025	0.128
NMFS Spring Y41 1978-1981 age 3	0.218	0.106	0.485	0.031	0.142
NMFS Spring Y41 1978-1981 age 4	0.208	0.108	0.520	0.024	0.113
NMFS Spring Y41 1978-1981 age 5	0.304	0.158	0.518	0.034	0.112
NMFS Spring Y41 1978-1981 age 6	0.292	0.133	0.454	0.021	0.073
NMFS Spring Y41 1978-1981 age 7	0.377	0.206	0.547	0.050	0.132
NMFS Spring Y41 1978-1981 age 8	0.331	0.168	0.508	0.040	0.120
NMFS Spring Y36 1982-1993 age 1	0.028	0.008	0.301	0.001	0.031
NMFS Spring Y36 1982-1993 age 2	0.131	0.036	0.275	0.006	0.042
NMFS Spring Y36 1982-1993 age 3	0.259	0.073	0.282	0.009	0.035
NMFS Spring Y36 1982-1993 age 4	0.315	0.085	0.269	0.012	0.037
NMFS Spring Y36 1982-1993 age 5	0.385	0.106	0.275	0.021	0.055
NMFS Spring Y36 1982-1993 age 6	0.407	0.116	0.284	0.018	0.045
NMFS Spring Y36 1982-1993 age 7	0.348	0.090	0.257	0.009	0.027
NMFS Spring Y36 1982-1993 age 8	0.382	0.098	0.257	0.012	0.031
NMFS Spring Y36 1994-2008 age 1	0.031	0.010	0.331	0.001	0.035
NMFS Spring Y36 1994-2008 age 2	0.122	0.027	0.225	0.002	0.017
NMFS Spring Y36 1994-2008 age 3	0.459	0.107	0.234	0.006	0.013
NMFS Spring Y36 1994-2008 age 4	1.064	0.252	0.237	0.026	0.025
NMFS Spring Y36 1994-2008 age 5	1.395	0.324	0.232	0.009	0.006
NMFS Spring Y36 1994-2008 age 6	1.256	0.294	0.234	0.035	0.028
NMFS Spring Y36 1994-2008 age 7	1.407	0.339	0.241	0.039	0.028
NMFS Spring Y36 1994-2008 age 8	1.599	0.469	0.294	0.041	0.026
NMFS Fall 1978-1993 age 1	0.072	0.016	0.220	0.002	0.021
NMFS Fall 1978-1993 age 2	0.068	0.015	0.219	0.002	0.025
NMFS Fall 1978-1993 age 3	0.097	0.022	0.223	0.002	0.022
NMFS Fall 1978-1993 age 4	0.054	0.013	0.235	0.001	0.023
NMFS Fall 1978-1993 age 5	0.045	0.012	0.270	0.001	0.030
NMFS Fall 1994-2008 age 1	0.050	0.012	0.245	0.002	0.033
NMFS Fall 1994-2008 age 2	0.121	0.030	0.247	0.003	0.026
NMFS Fall 1994-2008 age 3	0.223	0.053	0.238	0.003	0.015
NMFS Fall 1994-2008 age 4	0.223	0.053	0.236	0.008	0.037
NMFS Fall 1994-2008 age 5	0.270	0.069	0.256	0.007	0.025

Table 14. Statistical properties of estimates for population abundance (numbers in thousands) and survey calibration constants 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[2009 2]	1117	559	0.501	106.87	0.096
N[2009 3]	1310	557	0.425	105.08	0.080
N[2009 4]	1094	386	0.353	48.68	0.045
N[2009 5]	242	88	0.365	13.24	0.055
N[2009 6]	1452	446	0.307	63.34	0.044
N[2009 7]	76	33	0.428	4.52	0.059
N[2009 8]	119	43	0.366	6.04	0.051
N[2009 9]	41	15	0.368	2.05	0.051
DFO 1986-1993 age 1	0.023	0.007	0.309	0.001	0.031
DFO 1986-1993 age 2	0.210	0.072	0.342	0.012	0.059
DFO 1986-1993 age 3	0.403	0.131	0.326	0.020	0.050
DFO 1986-1993 age 4	0.385	0.126	0.326	0.017	0.044
DFO 1986-1993 age 5	0.616	0.203	0.330	0.028	0.045
DFO 1986-1993 age 6	0.637	0.202	0.317	0.022	0.035
DFO 1986-1993 age 7	0.735	0.245	0.333	0.033	0.046
DFO 1986-1993 age 8	0.984	0.318	0.323	0.043	0.044
DFO 1994-2009 age 1	0.009	0.002	0.272	0.000	0.043
DFO 1994-2009 age 2	0.084	0.019	0.231	0.003	0.034
DFO 1994-2009 age 3	0.648	0.146	0.225	0.013	0.020
DFO 1994-2009 age 4	1.439	0.331	0.230	0.026	0.018
DFO 1994-2009 age 5	1.733	0.398	0.230	0.036	0.021
DFO 1994-2009 age 6	1.822	0.418	0.230	0.051	0.028
DFO 1994-2009 age 7	1.940	0.479	0.247	0.048	0.025
DFO 1994-2009 age 8	1.842	0.454	0.247	0.052	0.028
NMFS Spring Y41 1978-1981 age 1	0.017	0.009	0.512	0.002	0.101
NMFS Spring Y41 1978-1981 age 2	0.197	0.118	0.598	0.025	0.125
NMFS Spring Y41 1978-1981 age 3	0.218	0.104	0.476	0.017	0.078
NMFS Spring Y41 1978-1981 age 4	0.208	0.104	0.498	0.023	0.108
NMFS Spring Y41 1978-1981 age 5	0.304	0.151	0.496	0.028	0.094
NMFS Spring Y41 1978-1981 age 6	0.292	0.145	0.496	0.022	0.075
NMFS Spring Y41 1978-1981 age 7	0.377	0.190	0.506	0.037	0.099
NMFS Spring Y41 1978-1981 age 8	0.331	0.170	0.514	0.028	0.085
NMFS Spring Y36 1982-1993 age 1	0.027	0.008	0.298	0.001	0.030
NMFS Spring Y36 1982-1993 age 2	0.128	0.034	0.266	0.005	0.035
NMFS Spring Y36 1982-1993 age 3	0.254	0.068	0.266	0.007	0.028
NMFS Spring Y36 1982-1993 age 4	0.307	0.075	0.244	0.002	0.008
NMFS Spring Y36 1982-1993 age 5	0.371	0.102	0.275	0.014	0.037
NMFS Spring Y36 1982-1993 age 6	0.393	0.100	0.256	0.015	0.039
NMFS Spring Y36 1982-1993 age 7	0.336	0.086	0.255	0.013	0.038
NMFS Spring Y36 1982-1993 age 8	0.369	0.095	0.259	0.010	0.027
NMFS Spring Y36 1994-2008 age 1	0.025	0.008	0.319	0.001	0.042
NMFS Spring Y36 1994-2008 age 2	0.099	0.022	0.226	0.002	0.022
NMFS Spring Y36 1994-2008 age 3	0.367	0.088	0.240	0.010	0.026
NMFS Spring Y36 1994-2008 age 4	0.805	0.189	0.234	0.015	0.018
NMFS Spring Y36 1994-2008 age 5	0.925	0.212	0.229	0.031	0.034
NMFS Spring Y36 1994-2008 age 6	0.720	0.173	0.240	0.007	0.010
NMFS Spring Y36 1994-2008 age 7	0.830	0.204	0.246	0.022	0.026
NMFS Spring Y36 1994-2008 age 8	0.947	0.277	0.293	0.022	0.023
NMFS Fall 1978-1993 age 1	0.070	0.016	0.222	0.001	0.015
NMFS Fall 1978-1993 age 2	0.067	0.014	0.215	0.001	0.019
NMFS Fall 1978-1993 age 3	0.095	0.020	0.214	0.001	0.006
NMFS Fall 1978-1993 age 4	0.053	0.013	0.247	0.001	0.019
NMFS Fall 1978-1993 age 5	0.044	0.012	0.271	0.001	0.031
NMFS Fall 1994-2008 age 1	0.041	0.011	0.257	0.002	0.038
NMFS Fall 1994-2008 age 2	0.098	0.022	0.229	0.002	0.018
NMFS Fall 1994-2008 age 3	0.175	0.041	0.232	0.003	0.015
NMFS Fall 1994-2008 age 4	0.161	0.037	0.232	0.000	0.000
NMFS Fall 1994-2008 age 5	0.164	0.039	0.239	0.005	0.031

Table 15. 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	12298	3350	10861	4024	1324	709	621	105	111	200	33604
1979	10100	10061	2645	5626	2247	730	434	394	66	225	32529
1980	9941	8256	7436	1506	3242	1352	434	289	268	223	32947
1981	17434	8133	5882	4603	962	1784	788	268	213	342	40411
1982	5680	14243	5949	3329	2637	533	985	466	128	377	34328
1983	5064	4637	8502	3104	1589	1187	262	449	243	325	25360
1984	14176	4126	3091	4707	1381	797	615	109	205	310	29517
1985	5109	11591	3170	1807	2638	642	317	254	54	280	25862
1986	23617	4174	6921	1337	888	1277	284	160	110	222	38990
1987	7602	19299	3011	3635	569	420	637	171	89	234	35667
1988	13335	6204	12099	1707	1946	319	225	365	104	233	36537
1989	4502	10898	4819	6150	788	828	145	80	137	195	28542
1990	6283	3655	8307	3215	3260	441	345	68	30	195	25799
1991	8768	5126	2332	4010	1701	1441	231	146	45	146	23947
1992	2334	7121	3277	1006	1567	588	515	95	58	113	16675
1993	3029	1853	3541	1452	414	491	202	141	38	100	11259
1994	1965	2471	1069	1209	382	75	85	47	30	73	7406
1995	1279	1604	1857	444	291	74	22	16	12	63	5663
1996	2315	1046	1262	1307	279	145	44	12	9	58	6477
1997	3654	1889	820	822	714	158	64	24	6	53	8205
1998	1431	2986	1416	486	353	265	55	20	8	43	7064
1999	3578	1169	2354	876	254	148	97	25	4	37	8542
2000	1478	2923	887	1491	416	110	67	29	8	31	7439
2001	1182	1202	2326	625	880	205	57	35	13	28	6555
2002	1791	919	860	1456	318	363	75	18	13	27	5839
2003	555	1465	741	592	799	165	160	35	7	25	4543
2004	4386	454	1166	464	270	294	63	52	12	21	7181
2005	645	3572	360	823	245	90	117	20	15	19	5906
2006	1778	526	2847	245	502	152	43	62	7	22	6186
2007	1516	1453	412	2112	133	240	83	20	35	20	6024
2008	988	1240	1122	264	1368	82	121	58	10	39	5291
2009	2500	808	978	802	160	885	52	67	43	37	6332

Table 16. 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	0.458	0.383	0.395	0.291	0.255	0.263	0.256	0.055	0.360
1979	0.002	0.102	0.363	0.351	0.308	0.320	0.207	0.185	0.196	0.031	0.324
1980	0.001	0.139	0.280	0.248	0.397	0.339	0.282	0.105	0.211	0.108	0.328
1981	0.002	0.113	0.369	0.357	0.390	0.394	0.325	0.539	0.379	0.083	0.372
1982	0.003	0.316	0.451	0.539	0.599	0.513	0.585	0.453	0.543	0.157	0.558
1983	0.005	0.206	0.391	0.610	0.490	0.458	0.677	0.584	0.618	0.268	0.557
1984	0.001	0.064	0.337	0.379	0.566	0.724	0.683	0.493	0.655	0.278	0.480
1985	0.002	0.316	0.663	0.511	0.526	0.616	0.479	0.641	0.551	0.154	0.534
1986	0.002	0.127	0.444	0.654	0.549	0.495	0.305	0.395	0.338	0.064	0.538
1987	0.003	0.267	0.368	0.425	0.378	0.423	0.356	0.301	0.345	0.058	0.407
1988	0.002	0.053	0.477	0.573	0.654	0.589	0.829	0.783	0.801	0.196	0.642
1989	0.009	0.071	0.205	0.435	0.381	0.676	0.551	0.776	0.631	0.166	0.463
1990	0.003	0.249	0.528	0.436	0.617	0.448	0.660	0.220	0.587	0.185	0.526
1991	0.008	0.247	0.640	0.740	0.862	0.829	0.686	0.727	0.702	0.229	0.782
1992	0.031	0.499	0.614	0.688	0.960	0.871	1.093	0.729	1.036	0.116	0.888
1993	0.004	0.350	0.875	1.135	1.506	1.550	1.249	1.355	1.293	0.240	1.287
1994	0.003	0.086	0.679	1.222	1.437	1.030	1.482	1.142	1.361	0.041	1.272
1995	0.001	0.040	0.151	0.264	0.501	0.317	0.431	0.324	0.386	0.005	0.356
1996	0.003	0.043	0.228	0.405	0.372	0.609	0.403	0.414	0.406	0.008	0.416
1997	0.002	0.088	0.322	0.645	0.792	0.859	0.994	0.898	0.968	0.036	0.740
1998	0.003	0.038	0.280	0.451	0.669	0.803	0.599	1.332	0.792	0.052	0.618
1999	0.002	0.075	0.257	0.546	0.634	0.591	1.003	0.976	0.997	0.024	0.607
2000	0.006	0.028	0.150	0.327	0.506	0.462	0.455	0.618	0.504	0.022	0.378
2001	0.052	0.135	0.269	0.477	0.686	0.809	0.936	0.775	0.875	0.042	0.639
2002	0.001	0.014	0.174	0.400	0.458	0.621	0.567	0.731	0.599	0.141	0.453
2003	0.000	0.029	0.268	0.584	0.800	0.761	0.931	0.894	0.925	0.079	0.738
2004	0.005	0.031	0.148	0.440	0.897	0.724	0.937	1.009	0.969	0.120	0.677
2005	0.003	0.027	0.187	0.294	0.275	0.533	0.425	0.834	0.486	0.090	0.329
2006	0.002	0.046	0.099	0.412	0.538	0.411	0.595	0.365	0.460	0.106	0.480
2007	0.001	0.058	0.244	0.235	0.282	0.483	0.157	0.522	0.227	0.032	0.259
2008	0.001	0.037	0.136	0.299	0.236	0.250	0.386	0.088	0.290	0.027	0.250

Table 17. Beginning of year population biomass (thousands of 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	1373	2969	17635	14343	7166	4429	5360	942	1137	2927	58281	53939
1979	1135	8729	4602	16851	10257	3788	4179	4289	725	3299	57854	47990
1980	2747	5830	14071	4195	16999	8491	2570	2592	3154	3269	63918	55341
1981	1649	6933	10742	15384	4782	12244	6453	3407	2399	5004	68998	60415
1982	523	12378	13203	10155	10851	3428	7941	4117	1379	5518	69492	56592
1983	1134	5243	15911	7023	4979	7133	2132	3888	2554	4753	54751	48373
1984	714	2399	6040	11500	3727	3285	3620	976	2108	4543	38913	35799
1985	445	7492	6104	5791	9977	3743	2776	2507	768	4094	43697	35760
1986	3099	3215	12055	4302	4368	7275	2110	1442	1171	3248	42284	35970
1987	1140	16308	5124	9761	3228	3143	4766	1139	894	3432	48936	31487
1988	2030	5773	21600	5154	8113	2002	1900	3187	1279	3403	54440	46637
1989	640	9066	8216	16966	3394	5329	1105	629	1547	2848	49740	40034
1990	1349	2878	15309	9319	14223	2647	2965	652	409	2847	52597	48371
1991	770	4597	4551	12701	7219	7052	1740	1469	449	2139	42686	37320
1992	296	6025	6704	2811	6522	3604	3592	813	573	1660	32599	26278
1993	213	1769	6531	4220	1868	2893	1411	1043	348	1456	21752	19771
1994	281	1622	1532	3177	1511	561	626	410	265	1061	11047	9143
1995	234	1274	2947	997	1012	349	147	126	147	925	8158	6651
1996	203	876	1959	3395	1091	884	242	141	112	855	9757	8678
1997	694	1354	1389	1790	2297	977	400	238	64	769	9971	7923
1998	112	1941	1957	1098	1072	1196	318	152	66	636	8548	6496
1999	396	1170	3178	1959	754	686	633	203	36	538	9554	7988
2000	89	2618	1408	3468	1344	492	436	240	87	449	10631	7924
2001	12	927	3298	1616	3170	1044	393	263	132	303	11158	10219
2002	28	455	1044	3303	1124	1591	438	154	132	285	8553	8070
2003	9	646	846	1114	2433	553	818	233	55	266	6973	6318
2004	95	131	1694	1136	932	1201	272	326	123	226	6134	5908
2005	37	2103	421	1457	727	297	459	155	99	203	5958	3818
2006	55	162	3278	385	1316	484	200	292	41	234	6447	6231
2007	82	909	442	3726	348	983	478	133	283	212	7596	6606
2008	45	715	1628	539	3426	284	505	458	96	416	8111	7351
2009	103	606	1466	2117	448	3284	260	377	391	394	9445	8737

Table 18. 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	12300	3350	10862	4025	1324	709	621	105	111	200	33607
1979	10102	10063	2645	5626	2247	730	434	394	66	225	32533
1980	9944	8257	7437	1506	3242	1352	434	289	268	223	32953
1981	17443	8136	5884	4604	962	1785	789	268	213	342	40425
1982	5682	14250	5951	3330	2638	533	985	467	128	377	34342
1983	5072	4639	8508	3105	1590	1187	262	449	243	325	25380
1984	14192	4133	3093	4712	1382	798	615	109	205	311	29549
1985	5140	11604	3175	1808	2642	643	317	254	54	280	25920
1986	23704	4200	6931	1342	889	1280	284	161	110	222	39125
1987	7727	19370	3033	3643	573	421	640	172	89	235	35902
1988	13489	6306	12158	1724	1953	322	226	367	104	233	36883
1989	4639	11023	4902	6197	802	834	148	81	138	196	28962
1990	6514	3767	8410	3283	3299	453	350	70	31	197	26374
1991	8998	5315	2424	4094	1757	1472	240	150	47	148	24645
1992	2614	7308	3432	1081	1635	633	540	103	61	117	17524
1993	3447	2082	3694	1577	475	546	238	162	44	105	12369
1994	2332	2813	1257	1332	483	124	129	77	46	82	8674
1995	1506	1904	2137	596	391	155	41	33	24	60	6848
1996	2691	1232	1507	1537	404	226	80	20	17	48	7761
1997	4349	2197	972	1023	902	259	91	38	9	37	9878
1998	1717	3555	1668	611	517	417	94	27	13	24	8644
1999	4340	1403	2820	1082	355	281	152	40	7	18	10499
2000	1718	3547	1079	1872	584	193	125	49	14	12	9193
2001	1505	1399	2837	782	1192	342	89	59	21	13	8239
2002	2461	1183	1021	1874	446	617	129	30	22	15	7797
2003	709	2014	958	724	1140	269	257	56	12	16	6155
2004	5760	581	1615	641	378	572	102	89	19	12	9769
2005	798	4696	464	1191	389	177	241	36	31	13	8036
2006	2189	652	3768	330	803	271	82	118	14	21	8247
2007	1853	1790	514	2866	202	486	128	36	58	18	7952
2008	1203	1516	1398	348	1985	139	230	70	16	41	6945
2009	2500	984	1204	1027	229	1389	71	113	39	32	7589

Table 19. 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	0.458	0.383	0.395	0.291	0.255	0.263	0.256	0.055	0.360
1979	0.002	0.102	0.363	0.351	0.308	0.320	0.207	0.185	0.196	0.031	0.324
1980	0.001	0.139	0.279	0.248	0.397	0.339	0.282	0.105	0.211	0.108	0.328
1981	0.002	0.113	0.369	0.357	0.390	0.394	0.325	0.539	0.379	0.083	0.372
1982	0.003	0.316	0.450	0.539	0.598	0.512	0.585	0.453	0.543	0.157	0.557
1983	0.005	0.205	0.391	0.610	0.490	0.458	0.676	0.584	0.618	0.268	0.556
1984	0.001	0.063	0.337	0.378	0.566	0.723	0.683	0.493	0.654	0.278	0.479
1985	0.002	0.315	0.662	0.510	0.525	0.615	0.478	0.640	0.550	0.154	0.533
1986	0.002	0.126	0.443	0.651	0.548	0.493	0.304	0.393	0.337	0.064	0.536
1987	0.003	0.266	0.365	0.423	0.375	0.422	0.355	0.300	0.343	0.058	0.405
1988	0.002	0.052	0.474	0.565	0.651	0.582	0.825	0.777	0.795	0.195	0.636
1989	0.008	0.071	0.201	0.430	0.373	0.669	0.540	0.767	0.620	0.165	0.458
1990	0.003	0.241	0.520	0.425	0.607	0.434	0.648	0.213	0.575	0.183	0.515
1991	0.008	0.237	0.607	0.718	0.821	0.803	0.649	0.700	0.668	0.225	0.755
1992	0.028	0.482	0.577	0.623	0.896	0.778	1.006	0.653	0.949	0.112	0.814
1993	0.003	0.305	0.820	0.983	1.146	1.244	0.933	1.052	0.981	0.227	1.055
1994	0.003	0.075	0.545	1.027	0.935	0.593	0.873	0.654	0.791	0.042	0.955
1995	0.001	0.034	0.130	0.190	0.349	0.162	0.240	0.168	0.208	0.006	0.238
1996	0.003	0.037	0.187	0.333	0.242	0.407	0.237	0.262	0.242	0.012	0.320
1997	0.002	0.076	0.264	0.483	0.570	0.512	0.707	0.559	0.663	0.059	0.531
1998	0.002	0.032	0.233	0.342	0.408	0.511	0.355	0.911	0.480	0.112	0.415
1999	0.002	0.062	0.210	0.417	0.410	0.314	0.621	0.573	0.611	0.057	0.421
2000	0.005	0.023	0.122	0.251	0.333	0.278	0.256	0.373	0.289	0.062	0.273
2001	0.041	0.115	0.215	0.362	0.459	0.478	0.588	0.459	0.536	0.106	0.436
2002	0.000	0.011	0.144	0.297	0.305	0.374	0.340	0.450	0.361	0.320	0.317
2003	0.000	0.021	0.201	0.450	0.491	0.466	0.562	0.549	0.559	0.147	0.485
2004	0.004	0.024	0.105	0.299	0.555	0.362	0.557	0.547	0.552	0.251	0.402
2005	0.002	0.020	0.142	0.194	0.164	0.276	0.214	0.459	0.245	0.159	0.203
2006	0.002	0.037	0.074	0.289	0.303	0.245	0.319	0.206	0.252	0.126	0.284
2007	0.001	0.047	0.191	0.168	0.176	0.245	0.114	0.293	0.153	0.041	0.177
2008	0.001	0.030	0.108	0.219	0.156	0.162	0.215	0.084	0.185	0.030	0.168

Table 20. Beginning of year population biomass (thousands of 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	1374	2969	17636	14344	7166	4429	5360	942	1138	2927	58285	53942
1979	1135	8730	4602	16852	10258	3789	4179	4290	725	3299	57859	47994
1980	2748	5831	14073	4196	17001	8492	2570	2593	3154	3269	63927	55348
1981	1650	6935	10744	15387	4783	12246	6454	3408	2400	5005	69012	60426
1982	523	12384	13207	10158	10853	3429	7943	4119	1380	5519	69514	56607
1983	1136	5246	15922	7026	4981	7136	2133	3889	2555	4754	54780	48398
1984	715	2403	6043	11512	3730	3288	3622	977	2109	4545	38946	35827
1985	448	7501	6115	5796	9992	3748	2781	2510	769	4098	43757	35808
1986	3110	3235	12073	4316	4374	7293	2115	1446	1174	3252	42389	36044
1987	1159	16369	5160	9784	3249	3150	4786	1144	898	3438	49136	31608
1988	2053	5868	21704	5206	8143	2020	1906	3206	1285	3413	54804	46883
1989	660	9170	8358	17097	3455	5366	1123	634	1567	2863	50293	40463
1990	1398	2966	15499	9518	14392	2716	3005	670	416	2879	53460	49096
1991	790	4766	4730	12967	7456	7207	1811	1508	464	2171	43871	38315
1992	332	6184	7020	3020	6805	3880	3770	879	604	1705	34199	27684
1993	242	1987	6813	4586	2142	3217	1667	1195	406	1530	23786	21557
1994	334	1847	1801	3503	1910	921	945	664	410	1195	13531	11350
1995	275	1512	3392	1339	1357	729	277	259	288	881	10309	8522
1996	236	1032	2340	3991	1578	1379	437	238	200	705	12136	10868
1997	826	1575	1647	2227	2901	1608	565	376	94	540	12357	9956
1998	134	2311	2305	1380	1568	1884	550	212	109	351	10804	8359
1999	481	1404	3807	2421	1057	1304	989	331	56	263	12112	10227
2000	104	3177	1712	4354	1888	862	811	406	158	183	13654	10373
2001	15	1079	4022	2021	4292	1743	613	442	212	143	14582	13488
2002	39	585	1239	4251	1578	2703	754	252	225	156	11782	11158
2003	11	888	1093	1362	3474	905	1318	372	89	170	9681	8782
2004	124	167	2348	1569	1303	2335	442	563	205	132	9188	8896
2005	46	2765	542	2108	1157	585	950	272	202	135	8761	5950
2006	67	200	4338	519	2104	861	377	554	78	228	9326	9058
2007	100	1119	552	5055	530	1990	743	245	466	191	10991	9772
2008	55	874	2027	710	4970	481	960	551	164	436	11228	10299
2009	103	738	1805	2712	640	5157	356	631	349	344	12835	11994

Table 21. 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)										
2009-2010	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)										
2009-2010	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)										
2009-2010	0.01	0.1	0.5	0.9	1	1	1	1	1	0.2
Fishery Partial Recruitment("split M 0.5" model)										
2009-2010	0.01	0.1	0.6	1	1	1	1	1	1	0.5
Fishery Weight at Age										
2009-2010	0.28	0.90	1.61	2.40	3.31	4.24	5.76	6.47	7.24	8.48
Population Beginning of Year Weight at Age										
2010-2011	0.05	0.65	1.34	2.15	2.64	3.76	4.98	6.78	9.02	10.69

Table 22. Deterministic projection results for eastern Georges Bank cod from benchmark model formulations.

a. "split M 0.2" model

	Age Group											
	1	2	3	4	5	6	7	8	9	10+	1+	4+
Projected Population Numbers												
2009	2500	796	999	815	161	888	53	68	44	37		
2010	2500	2042	635	723	534	103	569	34	44	57		
2011	2500	2043	1642	476	504	365	70	389	23	75		
Fishing Mortality												
2009	0.002	0.025	0.123	0.221	0.246	0.246	0.246	0.246	0.246	0.049		
2010	0.002	0.018	0.09	0.162	0.18	0.18	0.18	0.18	0.18	0.036		
Projected Population Biomass												
2009	100	597	1499	2150	449	3296	263	382	396	399	9531	9431
2010	125	1327	852	1555	1411	386	2832	229	395	611	9724	7336
2011	125	1328	2200	1022	1330	1374	350	2637	209	802	11378	7420
Projected Catch Numbers												
2009	6	18	105	147	32	176	10	14	9	2		
2010	4	33	50	98	80	15	85	5	7	2		
Projected Catch Biomass												
2009	2	17	190	371	107	778	63	92	63	17	1700	
2010	1	32	90	248	268	68	515	34	47	20	1323	

b. "split M 0.5" model

	Age Group											
	1	2	3	4	5	6	7	8	9	10+	1+	4+
Projected Population Numbers												
2009	2500	1010	1205	1045	229	1389	72	112	38	32		
2010	2500	2043	813	888	718	157	707	37	57	37		
2011	2500	2043	1643	597	608	491	80	358	19	50		
Fishing Mortality												
2009	0.002	0.018	0.105	0.175	0.175	0.175	0.175	0.175	0.175	0.088		
2010	0.002	0.018	0.108	0.18	0.18	0.18	0.18	0.18	0.18	0.09		
Projected Population Biomass												
2009	100	758	1808	2759	640	5152	358	629	347	343	12893	10228
2010	125	1328	1089	1910	1896	590	3521	248	517	400	11625	9083
2011	125	1328	2202	1284	1604	1847	396	2429	167	532	11914	8260
Projected Catch Numbers												
2009	4	16	109	153	33	177	9	14	5	2		
2010	4	33	76	133	108	20	92	5	7	3		
Projected Catch Biomass												
2009	1	16	197	384	112	779	55	97	35	23	1700	
2010	1	32	136	335	360	90	558	33	54	27	1628	

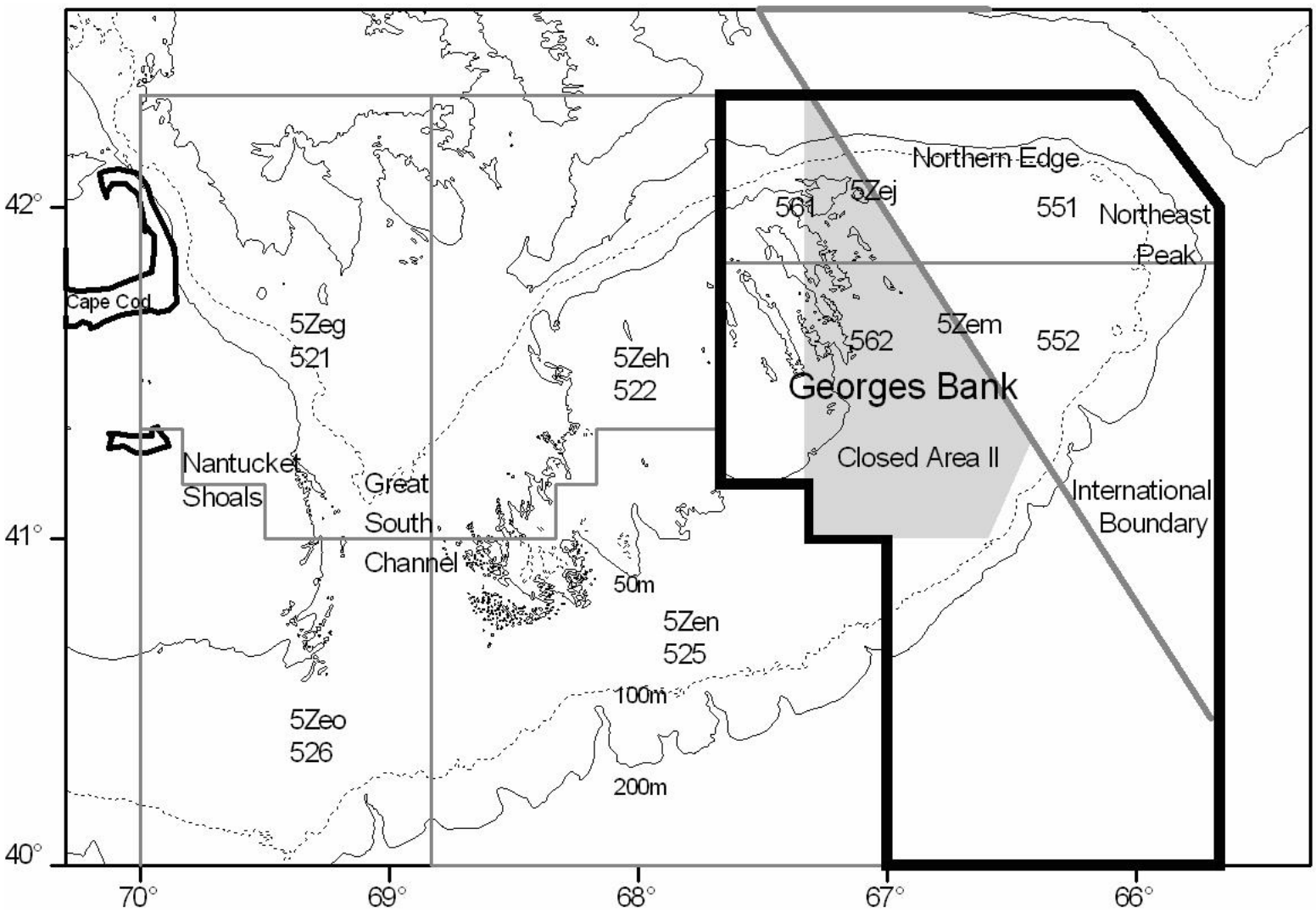


Figure 1. Fisheries statistical unit areas in NAFO Subdivision 5Ze. The eastern Georges Bank management unit is outlined by a heavy black line.

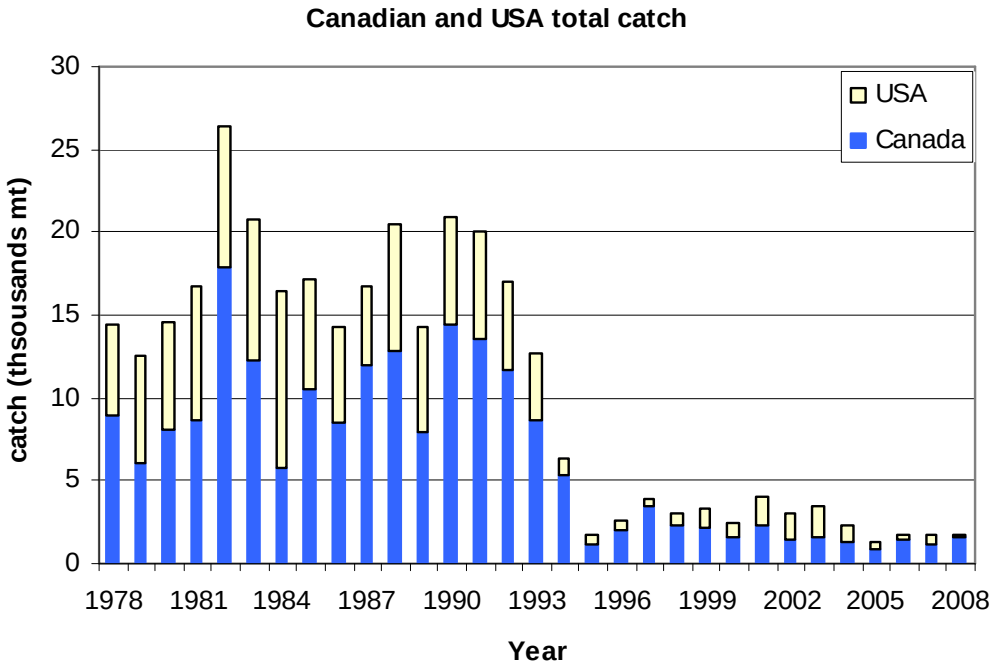


Figure 2. Catches (mt) of cod from eastern Georges Bank during 1978-2008.

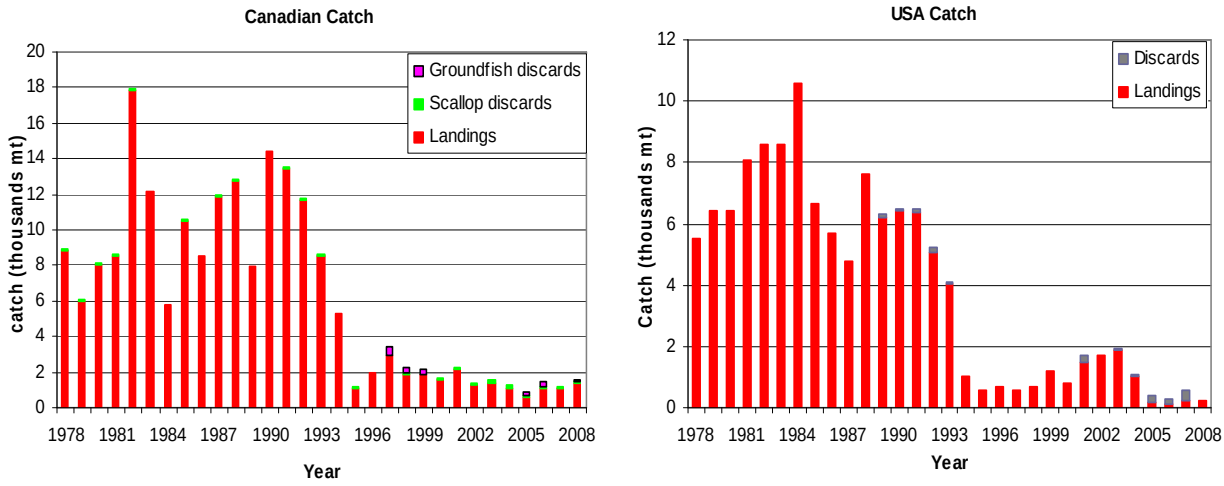


Figure 3. Canadian and USA landings and discards of cod from eastern Georges Bank during 1978-2008.

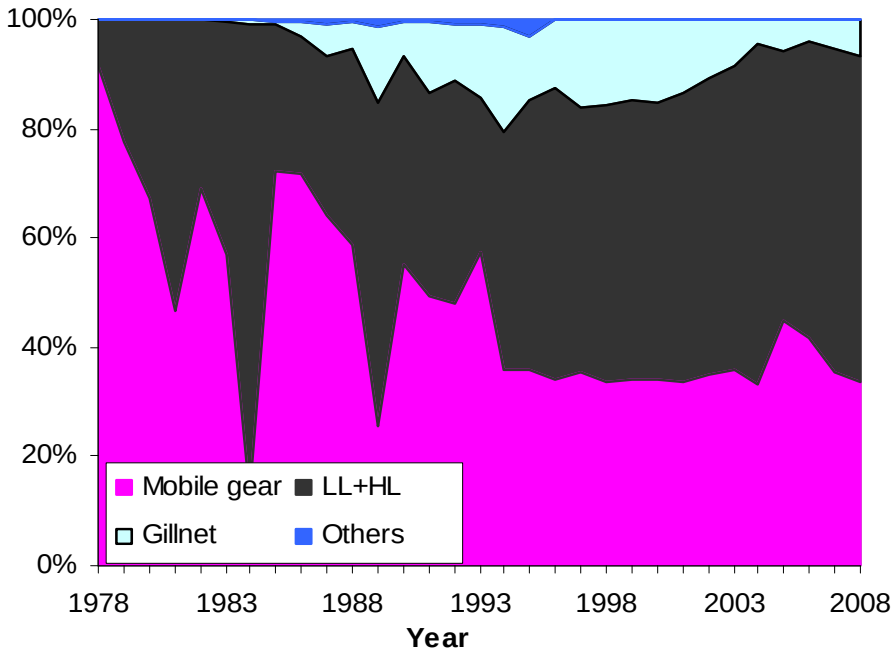


Figure 4. Proportion of Canadian gear specific landings of cod from eastern Georges Bank during 1978-2008.

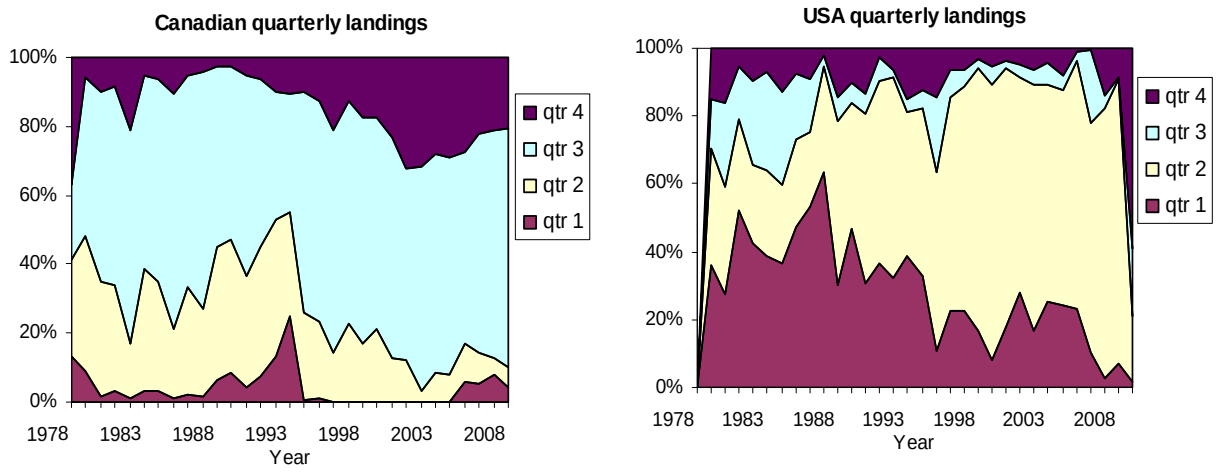


Figure 5. Proportion of Canadian and USA quarterly landings of cod from eastern Georges Bank during 1978-2008.

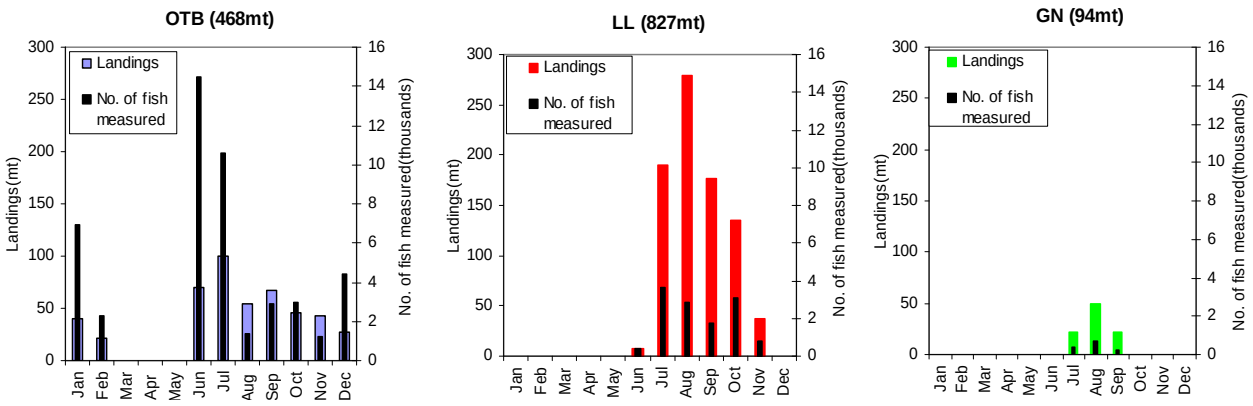


Figure 6. Landings (wide bars) and sampling (narrow dark bars) of cod by gear and month from the 2008 Canadian groundfish fishery on eastern Georges Bank.

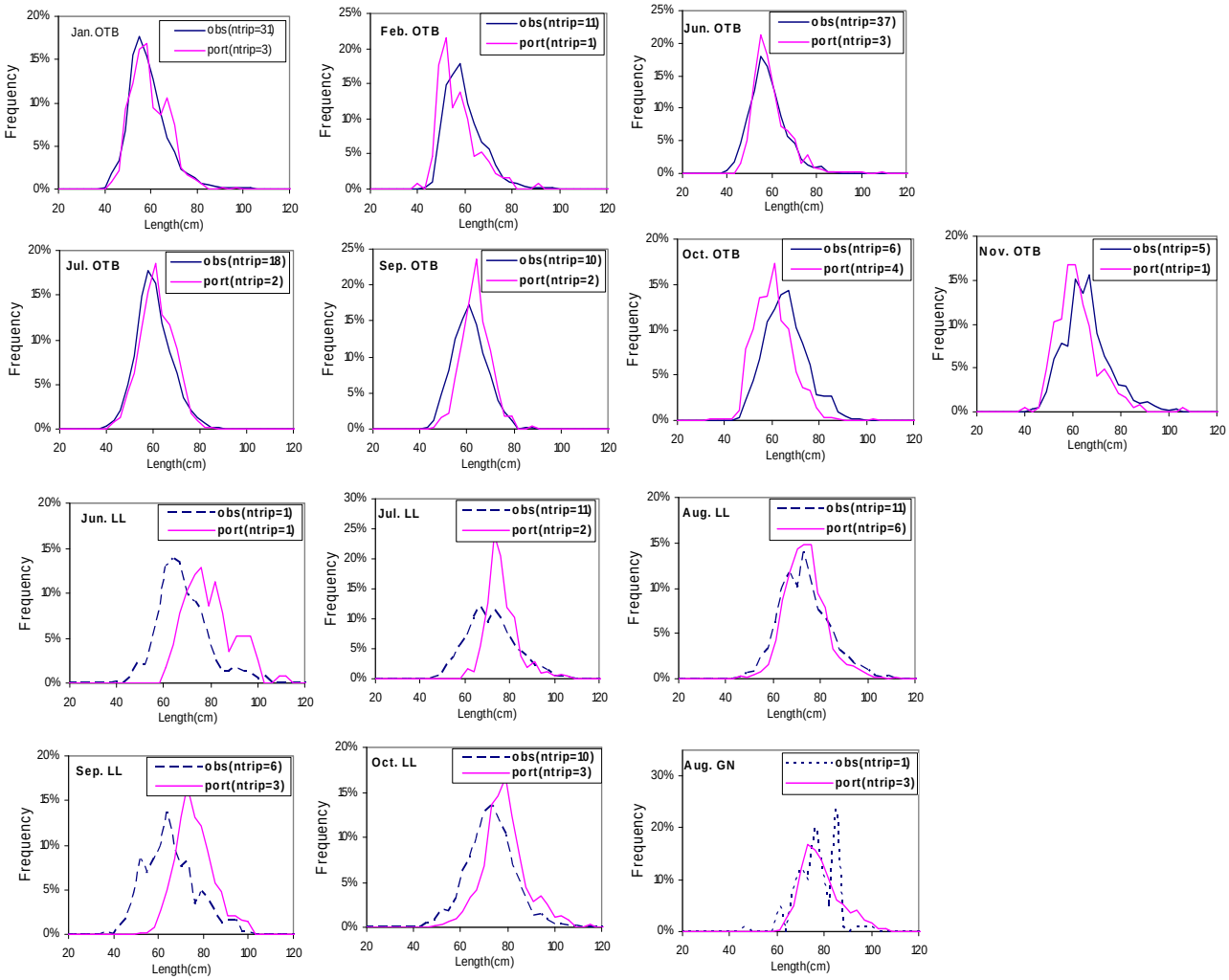


Figure 7. Comparison of cod length composition from port and sea sampling for the 2008 Canadian fishery on eastern Georges Bank.

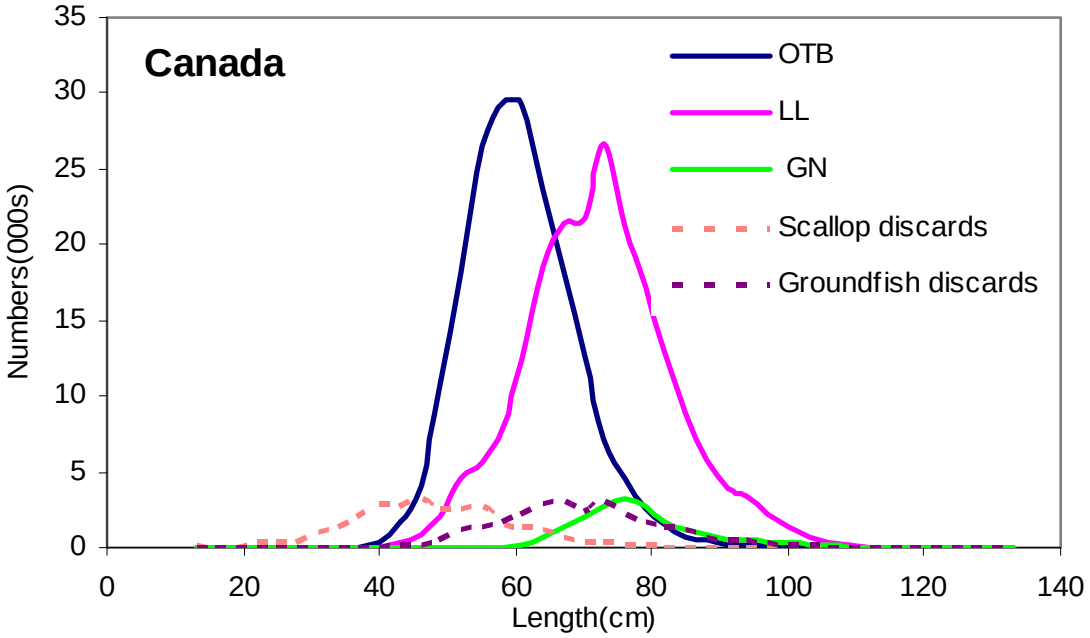


Figure 8. Cod catches at length by gear from the 2008 Canadian fisheries on eastern Georges Bank.

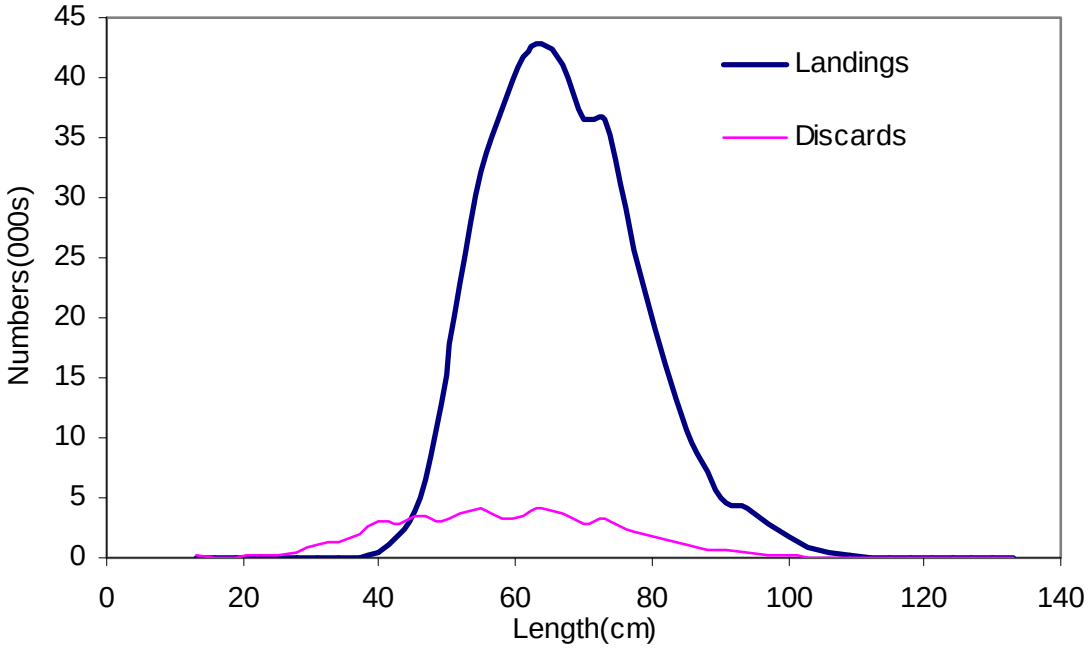


Figure 9. Cod landings and discards at length from the 2008 Canadian fisheries on eastern Georges Bank.

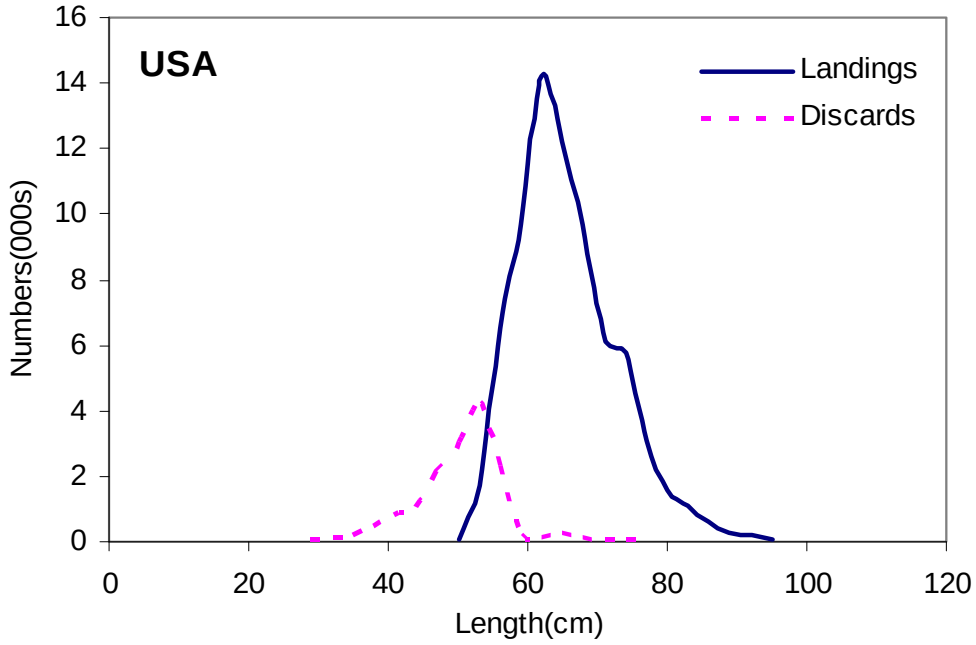


Figure 10. Cod landings and discards at length from the 2008 USA fisheries on eastern Georges Bank.

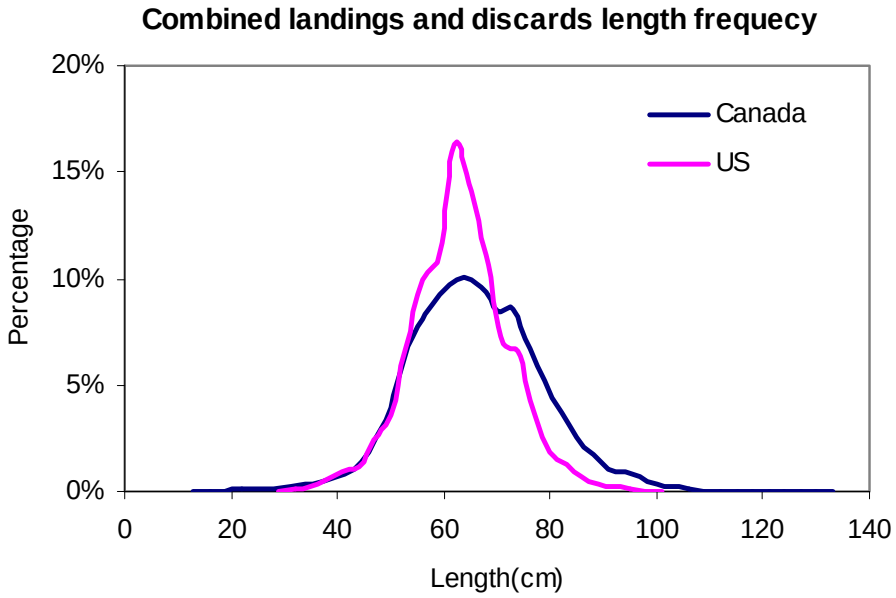


Figure 11. Catch composition from the 2007 Canadian and USA fisheries on eastern Georges Bank.

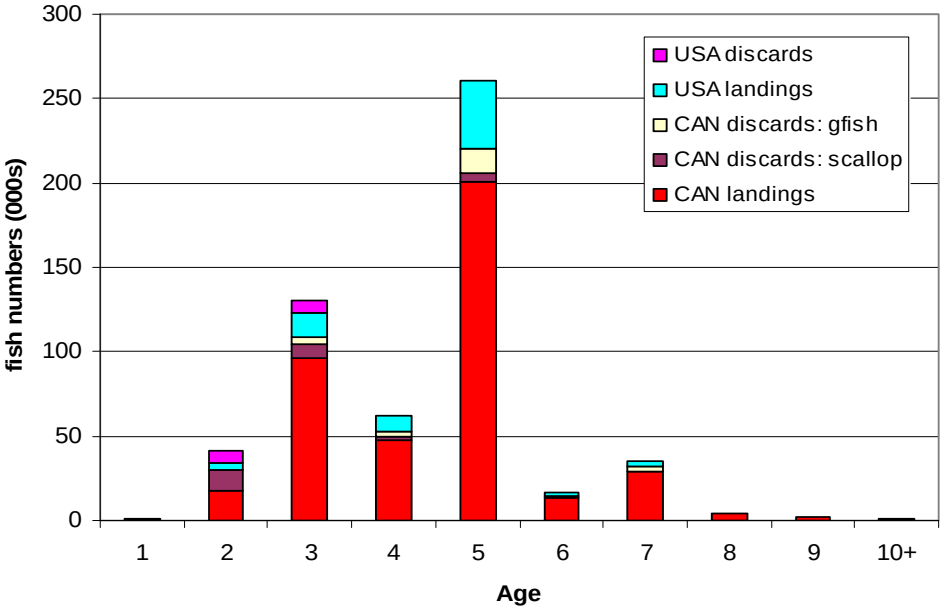


Figure 12. Catch at age for landings and discards of cod from the 2008 fisheries on eastern Georges Bank.

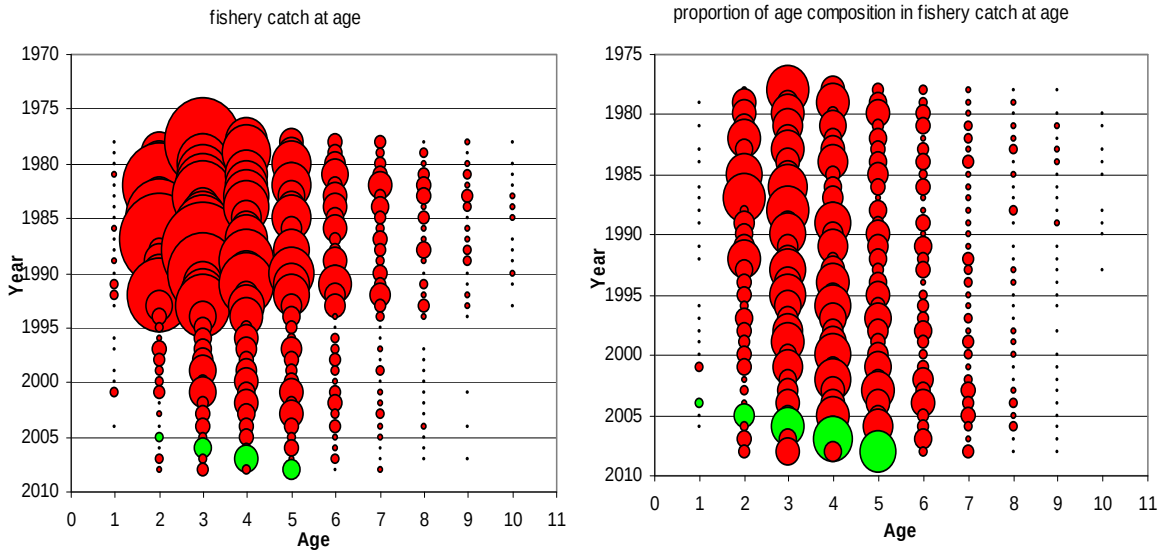


Figure 13. Total catch at age (numbers) of cod(left) and proportion catch at age from eastern Georges Bank for 1978 to 2008. The bubble area is proportional to magnitude. The lighter circles are the 2003 year-class.

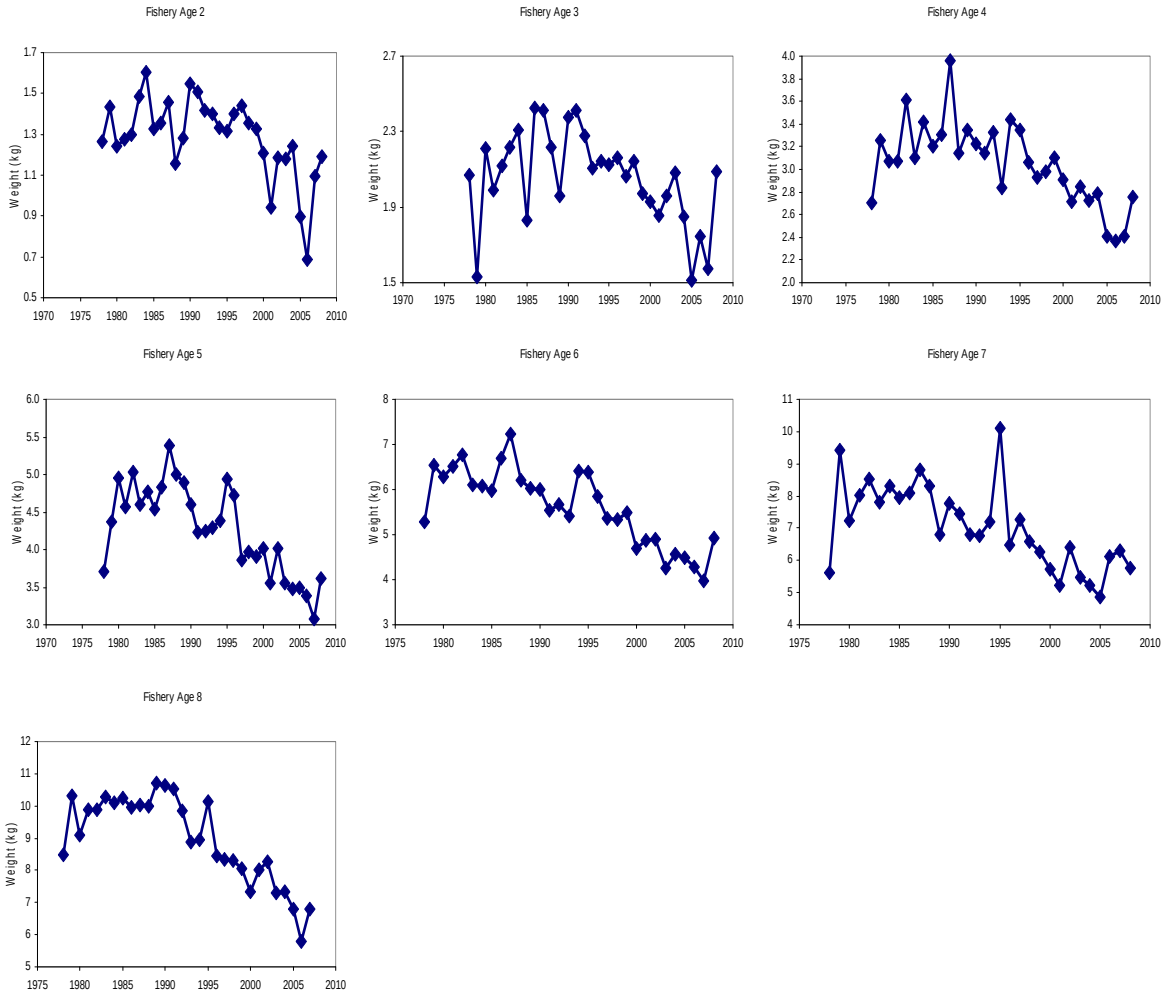


Figure 14. Average weights at ages 2 to 8 of cod from eastern Georges Bank fishery (1978 to 2008).

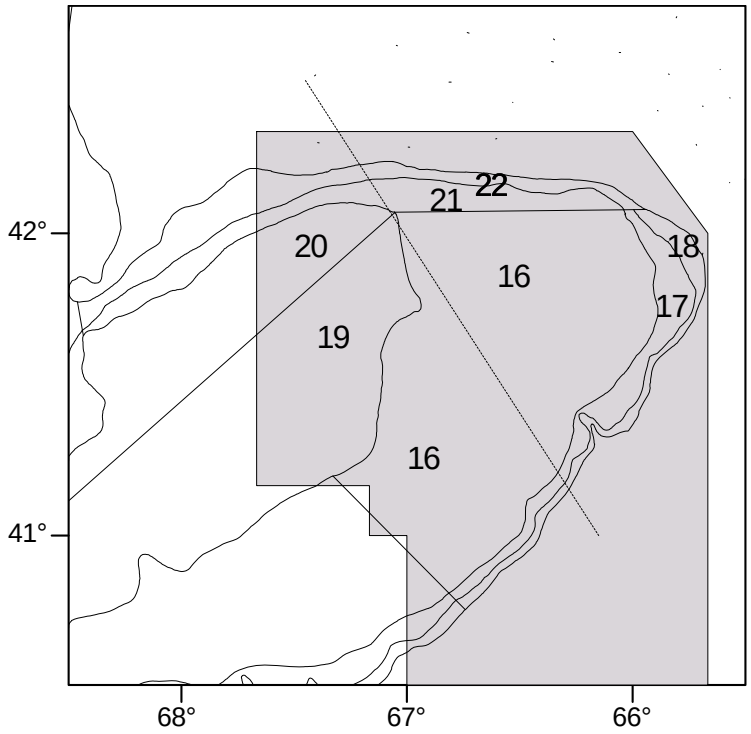


Figure 15. Stratification used for NMFS surveys. The eastern Georges Bank management unit is indicated by shading.

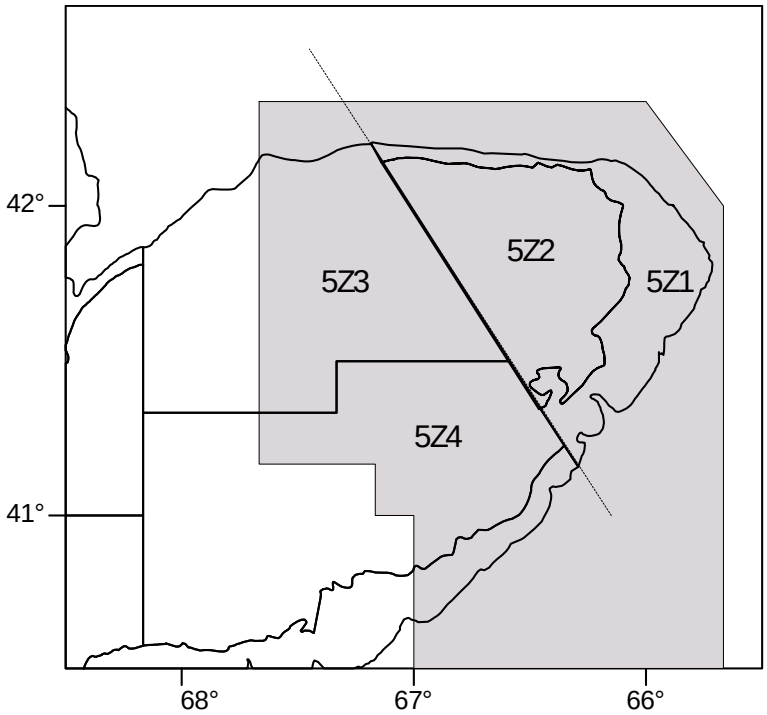


Figure 16. Stratification used for the DFO survey. The eastern Georges Bank management unit is indicated by shading.

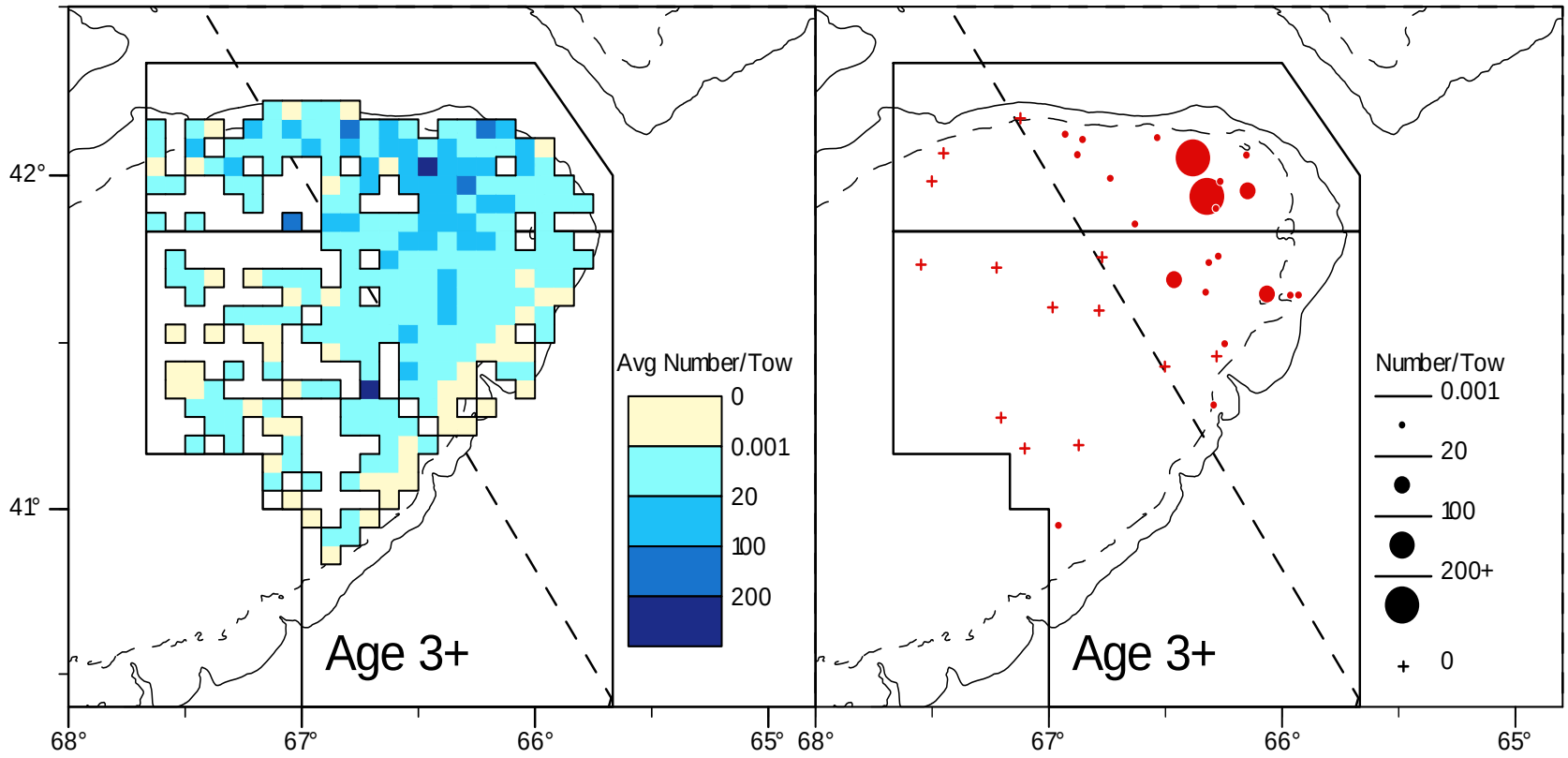


Figure 17. Spatial distribution of cod on eastern Georges Bank from the DFO survey for 2009 (right panel) compared to the average for 1999-2008 (left panel).

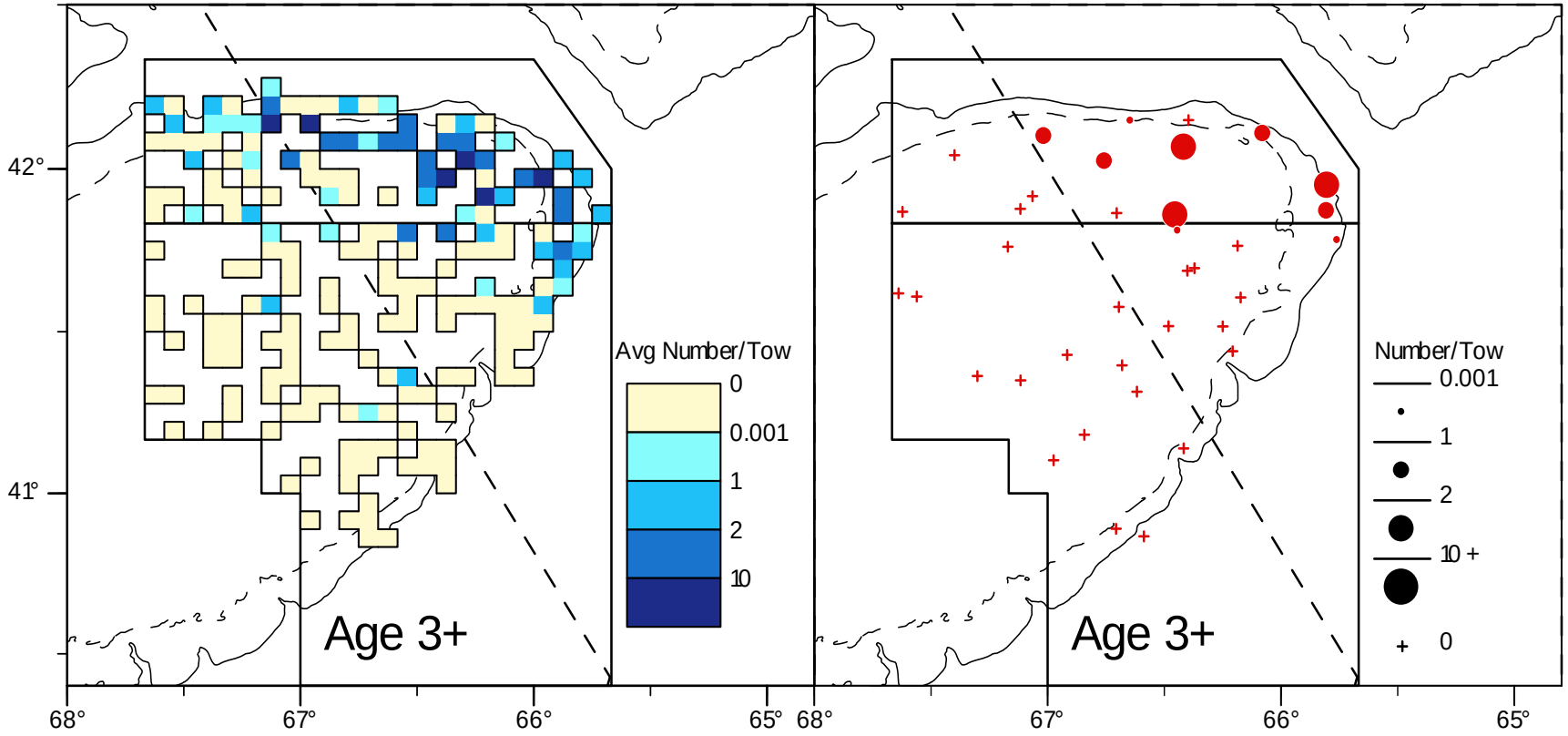


Figure 18. Spatial distribution of cod on eastern Georges Bank from the NMFS autumn survey for 2008 (right panel) compared to the average for 1998-2007 (left panel).

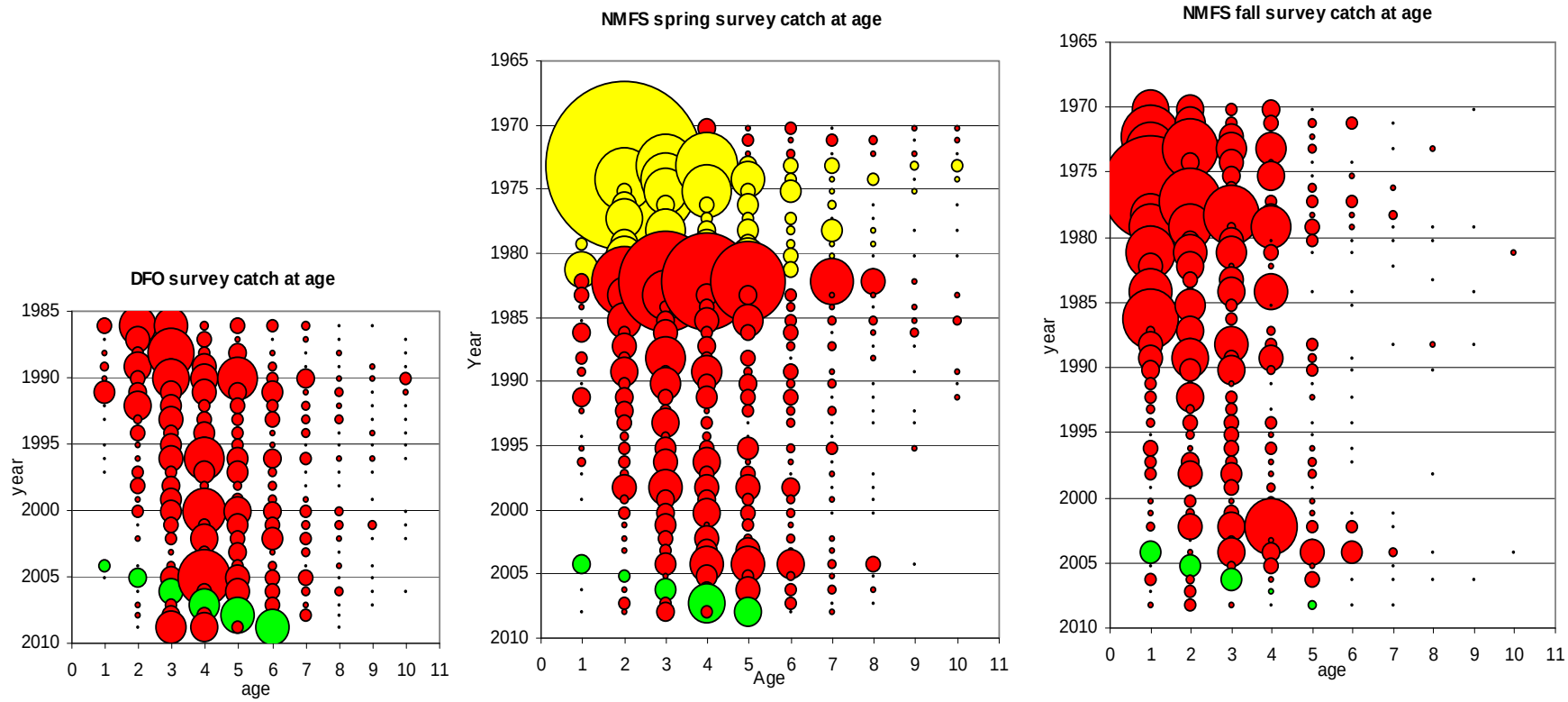


Figure 19. Survey abundance at age (numbers) of eastern Georges Bank cod. The bubble area is proportional to magnitude within each survey. Conversion factors to account for changes in door type and survey vessel were applied to the NMFS surveys. The NMFS spring survey was conducted using a modified Yankee 41 during 1978 to 1981 (lighter bubbles). The 2003 year-class is identified with lighter bubbles.

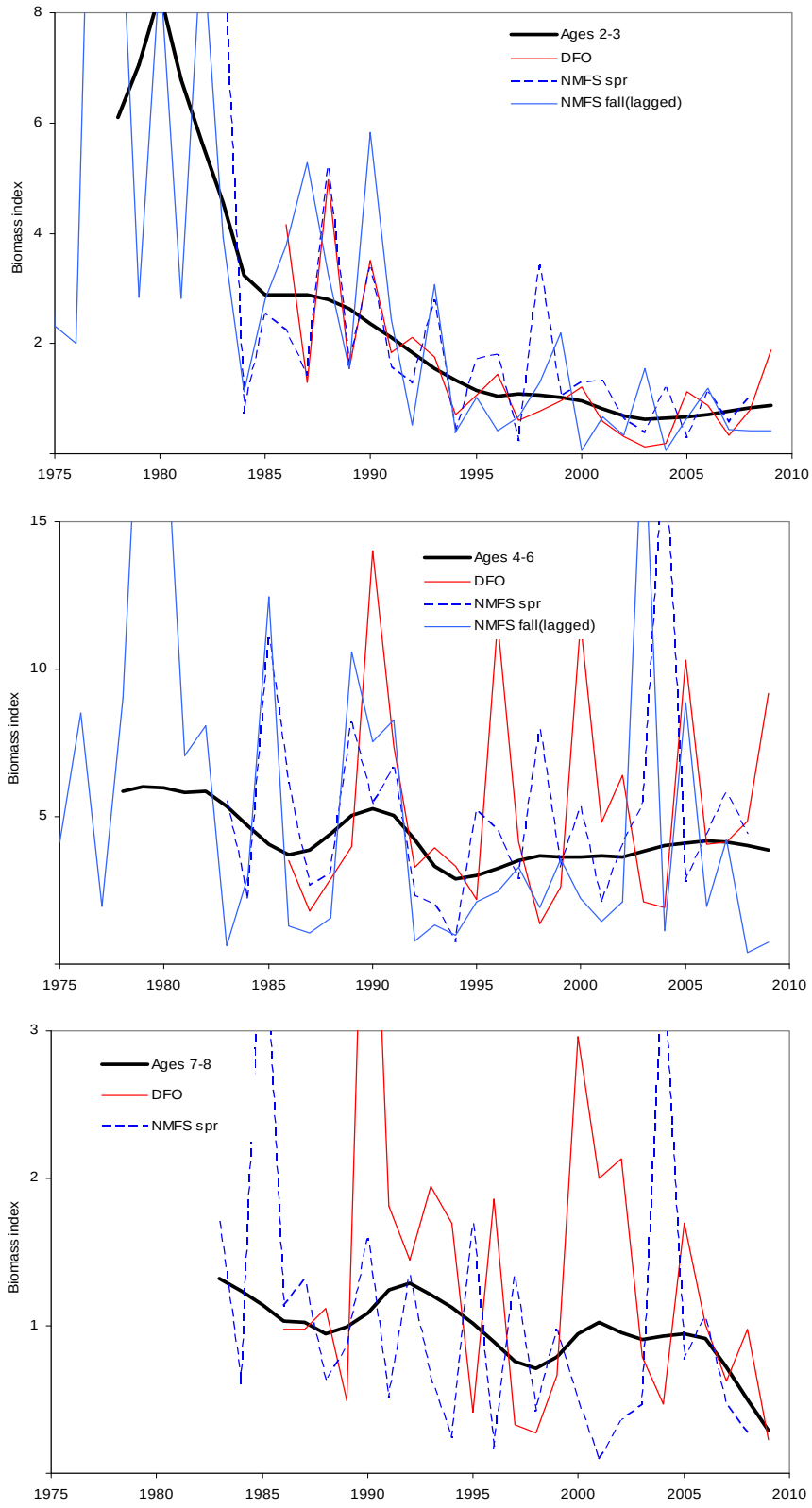


Figure 20. Survey biomass index and smoothed trend(black line) for different age group of eastern Georges Bank cod.

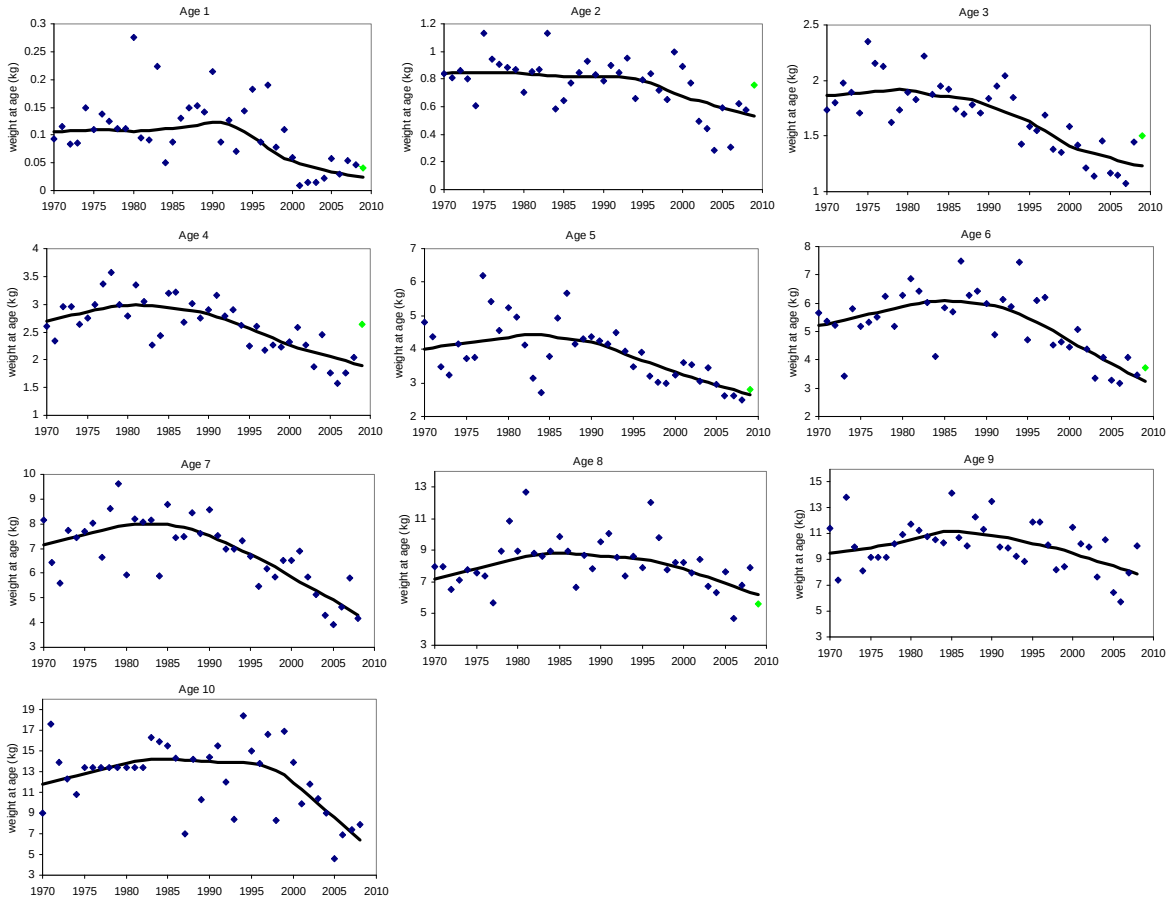


Figure 21. Beginning of year weights at age of eastern Georges Bank cod from DFO and NMFS spring survey. The lighter points are from 2009 DFO survey.

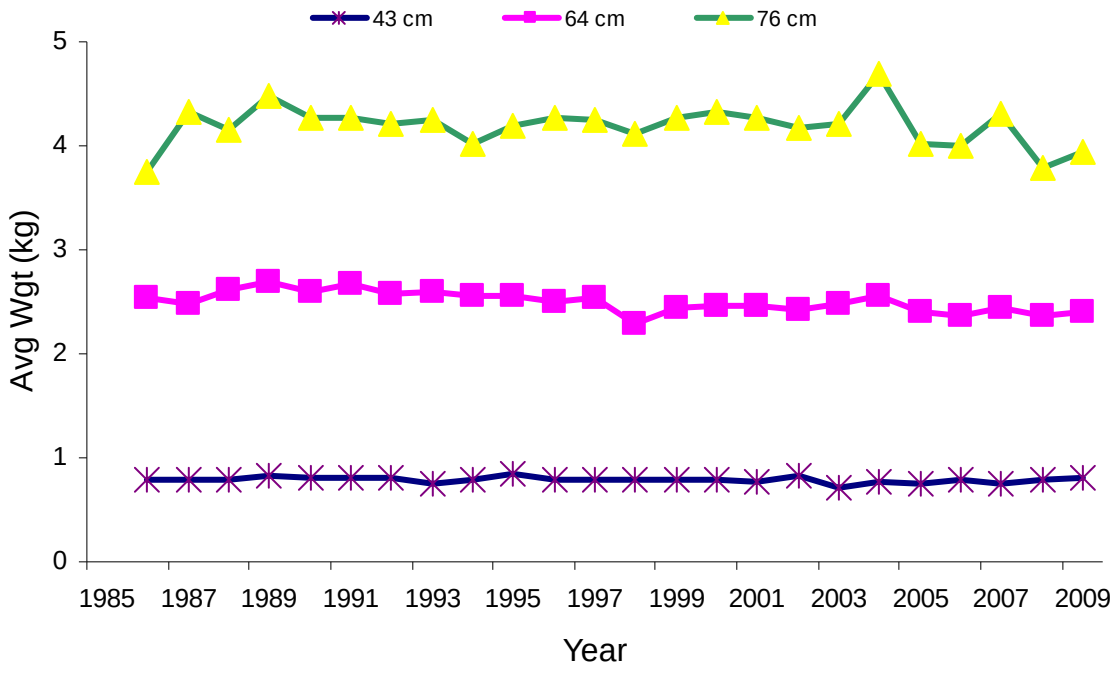


Figure 22. Condition, measured as average weight at three representative length groupings (center of 3 cm grouping used in label), for eastern Georges Bank cod from the DFO survey.

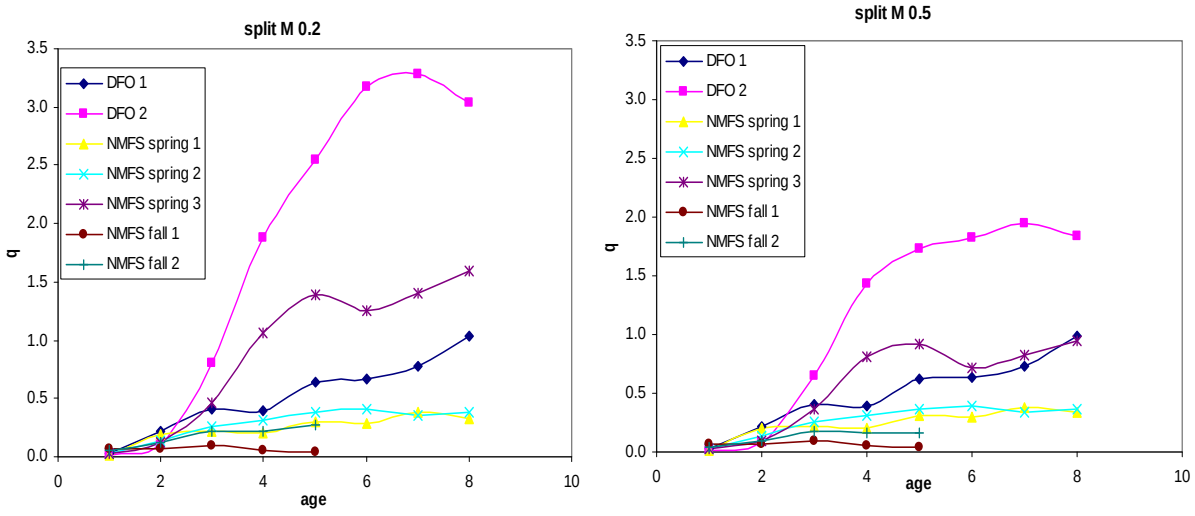


Figure 23. Survey catchability (q) for the DFO, NMFS Spring and NMFS fall surveys from the "split M 0.2" and "split M 0.5"model formulation.

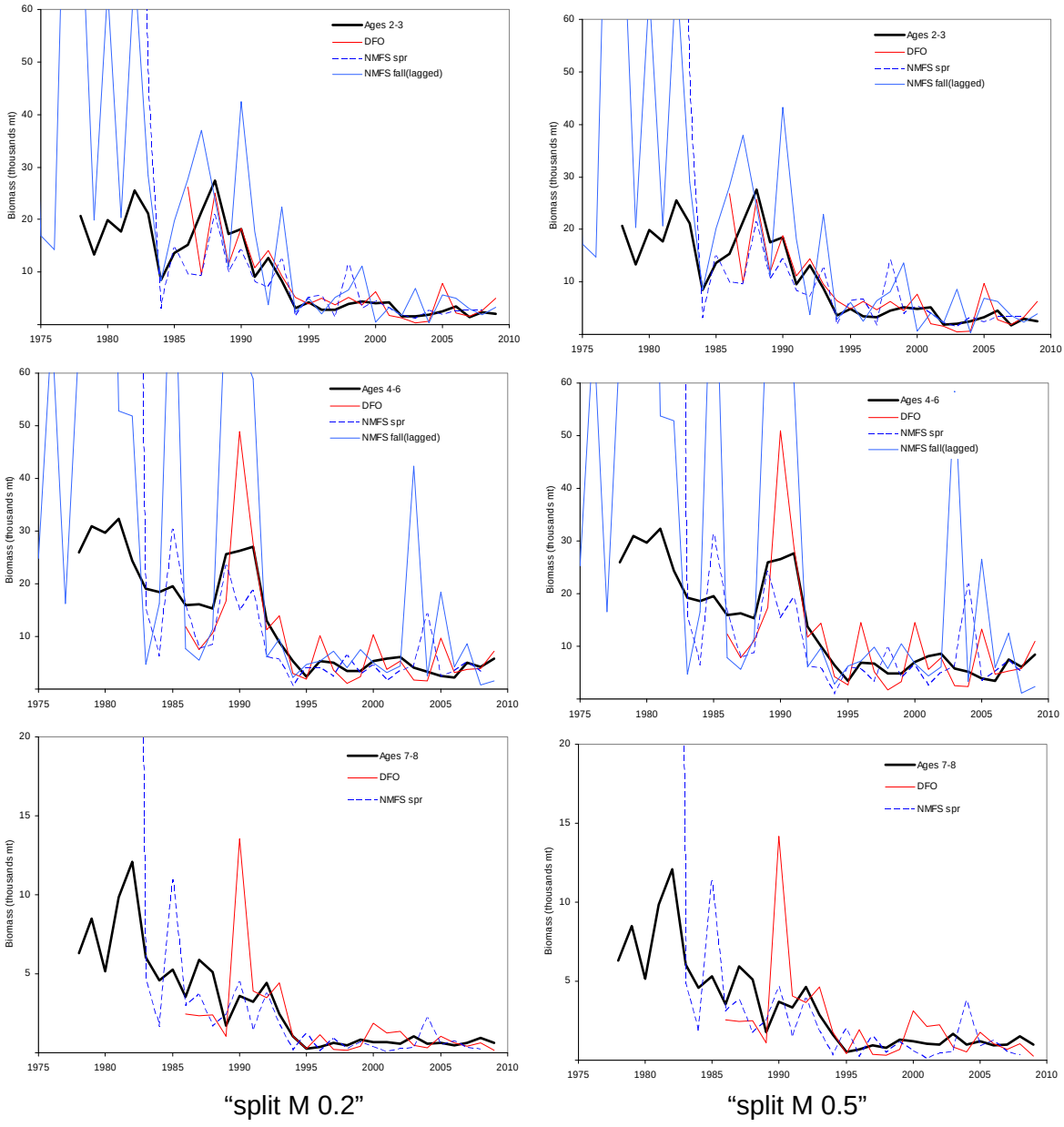


Figure 24. Assessment biomass trends comparison with DFO, NMFS Spring and NMFS fall surveys.

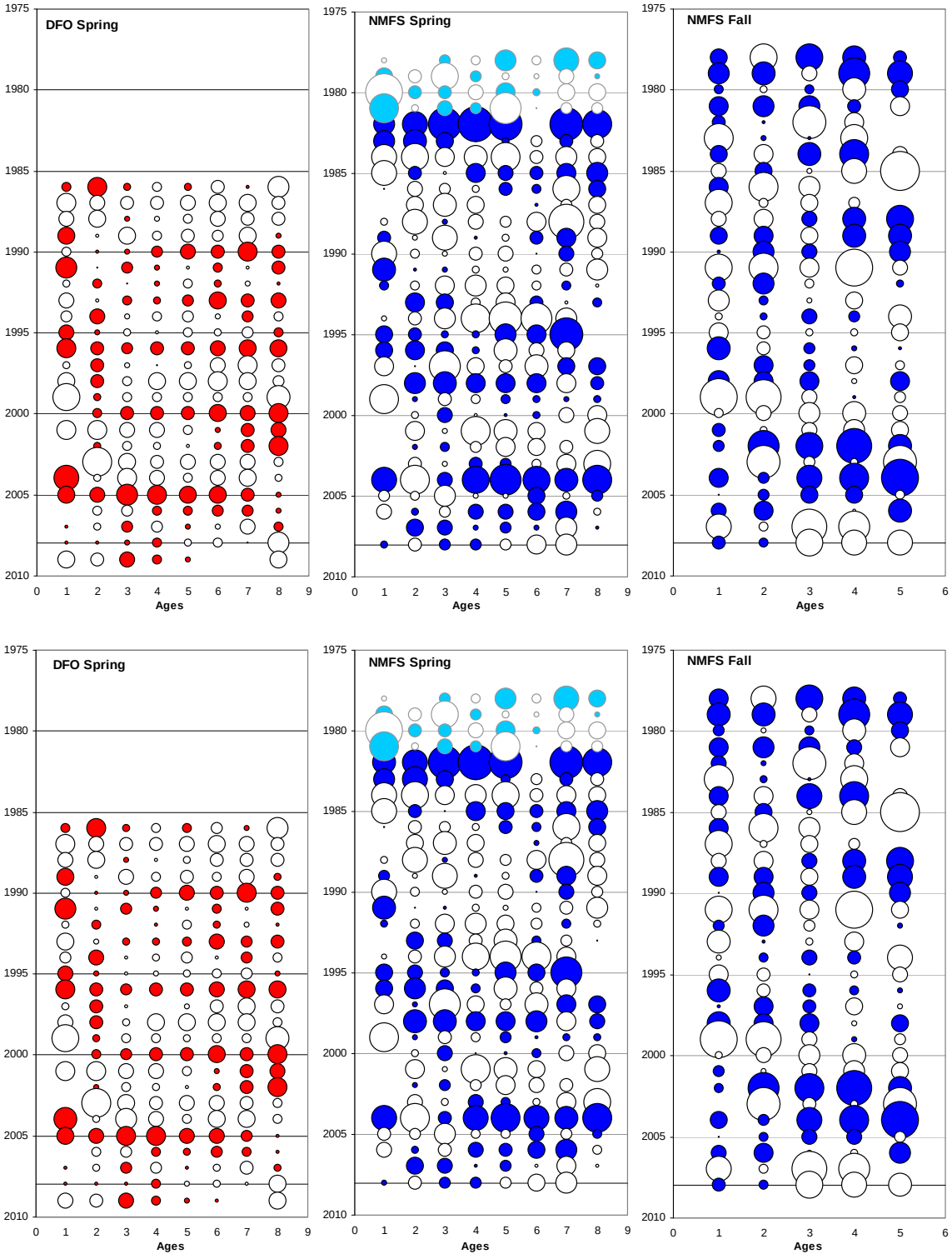
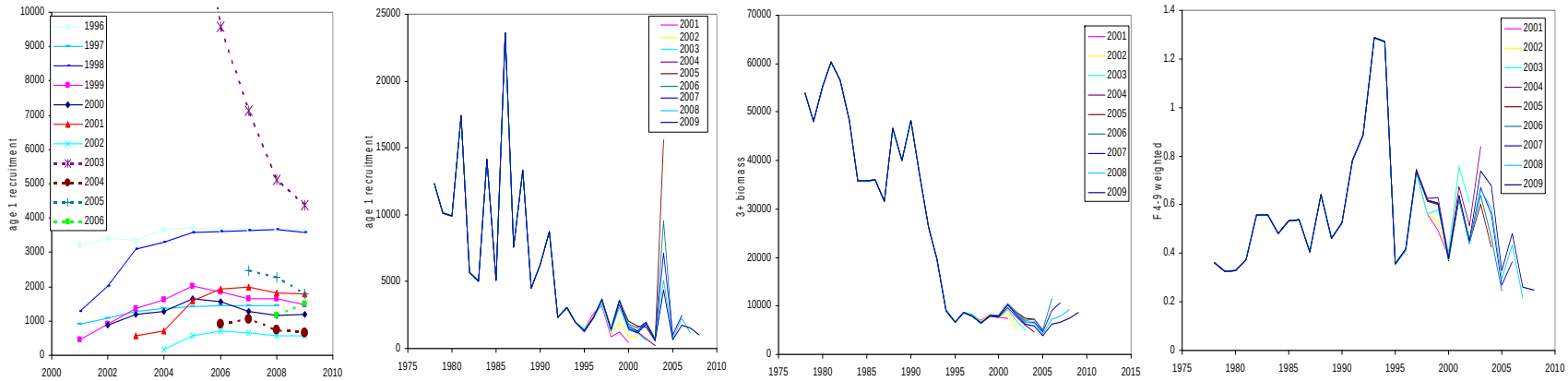
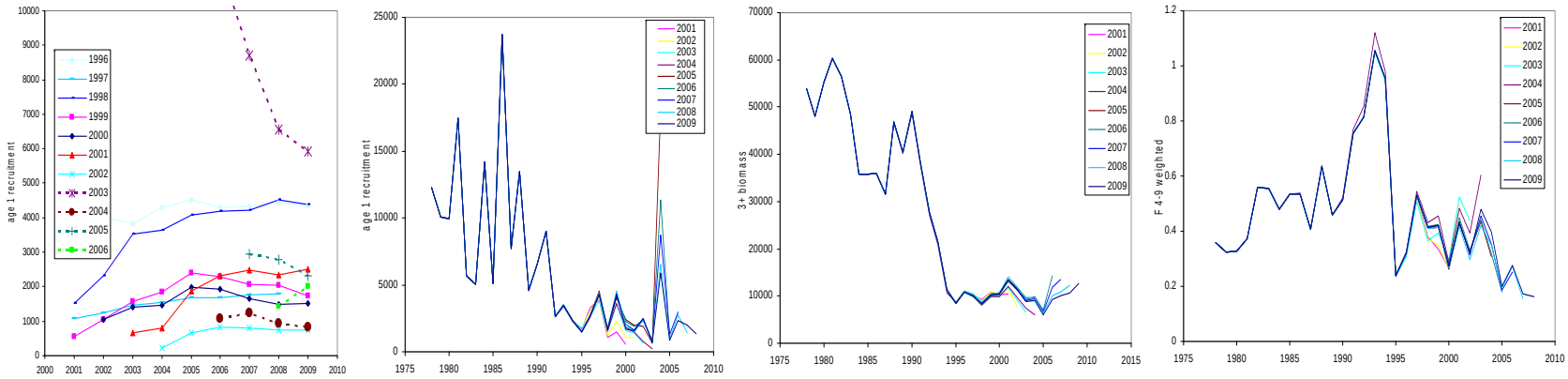


Figure 25. Residuals by year and age group from survey indices for eastern Georges Bank cod. Solid bubbles indicate positive values, open bubbles indicate negative values and bubble area is proportional to magnitude. The NMFS spring survey was conducted using a modified Yankee 41 during 1978 to 1981 (pale blue bubbles). The upper figures are from the "split M 0.2" model, the under figures from the "split M 0.5" model.

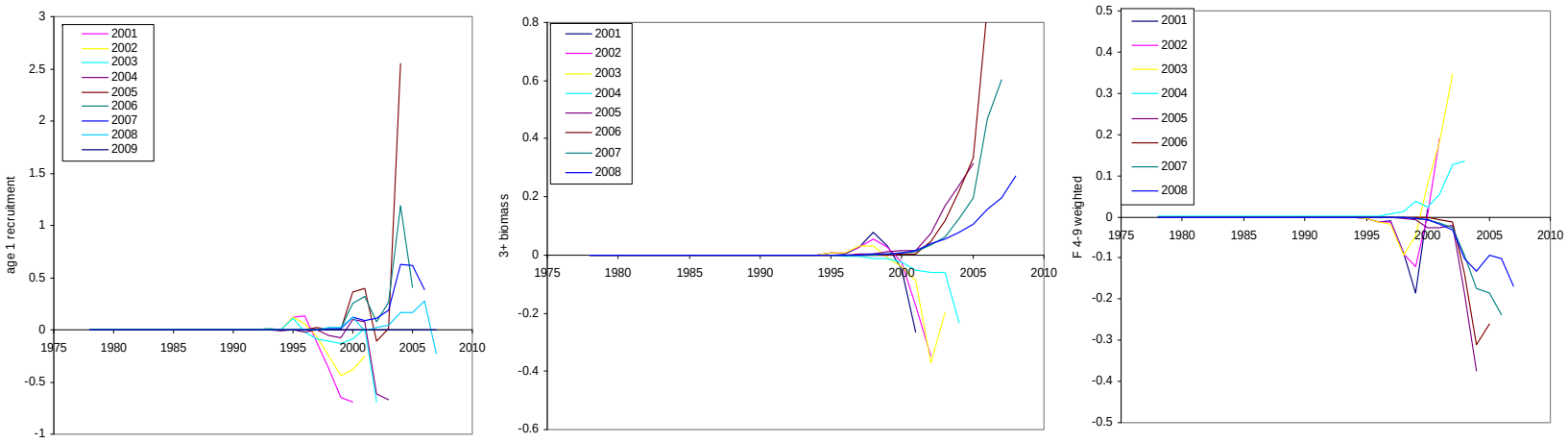


"split M 0.2"

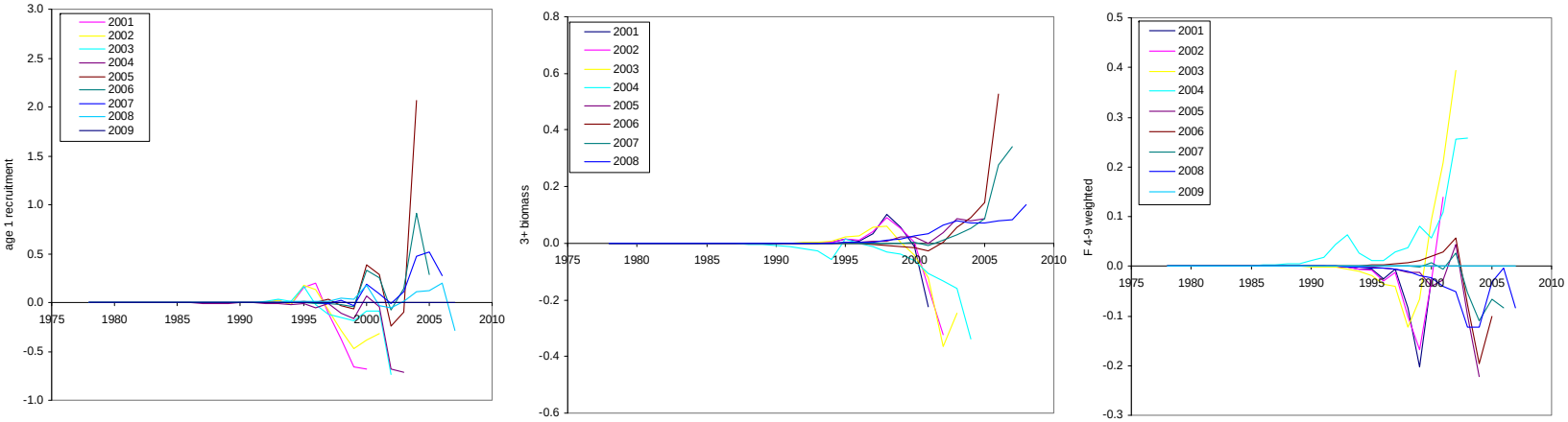


"split M 0.5"

Figure 26. Retrospective pattern for recruitment at age 1, 3+ biomass and Fishing mortality of eastern Georges Bank cod.



"split M 0.2"



"split M 0.5"

Figure 27. Relative retrospective pattern for recruitment at age 1, 3+ biomass and Fishing mortality of eastern Georges Bank cod.

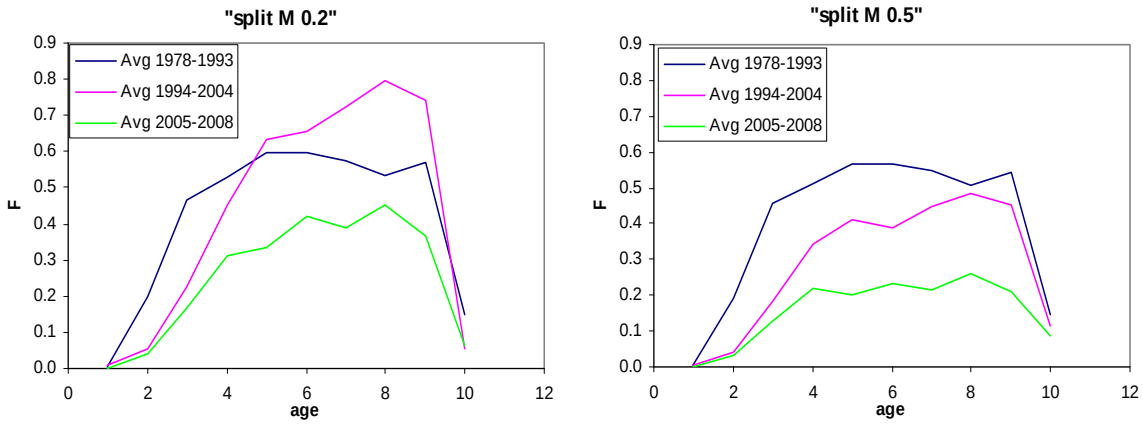


Figure 28. Average fishing mortality in 3 time series blocks (978-1993, 1994-2004, 2005-2008) from 2 model formulations of eastern Georges Bank cod.

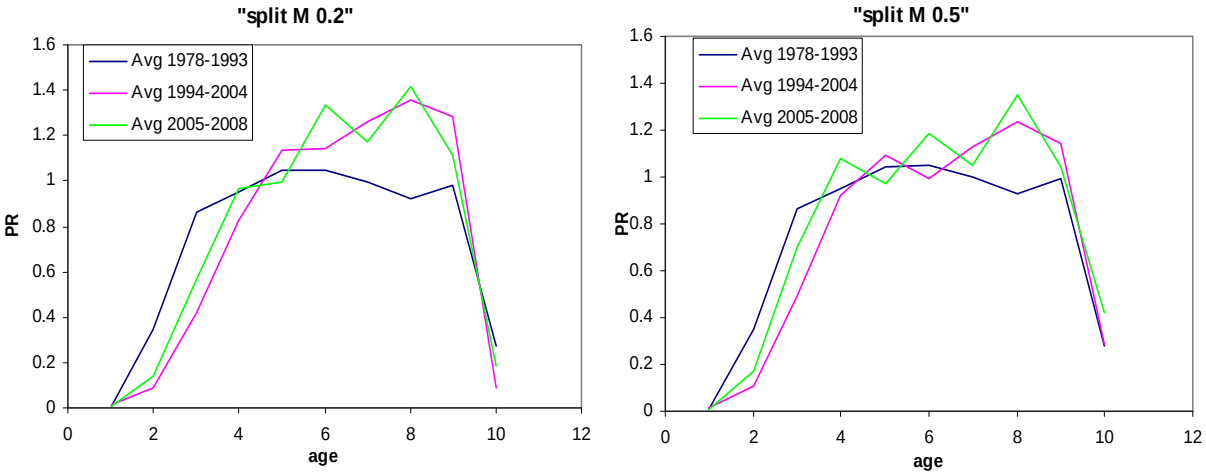
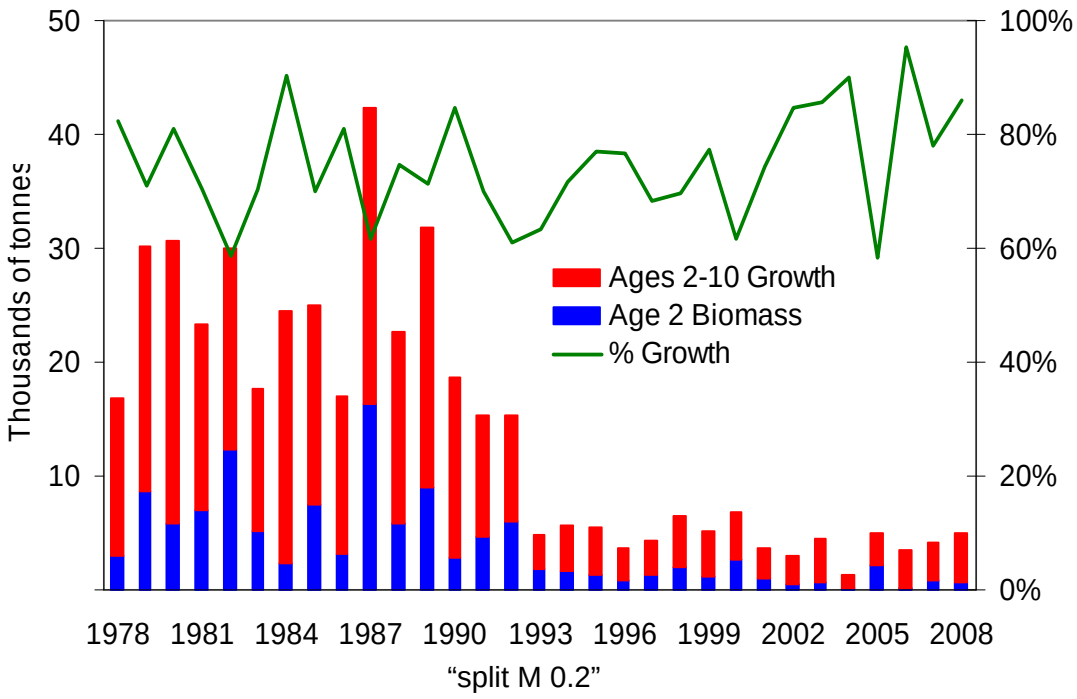


Figure 29. The fishing partial recruitment in 3 time series blocks (978-1993, 1994-2004, 2005-2008) from 2 model formulations of eastern Georges Bank cod.



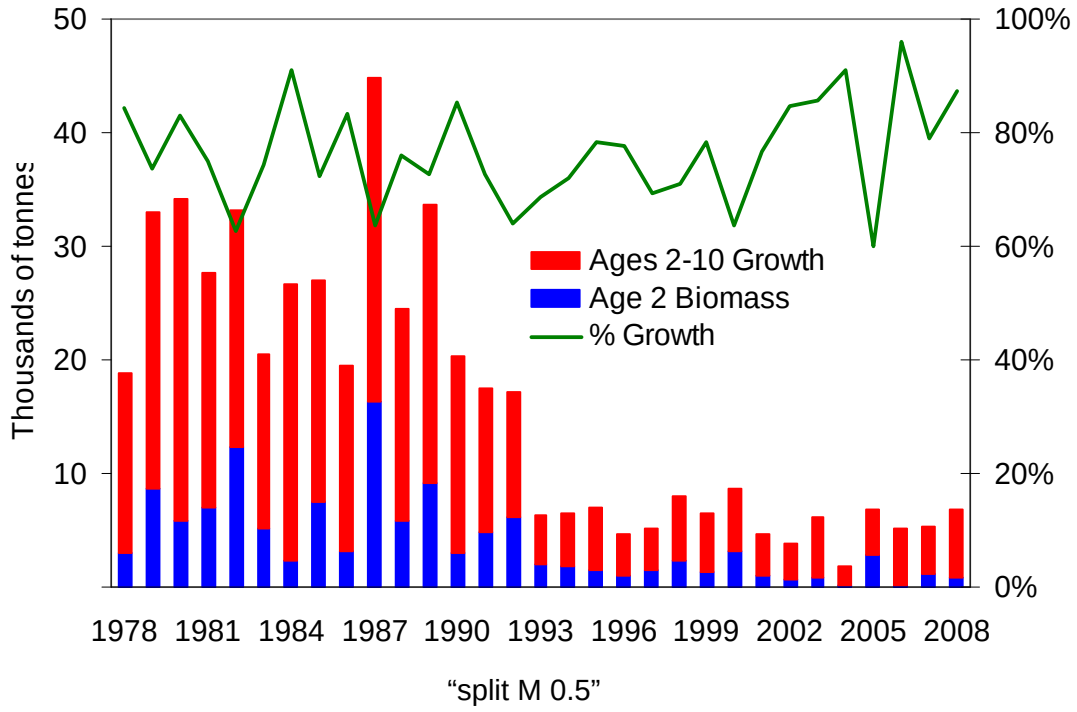


Figure 30. Components of annual production for eastern Georges Bank cod attributable to growth of ages 2 to 10 and to the amount contributed from incoming year-classes at age 2.

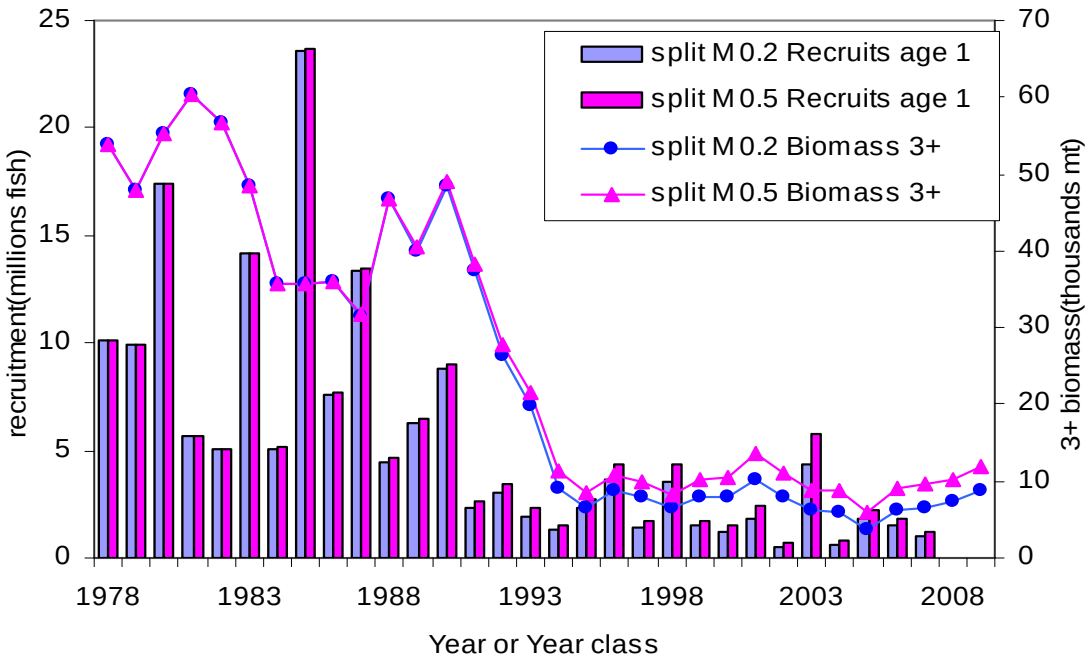


Figure 31. Adult biomass (ages 3+) and year-class abundance at age 1 for eastern Georges Bank cod.

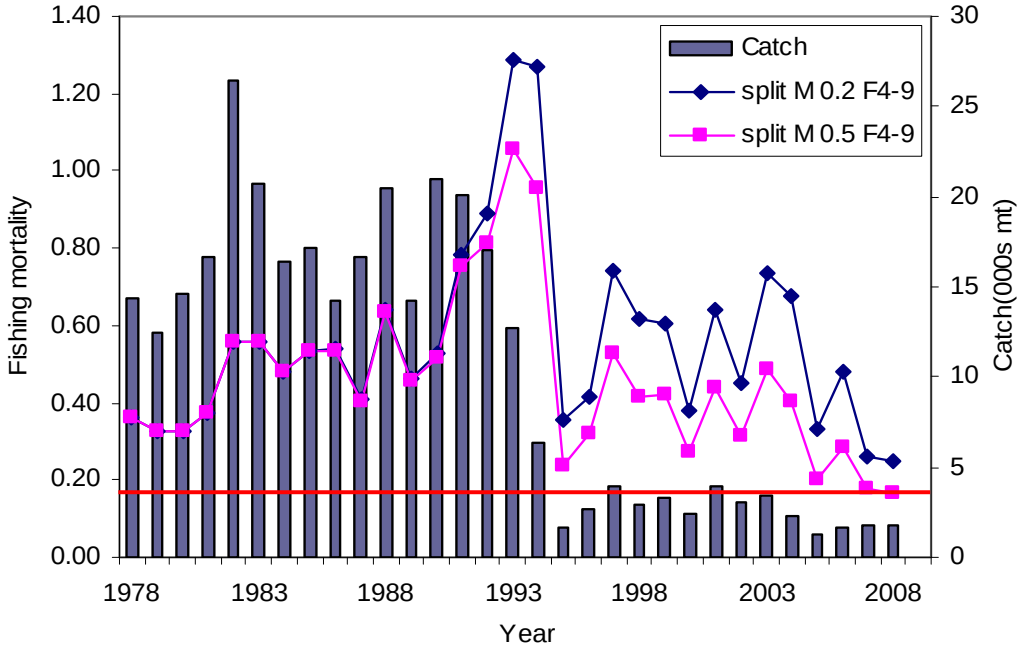
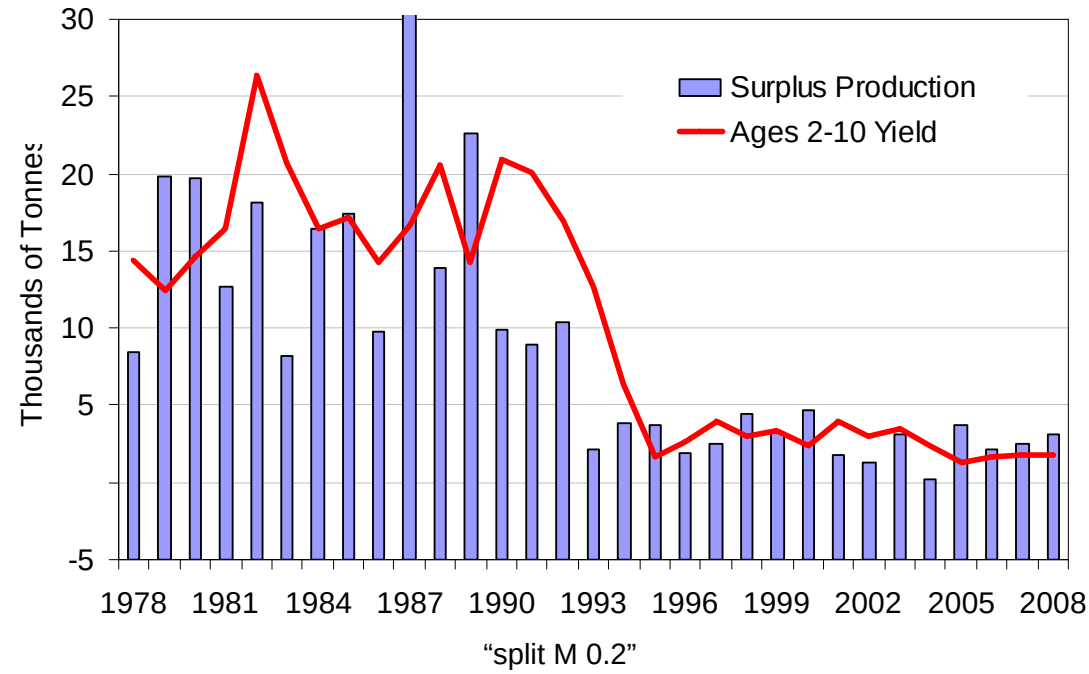


Figure 32. Fishing mortality rate at ages 4 to 9 and catches for eastern Georges Bank cod. The established fishing mortality threshold reference, F_{ref}=0.18, is indicated.



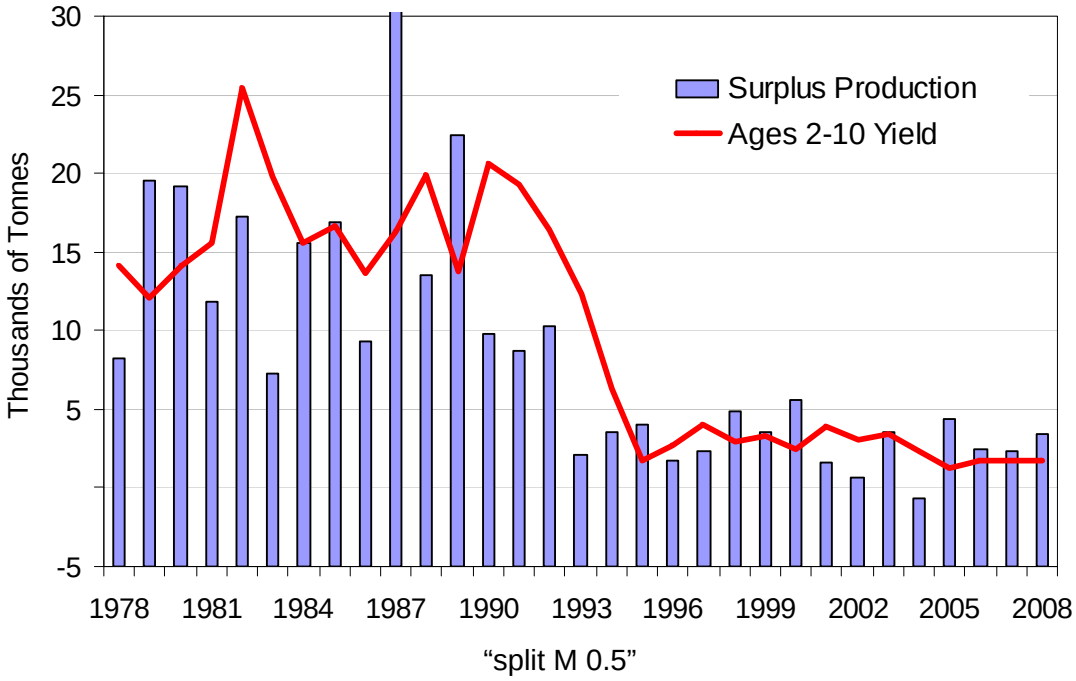


Figure 33. Surplus production of eastern Georges Bank cod compared to harvested yield.

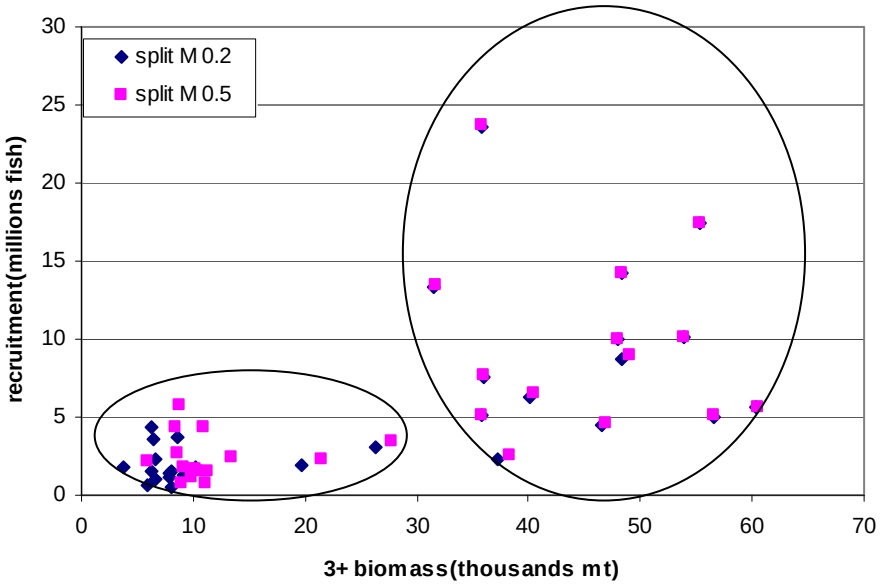


Figure 34. Relationship between adult biomass (ages 3+) and recruits at age 1 for eastern Georges Bank cod.

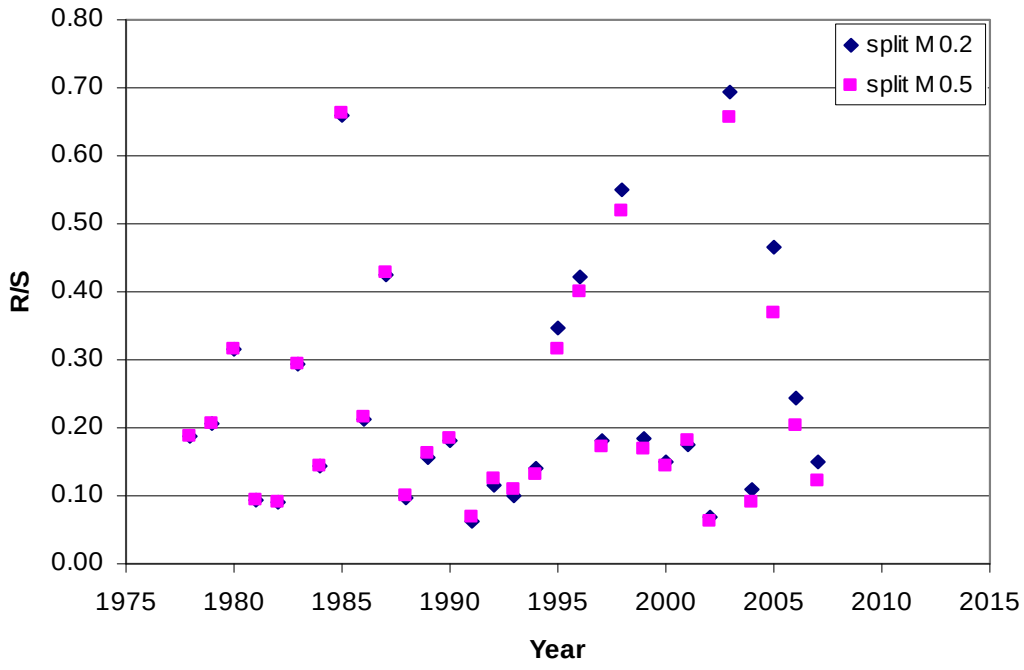


Figure 35. Recruitment rate (R/3+biomass) for eastern Georges Bank cod.

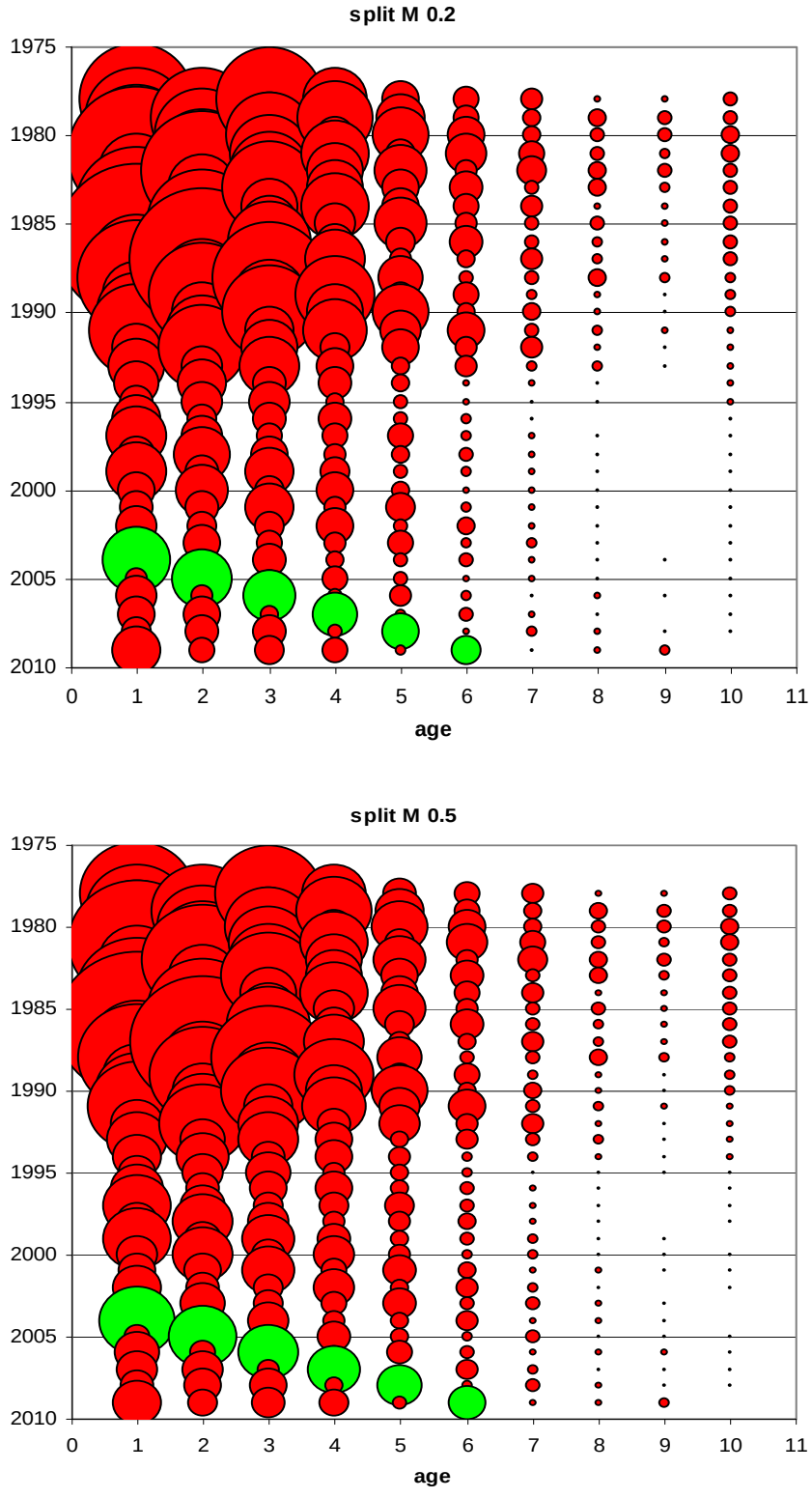


Figure 36. Population numbers from 2009 assessment of eastern Georges Bank cod. Bubble size are proportional to population numbers, lighter bubbles are 2003 year-class.

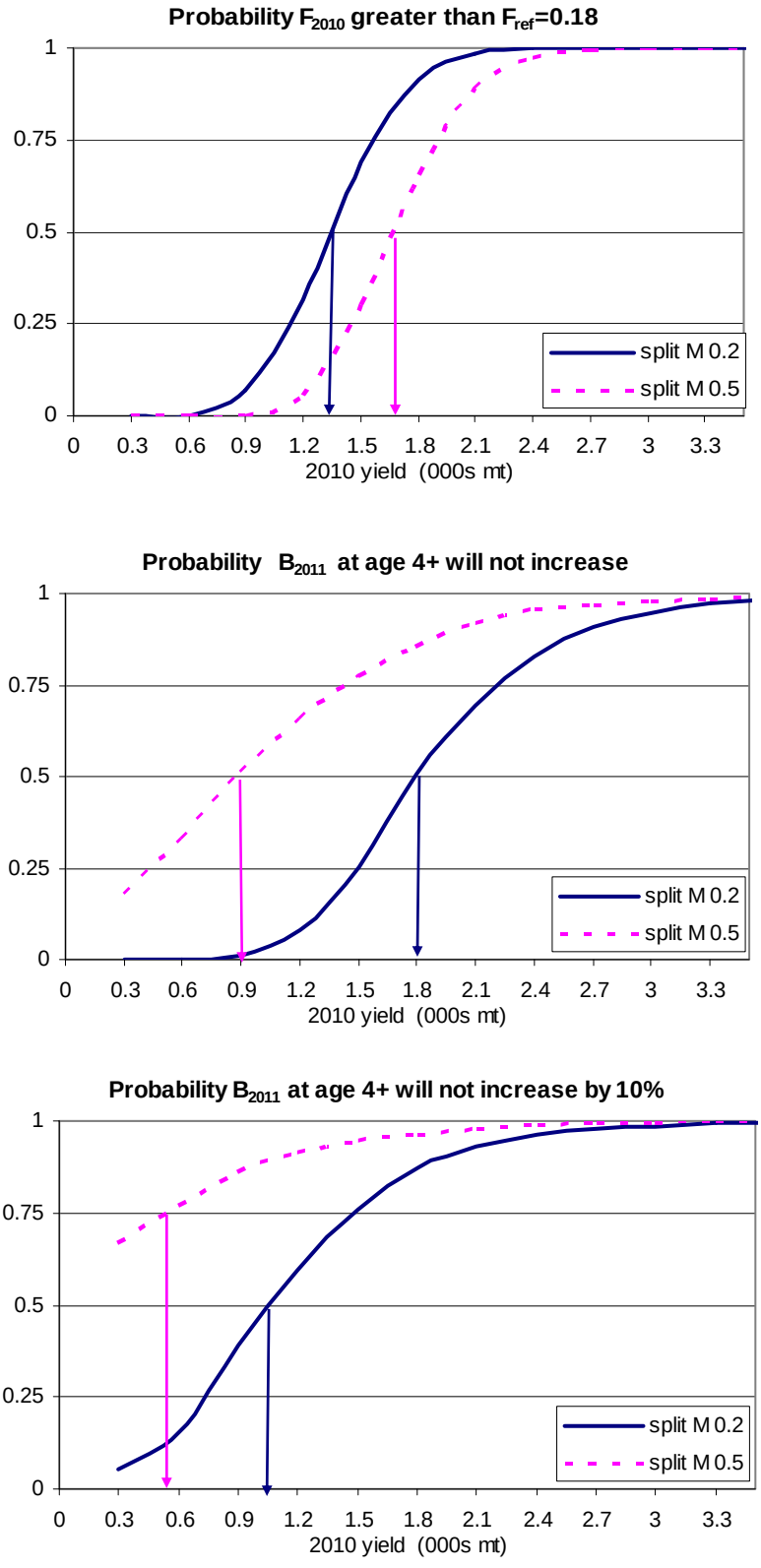


Figure 37. Risk of 2010 fishing mortality exceeding F_{ref} = 0.18 and risk of biomass not increasing or not increasing by 10% for alternative total yields of eastern Georges Bank cod.

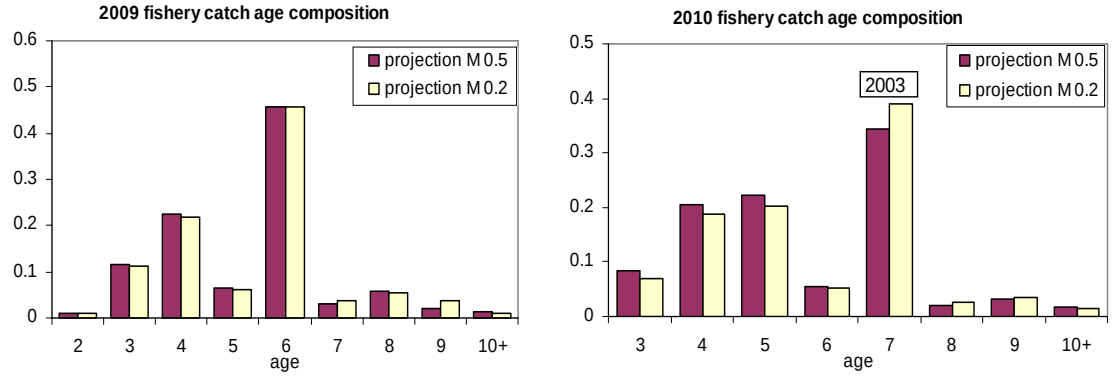


Figure 38. Projected fishery catch (in fish numbers) age composition of eastern Georges Bank in 2009 and 2010 if the catch is 1,700 mt in 2009 and F_{2010}=0.18.

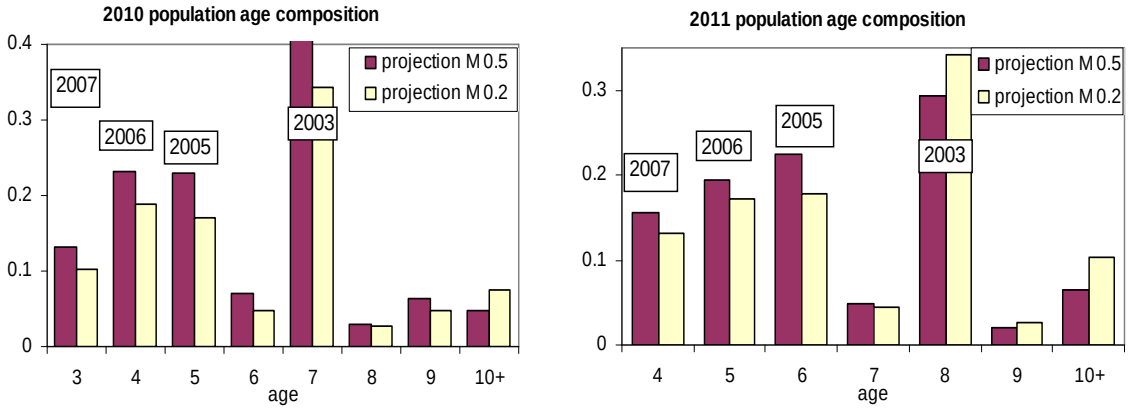


Figure 39. Projected fish population (in biomass) age composition of eastern Georges Bank in 2010 and 2011 if the catch is 1,700 mt in 2009 and F_{2010}=0.18.

APPENDIX

Discards of Cod from the 2008 Canadian Groundfish Fishery on Eastern Georges Bank

Data and Methods

Discards of cod from the Canadian groundfish fishery were estimated using the ratio of sums estimator methods described by Gavaris *et al*. (2007a). Landings of cod and haddock for 2008 were obtained from the fisheries statistics database maintained by the Maritimes Region of Fisheries and Oceans Canada. Trips were classified as observed or unobserved. Following Gavaris *et al.* (2007a), the basic record unit was the aggregate of catches from a trip within each zone, referred to as a sub-trip. Use of a separator panel when fishing with a bottom otter trawl on Georges Bank was mandatory in 2008, regardless of whether there was an observer on board. Therefore no sub-trips were excluded due to removal of the separator panel. Trips where the observer deployment was for management purposes, rather than routine monitoring, were excluded as these might not be representative.

As in previous recent years (Van Eeckhaute and Gavaris, 2004; Gavaris *et al.*, 2007a), virtually all the cod for 2008 were caught in Zones A and B during fishing targeting for haddock (Table A1, Figure A1). Accordingly, discards were only derived for Zones A and B and for the designated fleets targeting haddock, i.e. excluding pollock and yellowtail flounder targeted fishing by mobile gear and cod targeted fishing by gillnet and handline. Sub-trips that sought pollock were identified as those where the catch of pollock exceeded the catch of cod and haddock or observed sub-trips where the declared species sought was pollock. A small amount of catch by a vessel experimenting with a new bottom trawl configuration was excluded from comparisons because the by-catch from this vessel might not be comparable to the rest of the fleet. The amount of cod landed from other zones by all the excluded fishing activity was relatively low; therefore any potential estimated discards would be inconsequential.

The calculation of discards uses a landings multiplier that is based on ratios of cod to haddock. Factors that are expected to affect the species composition include fishing fleet, fishing ground location and season. Quarters were used to stratify season.

The Canadian quotas are sub-allocated to quota groups. Sub-allocation of shares to quota groups varies by species. Therefore, the quota mix varies substantially by quota group. The quota mix can be an important determining factor in discarding behaviour. Accordingly, fishing fleets were defined by quota groups (Table A2). Generally, quota groups comprise vessels that are similar with respect to size and gear. A quota group's allocation may be fished by vessels smaller than those in the group under the Temporary Vessel Replacement Program (TVRP is a mechanism by which a fleet can contract another fleet to catch their quota without transferring the quota). Almost all of the 2008 catch by the mobile gear (MG) 65'-100' and the >100' fleets was taken by vessels less than 65' under the TVRP program.

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

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

Results and Discussion

The ratio of sums method was applied to obtain the landings multipliers by fishing fleet, zone and quarter (Table A3). The associated standard errors from the bootstrap analyses are also shown. Bootstrap confidence distributions of the landings multiplier were examined to determine if it could be inferred that discarding occurred. The percentile and bias corrected confidence distributions were generally coincident, indicating that the bias is small. Discards were calculated for cases where the reference landings multiplier of 1 intersected the bias corrected confidence distribution at a probability of 0.2 or less. Discarding was only inferred for FG<45 in quarter 3, zone B (Figure A2) and MG<65 in quarter 1, zone B (Figure A3). There was insufficient data to estimate landings multipliers for FG 45-65, FG 65-100 and MG 65-100. Although discarding might be inferred for MG>100 in quarter 1, zone B, the estimated discards were less than 0.5 mt and therefore not used (Figure A4). Discarding might also be inferred for First Nations (FN) in quarter 1, zone B, but was only marginally significant with low sampling, and therefore also not used (Figure A5). In total, discards of cod from the Canadian groundfish fisheries on Georges Bank in 2008 were 103 mt (Table A4).

Table A1. Landings of cod used in the analysis of cod discards from the Canadian fisheries on Georges Bank in 2008. Trips targeting pollock, yellowtail and cod were removed. Discards may occur during unobserved fishing. Discard calculations were examined for haddock targeted fishing in Zones A and B by quarter for the designated fleets (shaded cells).

	Zone A				Zone B				other zones	Total
FLEET	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**all Q**	
Observed										**205**
FG<45			7	1			57	21		
FG 45-65								2		
MG<65			0.1	1	33	9	22	7	9	
FG 65-100							3	1		
MG 65-100						1	4	1	1	
>100						5	0.4	5	1	
FN						12	1	6	1	
Unobserved										**689**
FG<45			34	9		2	297	41	6	
FG 45-65							2		1	
MG<65		0.1	0.5	0.9	5	21	142	45	9	
FG 65-100							7	0.4		
MG 65-100			0.1		2	4	10		2	
>100			0.2	0.003	0.3	2	22	1		
FN			0.2		1	0.4	13	10	1	
Total										**895**

Table A2. Designated fisheries participating in the Canadian groundfish fishery on Georges in 2008.

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

Table A3. Estimated landings multipliers (± standard errors) for designated fleets by zone and quarter for 2008. Shaded values indicate that discarding was not inferred.

	Zone A				Zone B			
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
FG<45			0.92±0.23				1.33±0.21	1.04±0.28
FG 45-65								
MG<65			1.01±0.89	1.59±0.71	2.30±0.71	0.81±0.25	1.07±0.34	1.55±1.13
FG 65-100								
MG 65-100								
>100					2.54±1.39		2.36±1.53	
FN					1.70±0.88		1.54±0.81	

Table A4. Estimated discards of Atlantic cod from the Canadian groundfish fishery on Georges Bank in 2008.

	Zone A				Zone B				
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Total**
FG<45							97		**97**
FG 45-65									
MG<65					6				**6**
FG 65-100									
MG 65-100									
>100									
FN									
Total									**103**

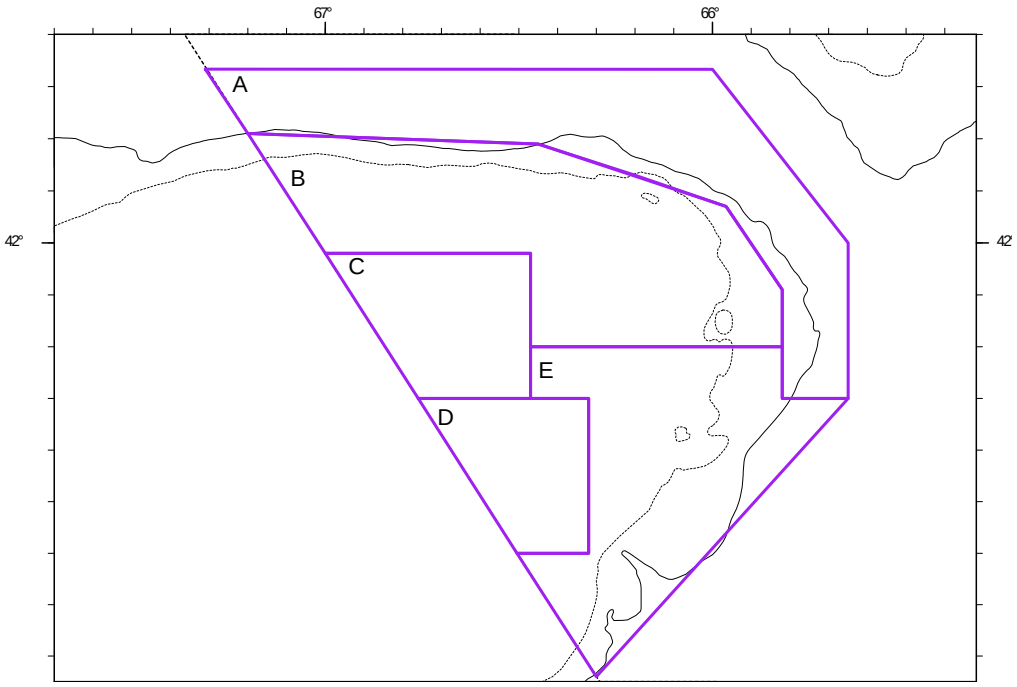


Figure A1. The Canadian portion of Georges Bank was partitioned into five zones that were used for the analysis.

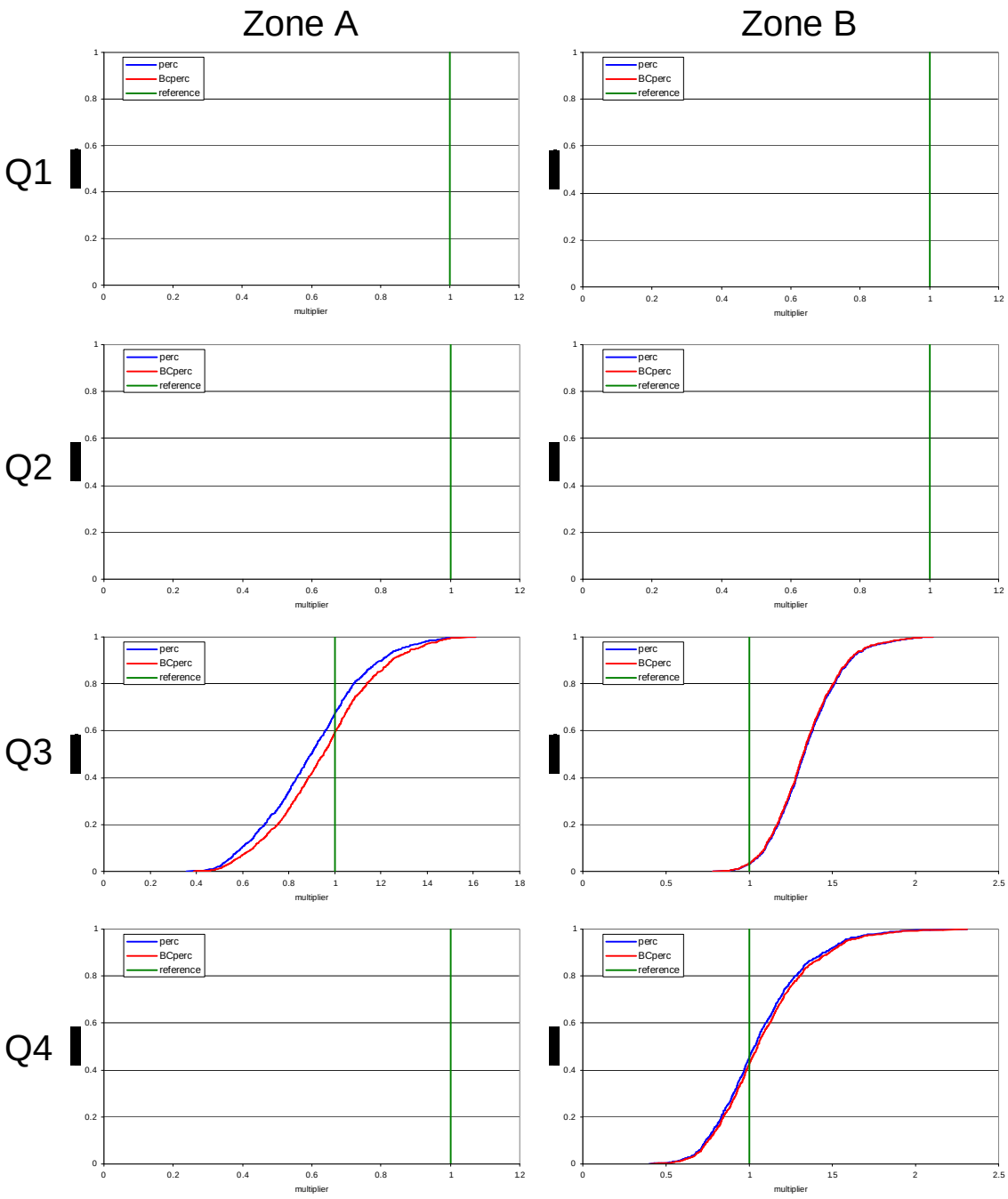


Figure A2. Confidence distributions of the landings multipliers for the FG<45' fleet.

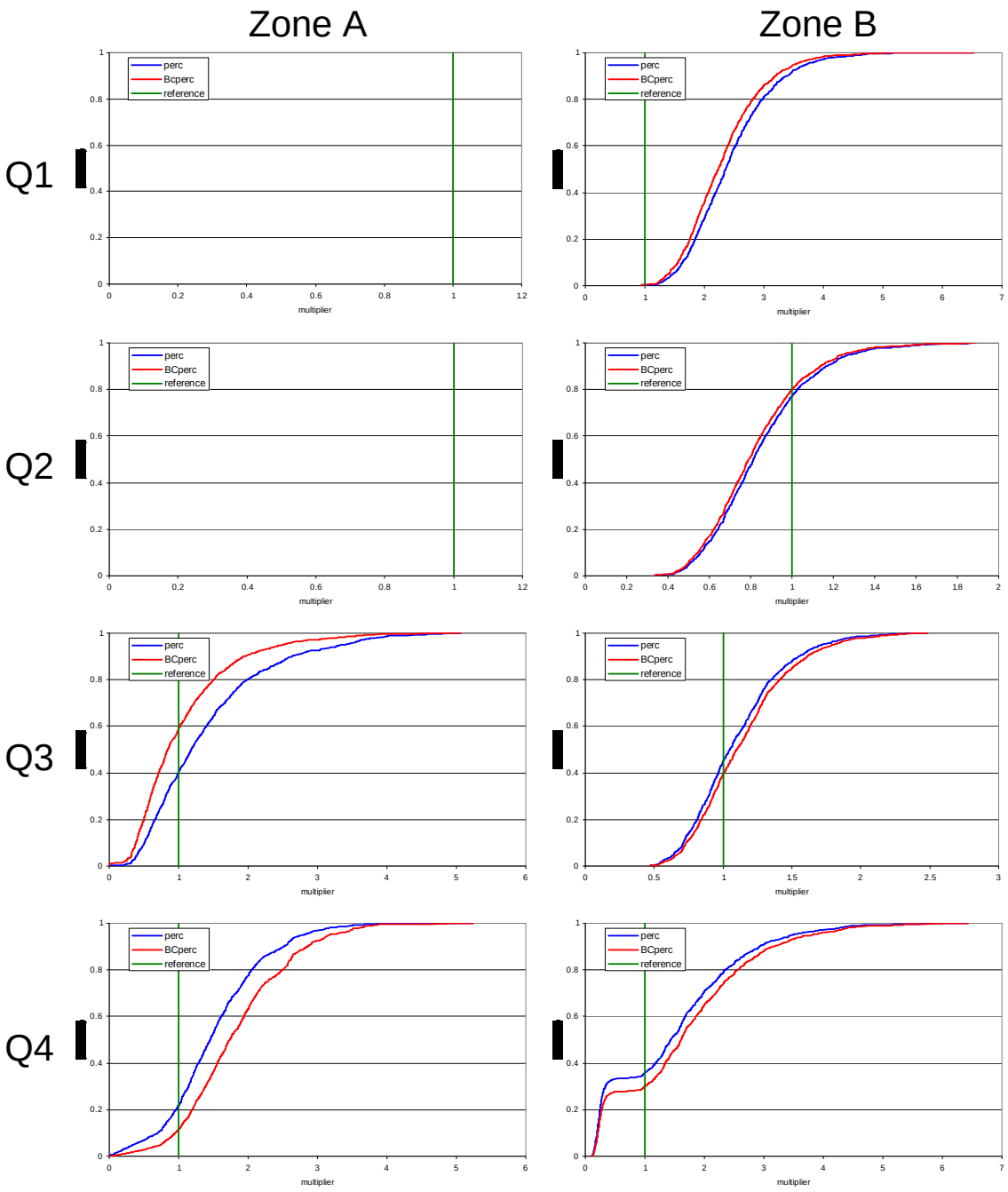


Figure A3. Confidence distributions of the landings multipliers for the MG<65' fleet.

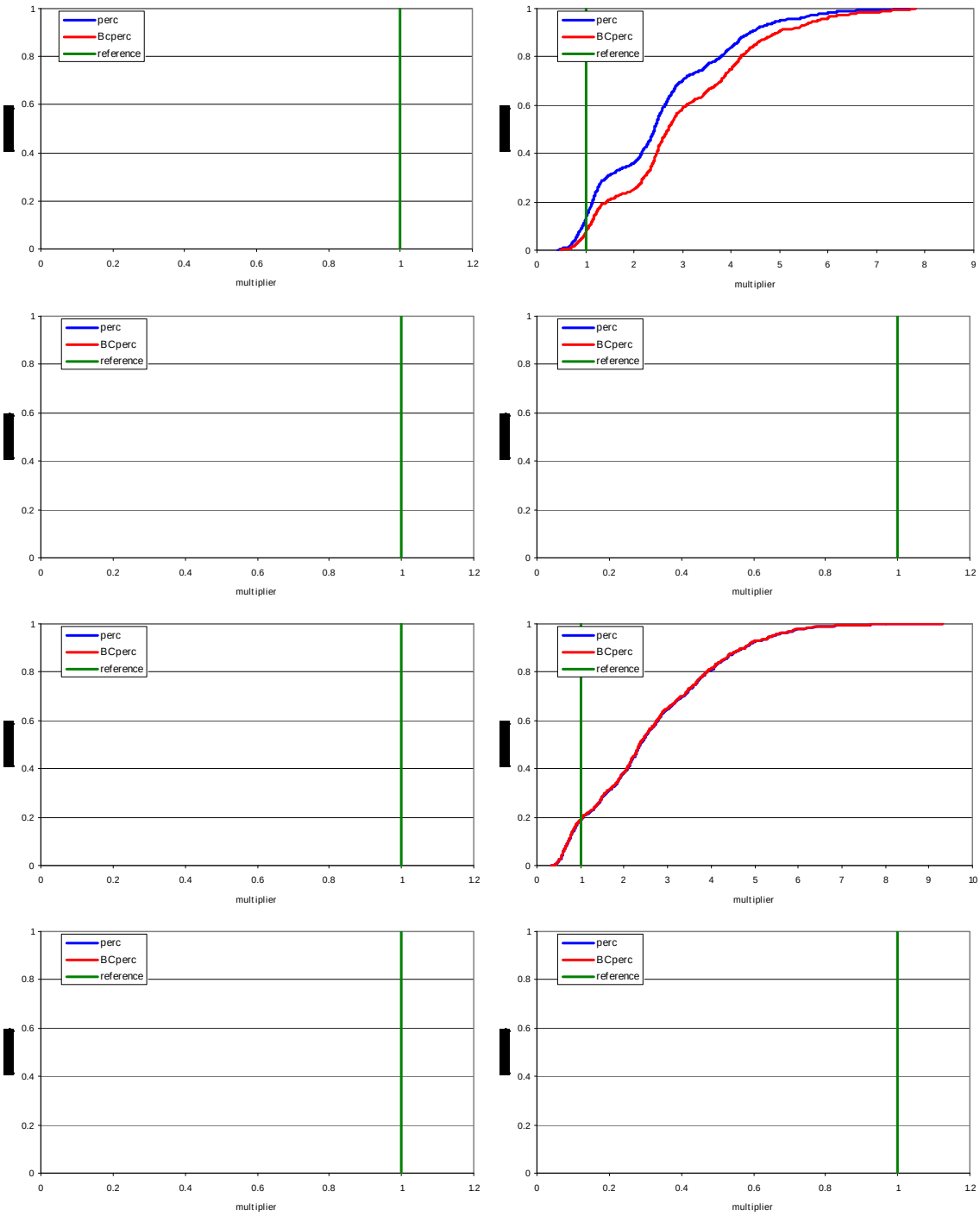


Figure A4. Confidence distributions of the landings multipliers for the >100' fleet.

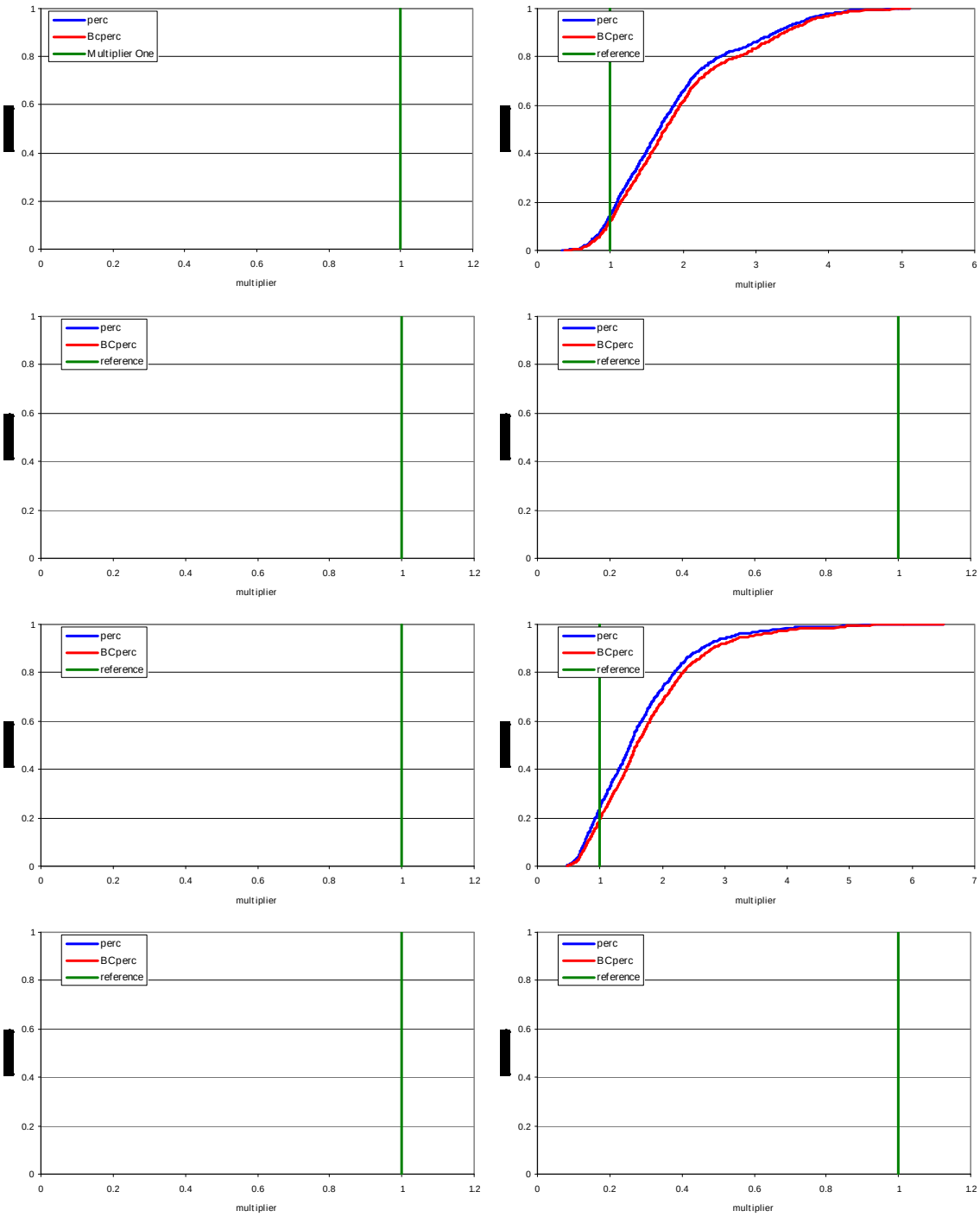


Figure A5. Confidence distributions of the landings multipliers for the First Nations fleet.