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Population Status of Eastern Georges Bank Cod (Unit Areas 5Zj,m) for 1978-2005

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ABSTRACT

An analytical assessment of the Georges Bank cod stock in 5Zj,m was completed using updated catch-at-age for ages 1-10 and research survey indices for ages 1-8. A benchmark ADAPT formulation, based on TRAC recommendations, was used to characterize the population. Results of the assessment provided statistically significant parameter estimates for the 2004 beginning-of-year population at ages 3 through 10**;** the estimate for age 2 in 2004 was not statistically significant**.** Bias and precision (SE range 39-48%) for the estimates were within acceptable limits. The adult biomass (3+) increased from the low of 8,600t in 1995 to about 18,700t at the beginning of 2001, primarily due to survival and growth of the 1995, 1996, and 1998 year-classes. Since 2001, adult biomass has declined and was 13,900t at the beginning of 2004. Exploitation rate on ages 4-6 decreased from more than 50% in the mid-1990's to about the F_{ref} level (F=0.18, 15% exploitation rate) in 1995 but has since been higher, ranging between 16%-28%. A change in partial recruitment to the fishery has occurred since 1994 with reduced catchability on ages 5+. This change is due to the by-catch nature of the Canadian fishery and to management measures that reduced spatial and temporal access to the resource for both the Canadian and USA fisheries. Recruitment in recent years has been poor. The 1996 and 1998 year-classes were above the recent average but still well below the long term average**.** Early indications from research surveys suggest improved recruitment from the 2003 year-class. With an expected 1,300t total catch in 2004, projections for 2005 indicate a decline in yield to about 1,100 t at F_{ref} and a decline in stock biomass between 2004 and 2005. The adult stock biomass remains below a threshold of 25,000 t, above which chances of good recruitment are improved.

With the current poor recruitment and exploitation rates near the present levels, improvement in stock status is not expected in the near term.

RÉSUMÉ

Nous avons effectué une évaluation analytique du stock de morue du banc Georges dans 5Zjm à partir de données à jour de captures par âge d'individus de 1 à 10 ans et d'indices de relevés de recherche pour les morues de1 à 8 ans. Nous avons caractérisé la population en appliquant une procédure ADAPT de référence fondée sur les recommandations du Transboundary Resources Assessment Committee (TRAC). L'évaluation a donné des estimations statistiquement significatives de paramètres de la population de morues âgées de 3 à 10 ans au début de l'année 2004, mais l'estimation pour les morues de 2 ans n'était pas statistiquement significative. Le biais et la précision des estimations (SE range 39-48 %) se situaient dans les limites acceptables. La biomasse des adultes (3+ ans) est passée de son niveau le plus bas, soit 8 600 t, en 1995 à environ 18 700 t au début de 2001, surtout en raison de la survie et de la croissance des classes d'âge 1995, 1996 et 1998. Depuis 2001, la biomasse des adultes a diminué; elle se chiffrait à 13 900 t au début de 2004. Le taux d'exploitation des morues de 4 à 6 ans a baissé, passant de plus de 50 % au milieu des années 1990 à une valeur environ égale au niveau de référence (F = 0,18, taux d'exploitation de 15 %) en 1995, puis il a augmenté et varie entre 16 et 28 %. Étant donné la capturabilité réduite des morues de 5+ ans, le recrutement partiel à la pêche a changé depuis 1994, ce qui s'explique par le fait qu'il s'agit de prises accessoires dans les pêches canadiennes et par les mesures de gestion qui ont réduit l'accès à la ressource, tant spatial que temporel, pour les pêcheurs canadiens et américains. Ces dernières années, le recrutement a été faible; bien que les effectifs des classes d'âge 1996 et 1998 se chiffraient au-dessus de la moyenne récente, ils étaient encore nettement inférieurs à la moyenne à long terme**.** Les premiers résultats des relevés de recherche donnent à penser à une amélioration du recrutement, imputable à l'arrivée de la classe d'âge 2003. Compte tenu d'un total prévu des prises de 1 300 t en 2004, les prévisions pour 2005 indiquent un déclin du rendement à environ 1 100 t pour un taux d'exploitation à $F_{réf}$ et un déclin de la biomasse du stock par rapport à 2004. La biomasse des adultes du stock se maintient sous le seuil de 25 000 t, au-delà duquel les chances d'obtenir un bon recrutement augmentent.

Les taux d'exploitation et le faible recrutement actuels ne laissent pas entrevoir une amélioration de l'état du stock à court terme.

INTRODUCTION

This report incorporates commercial catch data and research survey results for the 1978-2004 time period to estimate the stock status of cod in NAFO unit areas 5Zj and 5Zm (5Zj,m) (Figure 1a). Definition of this management unit was based on analysis of tagging results and commercial and survey catch distribution (Hunt, 1990). Hunt *et al*. (2003) and TRAC(2004) last reported the status of cod in this management unit.

A benchmark review of the model used for the assessement of cod in 5Zj,m was conducted in February, 2002 (TRAC, 2002a) and a new ADAPT model formulation was recommended. This new model differed from the previously used model in that some RV survey indices were excluded and population sizes at age 10 for the five years prior to the terminal year were estimated rather than assumed equal to a value derived from averaging fishing mortalities.

THE FISHERY

Canadian landings of cod from unit areas 5Zj,m of Georges Bank peaked at about 18,000 t in 1982 and have declined from about 14,000 t in 1990 to 1,100 t in 1995, reflecting the lower TAC (Table 1, Figure 3). The 2003 fishery opened in June and resulted in a 1,500t catch. Landings by gear sector in the Canadian fishery (Figure 2) shows a consistent pattern in recent years.

Prior to 1996, incidental Canadian catches by other than the primary gear sectors have been reported as ‘miscellaneous’ gear and landings included in the determination of catch at age. Most of this incidental catch was taken in Canadian offshore scallop fishery as an allowed by-catch. Since 1996, no by-catch or landings of groundfish by the scallop fishery has been allowed and it is thought that discarding of groundfish has occurred. To estimate the amount of discards, a model was developed based on Observed catches for a small number of scallop trips in 1998, 2001 and 2002. Annual CPUE by groundfish species using scallop effort hours was derived and used to prorate the catch of cod to the equivalent associated with total scallop fishery effort hours. Estimated discards are shown in Table 1 and ranged from 56 t to 169 t. Further work is required to confirm the extent of 1996-2003 discards and to include estimates of discards in the catch at age.

Between 1978-1984, USA landings increased from 5,500t to 10,500t then declined and remained stable at about 6,000 t during 1985-1993 (Table 2). Closed Area II was implemented in December 1994 and US cod landings during 1994-2000 ranged from between 560t to 1,230t and averaged about 800t. USA landings of cod from areas 5Zj,m in both 2001 and 2002 were about 1,400t, the highest since 1993, and increased to about 1,900 t in 2003. Almost 100 percent of USA catches in 5Zj,m were taken by otter trawl gear.

Combined USA and Canada landings during 1978-2003 are shown in Table 2 and Figure 3. Landings were 3,400t in 2003, a 23% increase from 2002. Canadian catches remained stable while USA landings increased by 600 t. USA landings accounted for about 55% of the 2003 total compared to the 1998-2002 average of about 37%.

Length composition from samples of landings and catches obtained by commercial port samples and at-sea Observer sampling was used to estimate catch at length and age composition in the Canadian fishery. A summary of the number of length and age samples used to estimate catch-at-age is shown in Table 3 and Figure 4a. The fishery was adequately sampled and about 20,000 length observations and 1,100 age determinations were available to construct the catch-at-age for 2003 (Table 4). Comparison of length distributions between the at-sea and on-shore samples by gear sector and month showed very little difference (Figure 4b).

Starting in 2000, quarterly weight-length relationships derived from at-sea Observer sampling from 1995-2000 were applied to estimate the catch-at-age. Landings were regulated by 100% dockside monitoring. Mobile gear catches by tonnage class group were derived to account for potential differences between large offshore trawlers and tonnage classes 2 and 3 trawlers in areas fished and size composition.

Precision estimates of intra-reader age determinations by the Canadian age reader were completed and results were acceptable with a CV of 1.37 and overall agreement of about 92% (Table 5a). Results for precision estimates of USA intra-reader age determinations were acceptable with a CV of 1.94 and overall agreement of 91% (Table 5c).

A Canada/USA Aging Workshop took place at the St. Andrews Biological Station from January 21 to 23, 2004. Prior to the Workshop, approximately 200 otoliths (100 from each site) were exchanged and resulted in an overall agreement of 84% with a CV of 3.37 (Table 5b). Images were digitized and annotated from all samples. Differences in sample preparation and examination (sectioned vs. baked and broken) continue to be a contributing source of differing interpretations. A total of 28 otoliths with a difference in age interpretation were re-examined by both agers during the workshop. The Can ager interprets her age reading from the sulcus to the distal edge and then compares it to the readings from the ventral and dorsal sides which could show an annulus at that edge which may not be visible at the distal edge. The proximal area is not always clear but in some cases can verify the interpretation. The US ager tries to interpret their age from the dorsal side and then refer to the ‘notch’ area of the otolith to clear out any checks. In many of the comments , looking at ageing differences, both the CAN and US ager noted differences in otolith quality and images resulting from two separate otoliths being set. A recommendation from the workshop to exchange and read the same otoliths could eliminate this problem. Included in the discussions were otolith samples from the commercial fishery from January and July. Most differences in interpretation for these samples were the result of a January vs. February birthdate convention. Discussion and resolution of some age differences during the workshop improved agreement to about 90 percent. Further work is required to address some of the outstanding recommendations from the workshop.

A back calculation analysis of the February 2004 Georges Bank research survey otoliths was initiated to quantify aging results. Approximately 415 otoliths were measured and a relationship between the otolith size (width) and the size of fish was established. A regression analysis was done and the resulting relationship was used to determine the back calculated length of fish when annuli were formed. The back calculated fish size from the 3rd annulus was compared to the observed size at age 3 in 2001 for the 1998 year class and results showed similar length distributions (Figure 5). Work on this study will continue and form the basis for a report on aging precision and accuracy.

Catch-at-age for the reported USA landings in 1994-2003 was estimated from USA length and age samples. For 1996-2003, USA samples from 5Zj,m were insufficient to characterize the size composition of the landings; samples from 5Ze were considered to be representative of 5Zj,m and therefore were included to supplement the 5Zj,m length frequencies. USA age samples for landings in 5Zj,m were limited and were supplemented with Canadian age samples (Table 3).

Total removals-at-age and percent-at-age are given in Table 6 and in Figure 6. Average fishery weight-at-age and average beginning-of-year weights are given in Table 7. Fishery weight at length was used for estimating catch at age. Calculations of the population biomass were made using weights-at-age obtained from Canadian spring survey data (Hunt and Johnson, 1999). The data collected during surveys most adequately represents a sample of the entire population, while fishery data represents that portion of the population available to commercial gear, that is, the larger fish of the partially recruited ages.

Comparisons between observed catch-at-age and projected catch-at-age from the 2003 assessment are shown in Figure 7, and shows good correspondence. In 2003, the 1998 year-class accounted for about 38% of the catch in numbers. Canadian (Fig. 8a) and USA (Fig.8b) catch-at-length and age contributions for 2003 indicate considerable overlap in length for adjacent age groups. However, both inter- and intra-reader age comparisons show an acceptable level of precision and no evidence of bias over the age range (Table 5a, 5b and 5c). Comparison of the 2003 percent catch at age (Canada + USA) with the short term and long term average is shown in Figure 9 and shows a continuing increase in the contribution of ages 5+ in 2003 over the long-term average.

DFO survey weight-at-age shows a declining trend in recent years (Table 7, Figure 10). Values from the 2002-2003 surveys were the lowest observed for some agegroups. The trend was reversed for some agegroups in 2004 but all weights remain below the long term average. The observed value for age one in 2004 was much lower than the average (0.015 vs. 0.115 kg) and this may be the result of an atypical spawning event. Mean size at age was examined and showed a less pronounced trend for smaller length at age in recent years (Figure 11).

Condition factor and maturity stage were examined to determine if the decline in weight at age was being influenced by variation in survey timing and proximity to peak spawning. For condition factors the average weight of fish in 3 cm groupings at 43, 64 and 76 cm were calculated for the 1986-2004 DFO Georges Bank surveys. Results are shown in Figure 12 and appear to be without trend.

Analysis of average maturity stage and mean survey date was completed. Results are shown in Figure 13 and indicate a range of about 30 days between the earliest and latest mean survey date. Since 1995, survey timing has been less variable but the 2004 survey is the earliest in the time series. Mean maturity stage (<6 pre-spawning; 6 spawning; >6 post-spawning), shows a trend towards more pre-spawning fish over the survey history, probably associated with closer co-incidence in peak spawning and date of the survey. In general, the decline in weight at age would not appear to be a consequence of variation in maturity condition. However, higher proportion of pre-spawning fish seen in 2004, and associated higher total weight, would be expected to have an impact on mean weight at age of adults in 2004.

INDICES OF ABUNDANCE

Research Surveys

Hunt (1990) describes the approach used to estimate mean catch per tow specific to the 5Zj,m area for Canadian and USA surveys. Only sets within the 5Zj,m area were used, with stratum areas adjusted to conform to the 5Zj,m boundary. Vessel and gear conversion factors, reported by Serchuk *et al*. 1994, were used to adjust results of the USA surveys conducted by the RV *Delaware II* to RV *Albatross IV* equivalents and to account for a change in trawl doors in 1985. The impact of vessel conversion factors was reported by Hunt and Buzeta (1996). The Canadian survey was initiated in 1986, while the USA autumn survey started in 1963 and the USA spring survey began in1968. The USA spring survey has used two different bottom trawls over the 1978-2004 time period. The Yankee #41 trawl was used between 1978 and 1981, and the Yankee #36 trawl has been used since 1982. No conversion factors are available to account for potential differences in catchability between trawls and therefore the two series were considered as separate indices in the ADAPT model.

Catch in numbers and weight for the 2001-2004 DFO surveys show a decrease from that observed in 2000 (Table 8). The highest catch rates occurred in the Canadian zone in the 5Zj area along the northern edge. The 2004 catch distribution pattern (shown as box symbols in Figure 14a) was similar to the average (shown as density contours in Figure 14a), however DFO stratum 5Z2 (Figure 1b) accounts for most of the survey biomass. A substantial variation exists in the contribution of DFO stratum 5Z2 (NE part of the Bank in the Canadian zone, Figure 15a). Single large sets of over 2 t of cod had a strong influence on the average catch per tow in both 2001 and 2002 but were not evident in 2003 or 2004.

Total catch in numbers for the 2004 NEFSC spring survey indicates an increase over 2002 and 2003, primarily due to the 1998,1999 and 2000 year classes (Table 8). The 2004 catch distribution is fairly dispersed with larger catches occurring in NEFSC strata 16 and 21 (Fig 14b and Fig.1c). The highest percent of total biomass of cod in the 5Zj,m strata occurred in the eastern part of stratum 21 (Fig.15b). Total catch in numbers for the 2003 NEFSC autumn survey indicates a decrease from that observed during 2002 for all age groups (Table 8). The 2003 autumn catch distribution is primarily along the Northern Edge (Fig. 14c) and similar to the average (1998-2002) density. The highest biomass occurred in both strata 21 and 16, which has been seen historically, however, a substantial amount of biomass also occurred in strata 19 which is unusual (Fig. 15c).

The research vessel surveys were assigned a decimal year value (DFO=0.16, NMFS spring 0.29, NMFS fall 0.69) to correspond to the season in which the survey was conducted. This eliminated the requirement to lag the NMFS fall survey as an index of beginning of year abundance for use in the ADAPT formulation.

Catch per tow in numbers at age for the three surveys is shown in Figure 16. Some year effects are apparent in the data (1982 NMFS spring, 2003 NMFS fall, 1997 DFO, etc) but overall year-class progression and relative abundance is consistent. While not estimated in the assessment, the 2003 year-class at age one is evident in both the 2004 DFO and NMFS survey.

The three survey indices for ages 3+ biomass, adjusted by the estimated average catchability (Q's) at age from recent ADAPT formulations (Gavaris, 1988) are shown in Figure 17. In general, all three surveys appear to provide a consistent index. The DFO surveys show a decline between 1990 and 1995, a substantial increase in 1996, a decline in 1997 and 1998, followed by an increase in 1999 and 2000 and a decrease to lowest observed values in 2003 and 2004. The NMFS fall survey catch per tow remained at a low and stable level between 1994 and 2001 but increased to an anomalously high level in 2002 and subsequently returned to a low value in 2003. The NMFS spring survey has been increasing slightly since 2001 with a substantial increase between 2003 and 2004.

Estimates of recruitment at age two from the surveys are shown in Figure 17 as population numbers derived from catch per tow, adjusted by catchability factors. The index of recruitment of the 1996 year-class is similar to the 1990 year-class. Overall, recruitment remains well below the average. The DFO and NEFSC spring survey caught relatively high numbers of age one cod (2003 year-class) but these fish were small in size and could be associated with an unusual fall spawning event.

Commercial Fishery Catch Rates

The mobile gear catch rate was used as an index of abundance in the 1995 DFO evaluation of cod in 5Zj,m (Hunt and Buzeta, 1995). However, the reduced TAC and bycatch limitations imposed since 1995 and the change from a directed to a bycatch fishery preclude use of catch rates as an indicator of abundance. Effort information for the longline fleet was not collected in 1994 and therefore catch rates for this fleet sector in 1994 are not available.

The number of Canadian vessels, by gear sector, for the 1990-2003 time period are shown in Figure 18. Overall, the number of vessels participating in the fishery declined between 1990 and 1995 with an increase in again 1996. Most of this increase was due to the addition of about 20 tonnage class one longline vessels in 1996. The number of vessels has remained relatively stable since 1996.

Landings per day fished declined for all three gear sectors but has remained relatively constant between 2000 and 2004 with some seasonal variability (Figure 19a). Generally, catch rates are higher for the fixed gear sector compared to the mobile gear sector.

Fishers continue to report difficulty in avoiding areas of cod abundance. Substantial changes to fishing practices have been required to ensure that cod allocations are not overrun in advance of taking haddock allocations.

Landings of cod taken by the USA fishery in 5Zj,m are almost exclusively caught by otter trawl, primarily during the 2^{nd} calendar quarter (O'Brien and Munroe 2001). Since 1994, the majority of vessels fish near the northwest corner of Closed Area II, and since 2000, vessels are also fishing near the southwest corner of Closed Area II. A preliminary measure of fishery performance of otter trawl gear was estimated by summing catch and effort for vessels in this area during 1990-2003. The data were not standardized for any variable, i.e. tonnage class, season, depth. Fishery performance (t/day fished) indicates a declining trend from 1990 to 1995 and then a generally increasing trend to 2003 (Fig.19b). This estimate is not a true indicator of abundance but more an indicator of localized aggregations and is influenced by the movement of cod across the western boundary of the closed area.

Longline Research Survey

A longline research survey of the Georges Bank area was initiated in 1995 using a box design with one set in each selected box. A detailed description of methods, results and comparison of the annual results with Sequential Population Analysis (SPA) population estimates is reported in Johnston and Hunt (1999) and by Hunt and Hatt (2001). Results for 1996-2003 standardised catch in weight and numbers are shown in Figure 20. A general increase in catch rates is evident from 1999 to 2002 followed by a decline between 2002 and 2003. A further analysis of the survey results was completed in an attempt to reduce inter-annual varaiblity associated with changes in set coverage. Annual catches for each sampled location were standardized to the 1996-2003 mean for the same location and an overall mean determined (Figure 20).

Utility of the survey as an indicator of changes in stock abundance was considered at the benchmark review (TRAC, 2002a). It was concluded that the trend from the survey showed consistency with population trends but that the uncertainties associated with conformity to the experimental design and the limited spatial coverage of the survey precluded using the longline index within the ADAPT formulation. The survey may provide some supplemental information if it continues to be conducted in the future but it is considered to have limited analytical merit.

Partial Recruitment to the Fishery

Investigation of partial recruitment was completed in the benchmark review (TRAC, 2002a) and it was concluded that a change in partial recruitment associated with fishing patterns and seasons had occurred (Hunt and Hatt, 2002).

ESTIMATION OF STOCK PARAMETERS

The adaptive framework (Gavaris 1988) was used to calibrate the Sequential Population Analysis with the three research survey age-specific indices of abundance. The integrated formulation used the following data:

$C_{a,y}$ = catch
a=1 to 10, y=1978 to 2003

$I_{1,a,y}$ = USA fall survey
a=1 to 5 y=1978.69 to 2003.69
$I_{2,a,y}$ = USA spring survey (Yankee #41 trawl)
a=1 to 8, y=1978.29 to 1981.29

$I_{3,a,y}$ = USA spring survey (Yankee #36 trawl)
a=1 to 8, y=1982.29 to 2004.29 (includes the current year results)

$I_{4,a,y}$= Canadian spring survey
a=2 to 7, y=1986.16 to 2004.16 (includes the current year results)

$\theta_{a,t'} = \ln \text{ population abundance}$ for ages *a* = 2, 3 ... 10 at time $t' =$ 2004
$\kappa_{s,a} = \ln \text{ calibration constants}$ for each abundance index source *s*, and ages, *a*.

A solution for the parameters was obtained by minimizing the sum of squared differences between the natural logarithm observed abundance indices and the natural logarithm population abundance adjusted for catchability by the calibration constants. The objective function for minimization was defined as

$$\Psi_{s,a,t}\left(\hat{\theta},\hat{\kappa}\right)=\sum_{s,a,t}\left(\psi_{s,a,t}\left(\hat{\theta},\hat{\kappa}\right)\right)^2=\sum_{s,a,t}\left(\ln I_{s,a,t}-\left(\hat{\kappa}_{s,a}+\ln N_{a,t}\left(\hat{\theta}\right)\right)\right)^2$$

For convenience, the population abundance $N_{a,t}\left(\hat{\theta}\right)$ is abbreviated by $N_{a,t}$. At time t', the population abundance was obtained directly from the parameter estimates, $N_{a,t'} = e^{\hat{\theta}_{a,t'}}$. For all other times, the population abundance was computed using the virtual population analysis algorithm, which incorporates the common exponential decay model

$$N_{a+\Delta t,t+\Delta t} = N_{a,t}e^{-\left(F_{a,t}+M_a\right)\Delta t} \quad .$$

Partitioning of the USA spring survey was introduced in 1998 to account for a change in the survey trawl in 1982. Experimentally derived conversion factors between the two trawl types for cod are not available and further investigation of trawl gear and vessel effects may be required.

The survey indices were compared to beginning of year population abundance. Natural mortality was assumed constant and equal to 0.2 for all age groups. Beginning of year 2004 population estimates were dervied for ages 2-10 with the population number at ages 0 and 1 set equal the average of 1993 to 2003 values. The fishing mortality rate on age 10 for 1999-2003 was estimated from the SPA model. The fishing mortality rate on age 10 for 1978-1998 was calculated as the weighed average for ages 8 to 9 in the same year. Errors in the catch-at-age were assumed negligible relative to those for the abundance index. The errors for the log transformed abundance index were assumed independent and identically distributed.

ADAPT was used to solve for the parameters using the techniques described by Gavaris (1988) and Hunt and Johnson (1999). Parameter estimates and associated precision were derived using a bootstrap (1,000 replicates) statistical technique.

ASSESSMENT RESULTS

Parameter estimates, bias adjustment and standard error derived from the above ADAPT formulation are given in Table 9. Population parameter estimates for 2004 have a relative error of 33% to 48% for ages 3 to 10. Estimates of the 2002 year-class at age 2 were not statistically significant. In general, catchabilities for survey indices show a flat topped selection at ages 4 and older. Catchabilities were highest for the DFO spring survey, followed by the NMFS spring surveys and the NMFS fall survey.

There appear to be some year effects in the residuals for survey indices (Figure 21), particularily for the NEFSC fall 2003 and NEFSC 2004 spring surveys. However, residuals by age for all three surveys appear to be reasonably well balanced and without trend within cohorts. The relatively high number of positive residuals for NEFSC surveys prior to 1985 may be a function of trawl door conversion factors. As noted above, preliminary analysis of the impact of trawl door conversion has been completed but further work is required before alternative conversion factors can be recommended.

The decline in adult stock biomass (ages 3+) between 1990 and 1995 was substantial, and the biomass was the lowest observed in 1995 at 8,600 t (Figure 22, Table 10). However, the biomass shows a gradual increase from 1995 to about 18,700 t in 2001. A decrease in biomass occurred since 2001 and it is estimated to be about 13,900 t (80% confidence interval : 11,500 to 17,400 t) at the beginning of 2004. Much of this decrease is associated with the low weight-at-age from recent DFO surveys. About 35% of the 2004 biomass is comprised of ages 8-10 and biomass remains well below the long term average of over 30,000 t.

Fishing mortality on ages 4-6 is considered to be representative of average exploitation rate. Exploitation (Table 10) increased rapidly between 1989 and 1991 and was over three times the F_{ref}= 0.18 level in 1991-93. The decline that began in 1994 is consistent with reduced effort. Fishing mortality in 1995 was near the F_{ref} level. The rate of exploitation for the stock has been over 30% for most of the time series, above 50% in 1991-93, close to the F_{ref} level of about 15% in 1995, but between 16%-23% in recent years (Figure 23). The F_{2003} is estimated to be 0.283 (80% confidence interal of 0.25 to 0.41) and a corresponding 22% exploitation rate.

The reduced exploitation starting in 1995 has resulted in improved survival of the 1992 and 1995 year-classes and increased the relative contribution of ages 5 and older (Figure 24). The higher mean weight-at-age and survival associated with these older fish has generated most of the increased stock biomass but reflects growth rather than recruitment.

Recruitment since the 1990 year-class has been below the time series average (6.3 million age 1 fish). The 1996 and 1998 year-classes show some improvement to the recent average recruitment. Subsequent year-classes show very poor recruitment prospects (Figure 22 and Table 10).

RETROSPECTIVE ANALYSIS

Retrospective analysis of F and population biomass indicates that F in the mid-1990's was under-estimated and abundance over-estimated relative to current estimates (Figure 25). A reverse trend to under-estimate initial year-class size is evident for abundance at age one and is most pronounced for the 1999 year-class. The retrospective pattern seen in this assessment is similar to that seen in the 2003 assessment results (Hunt *et al*., 2003) .

YIELD PER RECRUIT ANALYSIS

Hunt and Johnson (1999) reported on a yield per recruit analysis using average mean weight-at-ages 1-15 and partial recruitment reflecting the recent 1995-98 trend in the fishery. They reported an $F_{0.1}$ fishing mortality of 0.199, however recent bi-lateral discussions with the USA recommended a value of F_{ref} of 0.18 and this was used as a reference level.

PROGNOSIS

Catch projections were completed using the bias-adjusted beginning of year population abundance for 2004 derived from ADAPT. Partial recruitment was derived from the 2000-2002 fishing mortality matrix (Table 10), to reflect changes in PR associated with both gear and season. Mean (2001-2003 fishery) and beginning of year (2002-2004 RV survey) weights-at-age were used to reflect the recent weights-at-age. Recruitment for 2003 and 2004 age one was set to the 1999-2003 average of 2.3 million (Table 11).

Yield projection at F_{ref} for 2004-2005 with an expected catch in 2004 of 1,300 t indicates a **combined** Canada/USA 2005 yield of about 1,110 t. Details of the projection are given in Table 11 and Figure 26 and 27. There is about a 20% relative error associated with the projected catch. The 1998 year-class at age 6 is expected to account for about 25% of the catch biomass in 2005.

Adult biomass levels and subsequent **recruitment** abundance-at-age 1 are compared in Figure 28 for the 1978-2003 time period. Recruits appear to have a positive correlation with biomass and the probability of good recruitment increases at higher biomass levels. The projected 2004 adult biomass of 13,900 t is well below the threshold stock size (25,000t) at which improved recruitment would be expected to occur. Rebuilding to increase the adult biomass would enhance the prospects for the future. The relationship between recruits and adult biomass (Figure 29) shows a decline since 1996 indicating poorer survivorship.

Gains in fishable biomass may be partitioned into those associated with somatic growth of cod which have previously recruited to the fishery and those associated with new recruitment to the fishery (Rivard 1980). Over the long term, over 80% of the total stock production (Figure 30) has been derived from growth and the rest has come from recruitment. In recent years, due to weak recruitment, the amount due to growth has increased and is now over 90% of the total.

Yields from the fishery have exceeded surplus production in some years (Figure 31), particularily in the early 1990's. Low productivity since 2001 and current catches have resulted in yield greater than production (growth overfishing).

With the current poor recruitment and exploitation rates near the present levels, improvement in stock status is not expected in the near term.

Cod and haddock are often caught together in the Canadian groundfish fisheries. However, their catchabilities to the fisheries differ and they are not necessarily caught in proportion to their relative abundance. Exploitation of haddock at F_{ref} levels with current fishing practices may compromise the achievement of rebuilding objectives for this cod stock.

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Table 1. Nominal landings(t) of cod by year, gear and month for Canada in unit areas 5Zj,m for 1995-2003. (see Hunt and Hatt (2000) for 1978-1994 landings detail.)

YEAR	GEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
1995	Gillnet						17.3	39.4		69.7				126.4
	Longline						116.3	162.7	122.5	97.6	19.9	20.3	6.7	545.9
	Misc[1]	1.6	3.7	4.3	4.6	4.4	4.6	7.7	2.9	0.6	0.1	0.0		34.6
	Mobile	1.0					100.2	62.1	56.9	82.3	25.3	41.1	24.4	393.4
1995	Total	2.6	3.7	4.3	4.6	4.4	238.4	271.9	182.3	250.2	45.3	61.4	31.1	1100.3
1996	Gillnet						25.8	137.5	81.3					244.5
	Longline						28.8	389.0	290.3	91.0	136.9	65.5	21.4	1023.0
	Mobile	2.2					217.2	96.3	99.9	57.8	42.2	40.0	103.2	658.8
	Discards[2]													81.1
1996	Total	2.2					271.8	622.8	471.5	148.8	179.1	105.5	124.6	2007.4
1997	Gillnet						132.6	132.8	107.4	50.6	46.9			470.3
	Longline						176.6	431.8	384.8	254.8	132.0	14.7	21.2	1415.9
	Mobile						360.4	165.9	210.4	134.9	55.9	52.0	53.0	1032.5
	Discards[2]													88.6
1997	Total						669.6	730.5	702.6	440.3	234.8	66.7	74.2	3007.3
1998	Gillnet						75.7	89.6	62.8	25.1	46.4			299.6
	Longline						74.0	344.5	220.8	196.7	87.3	21.2	18.2	962.8
	Mobile						177.9	70.5	138.3	94.6	98.6	38.6	26.5	645.1
	Discards[2]													138.4
1998	Total					0.0	327.6	504.6	421.9	316.4	232.3	59.8	44.7	2045.9
1999	Gillnet						58.5	100.0	48.2	14.7	36.0	6.5	5.8	269.6
	Longline						94.7	288.1	243.7	152.4	106.7	26.5	17.2	929.4
	Mobile	3.2					226.1	156.0	46.8	71.6	58.6	37.7	19.4	619.5
	Discards[2]													84.1
1999	Total	3.2					379.3	544.1	338.7	238.7	201.3	70.7	42.4	1902.6
2000	Gillnet						55.1	76.2	28.3	23.6	40.7	9.4	4.4	237.7
	Longline						40.7	190.8	177.2	221.6	137.5	15.3	16.4	799.4
	Mobile	0.0					101.5	140.3	81.6	73.0	69.5	38.3	30.4	534.5
	Discards[2]													56.0
2000	Total	0.0					197.3	407.3	287.1	318.2	247.7	63.0	51.2	1627.6
2001	Gillnet						36.7	75.3	47.8	60.1	42.7	21.0		283.6
	Longline						62.4	211.6	273.3	282.4	229.3	61.7	16.2	1136.9
	Mobile						159.6	84.3	58.2	103.5	133.5	110.7	72.3	722.1
	Discards[2]													121.1
2001	Total						258.7	371.2	379.3	446.0	405.5	193.4	88.5	2263.7
2002	Gillnet						3.1	45.4	51.1	23.3	0.5	8.8	7.3	139.6
	Longline						1.6	150.6	198.6	161.9	126.9	30.9	29.9	700.3
	Mobile						38.2	87.0	33.5	77.6	62.2	55.3	85.5	439.4
	Discards[2]													76.6
2002	Total						42.9	283.0	283.2	262.8	189.6	95.0	122.7	1355.9
2003	Gillnet						6.3	30.4	31.4	24.2	3.0	13.7	0.7	109.7
	Longline						21.7	180.7	237.9	138.3	120.6	28.2	14.2	741.6
	Mobile						87.6	83.9	54.3	64.0	69.2	70.5	44.5	474.0
	Discards[2]													169.4
2003	Total						115.6	295.0	323.6	226.5	192.8	112.4	59.4	1494.7

[2] includes reported catch by scallop and other incidental fisheries 1978-1995

[1] estimated from Canadian scallop fishery effort

Table 2. Summary of total landings (t) by Canada and the USA in unit areas 5Zj,m for 1978-2003. Canadian values for 1996-2003 include derived estimates from scallop fishery.

	Canada			USA	Total
Year	Fishery	Discards	Total		
1978	8778			5502	14280
1979	5978			6408	12386
1980	8063			6418	14481
1981	8499			8094	16593
1982	17824			8565	26389
1983	12130			8572	20702
1984	5763			10551	16314
1985	10443			6641	17084
1986	8504			5696	14200
1987	11844			4792	16636
1988	12741			7645	20386
1989	7895			6182	14077
1990	14364			6378	20742
1991	13462			6777	20239
1992	11673			5080	16753
1993	8524			4019	12543
1994	5278			1229	6507
1995	1100			665	1765
1996	1926	81	2007	773	2780
1997	2919	89	3007	557	3564
1998	1908	138	2046	795	2841
1999	1819	84	1903	1150	3053
2000	1572	56	1628	662	2290
2001	2143	121	2264	1361	3625
2002	1279	77	1356	1382	2738
2003	1325	169	1495	1869	3364

Table 3. Canadian and USA 5Zj,m commercial landings samples for 1978-2003. At-sea observer samples are included in Canadian length samples since 1994. USA length samples are for 5Zj,m only for 1978-1995, and for 5Ze for 1996-2003 and USA 5Zj,m age samples were supplemented with DFO 5Zj,m age samples for 1996-2003.

	USA			Canada		
Year	Sample	Lengths	Ages	Samples	Lengths	Ages
1978	29	2047	385	29	7684	1308
79	21	1833	402	13	3991	656
1980	16	1258	286	10	2784	536
81	21	1615	456	17	4147	842
82	45	4111	778	17	4756	858
83	40	3775	903	15	3822	604
84	44	3891	1130	7	1889	385
85	23	2076	597	18	7644	1062
86	27	2145	644	19	5745	888
87	23	1865	525	33	9477	1288
88	37	3229	797	43	11709	1984
89	19	1572	251	32	8716	1561
1990	28	1989	287	40	9901	2012
91	23	1894	397	45	10873	1782
92	25	2048	445	48	10878	1906
93	29	2215	440	51	12158	2146
94	13	1323	260	104	25845	1268
95	-	-	-	36	11598	548
96	3	284	74(953)	129	26663	879
97	80	6638	55(1299	118	31882	1244
98	82	7076	46(1766)	139	26549	1720
99	70	6045	250(1168)	84	24954	918
2000	156	12219	41(1551)	107	20782	1436
1	108	8389	351(2423)	108	18190	1509
2	86	6306	378(1642)	91	18974	1264
3	47	2785	385(1569)	94	20199	1070

Table 4. Summary of 2003 Canadian commercial and Observer samples used to estimate catch-at-age. USA catch-at-age for 1994-2003 was provided by the USA, and based on commercial landings samples prorated by market category supplemented with Canadian age samples

GEAR	MONTH	Landings (T) MONTH	#LEN	#AGES	Landings (T) QUARTER
OTB+Misc	Jan				
	Feb				
	Mar				0
	Apr				
	May				
	Jun	88	2763	170	88
	Jul	84	703	41	
	Aug	54	1696	53	
	Sep	64	250	37	202
	Oct	69	490	74	
	Nov	70	1974	148	
	Dec+Jan/03	45	727	70	184
Total Canadian		474	8603	593	474
Total USA		1869	2875	1569	1869
Total		2343	11478	2162	2343
Longline	Jan				
	Feb				
	Mar				
	Apr				
	May				
	Jun	22	417		22
	Jul	181	1117	43	
	Aug	238	4786	192	
	Sep	138	1328	26	557
	Oct	121	2386	216	
	Nov	28			
	Dec	14	157		163
Total		742	10191	477	742
Gillnet	Jan				
	Feb				
	Mar				
	Apr				
	May				
	Jun	6	174		6
	Jul	30	712		
	Aug	31			
	Sep	24	243		86
	Oct	3			
	Nov	14	276		
	Dec	1			17
Total		109	1405		109
Age Keys	Q1				
	Q2	116	3354	170	
	Q3	845	10835	392	
	Q4	364	6010	508	
Total Canada		**1325**	**20199**	**1070**	**1325**
Total Canada + USA		**3194**	**23074**	**2639**	**3194**

Table 5a. Results of intra-reader ageing agreements

Results of intra-reader aging comparisons

Canadian samples include: qtr 1 - NED2002002 (25); qtr 2 - 20010317 (30); 20000374 (35); random 2002 (26); qtr 3 - 19990417 (33); 20000566 (24); 20020506 (25); qtr 4 - 20000826 (26); 20010944 (25); 20020643 (19); 20020608 (25).

1st Age	2nd Age - BH							
BH	2	3	4	5	6	7	8	Total
2	19							19
3	1	54	2					57
4		3	95	5	1			104
5			2	41	2			45
6				4	37			41
7					3	10	1	14
8							2	2
Total								282

DIFF		
-1	0	+1
13	258	11

CV=1.37
92% Agreement

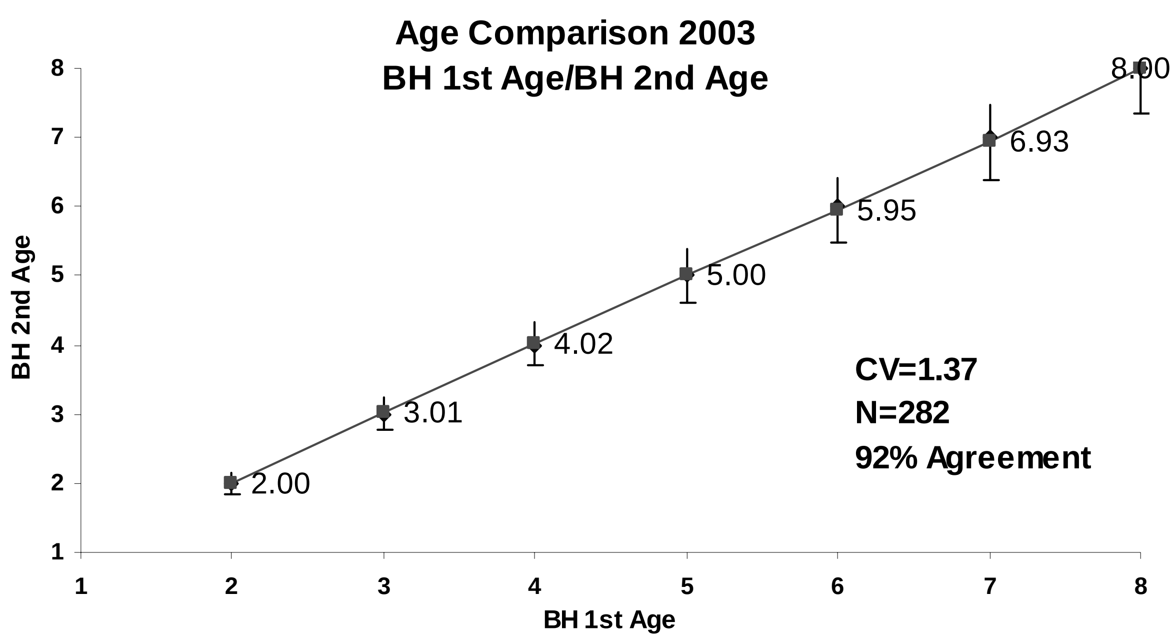

Table 5b. Results of inter-reader aging comparisons.

Results of Inter-reader (Canada vs. USA) 2003 Aging Comparisons.
Canadian exchange samples: NED2003002 RV Feb. Survey - quarter 1 (50); Canadian Commercial sample 2002 - quarter 3 & 4 - (51)
US exchange sample: US Commercial - Document 240951, Mar 2002, quarter 1 (25); US Fall Survey - AL200209, Oct. 2002, quarter 3 (52)

1st Age	**2nd Age**	**CAN**									
US	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
1	1	2									3
2		14	4								18
3			20	5							25
4			1	44	1						46
5				2	14	4					20
6				1	1	25	1				28
7						2	13	1			16
8								5	1		6
9							1	2	1	1	5
Total	**1**	**16**	**25**	**52**	**16**	**31**	**15**	**8**	**2**	**1**	**167**

	DIFF	
-1	**0**	**1**
10	**137**	**20**

CV=3.37
84% Agreement

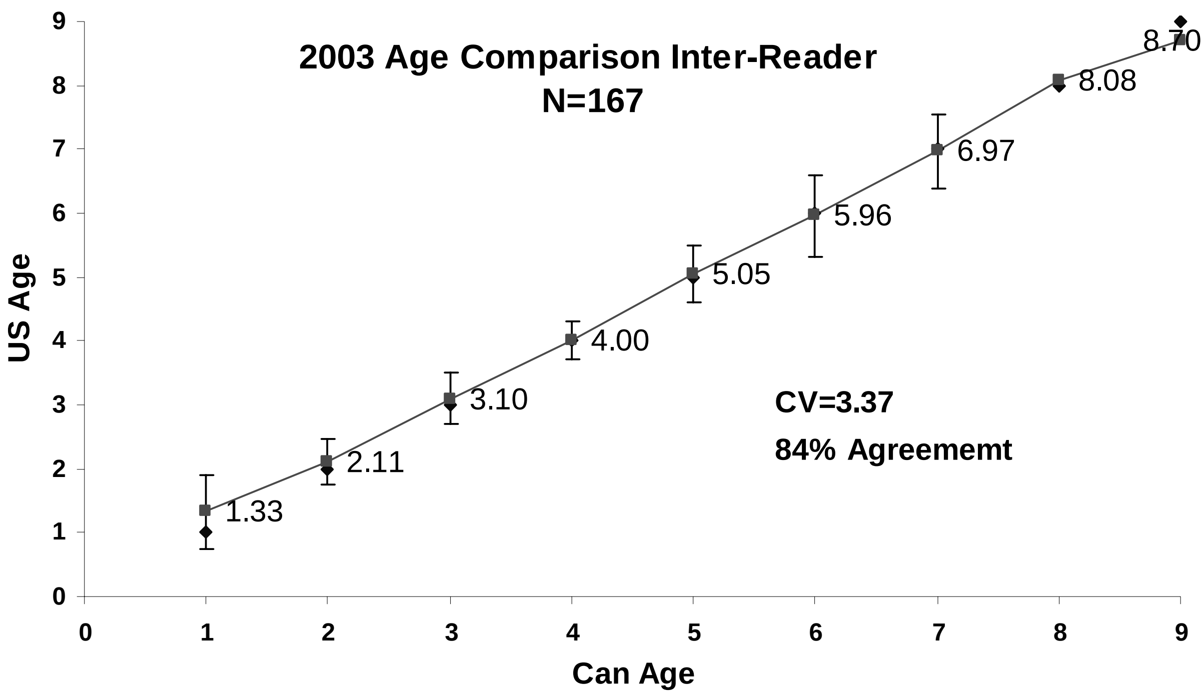

Table 5c. Results of USA age reader comparison testing against reference collection samples.

	Testee's Age										
Ref Age	1	2	3	4	5	6	7	8	9	10	Total
1	5										5
2		10	2								12
3		1	25	2							28
4			1	14		1					16
5					10						10
6						13	1				14
7							7				7
8								2			2
9									3		3
10									1	1	2
Total	5	11	28	16	10	14	8	2	4	1	99

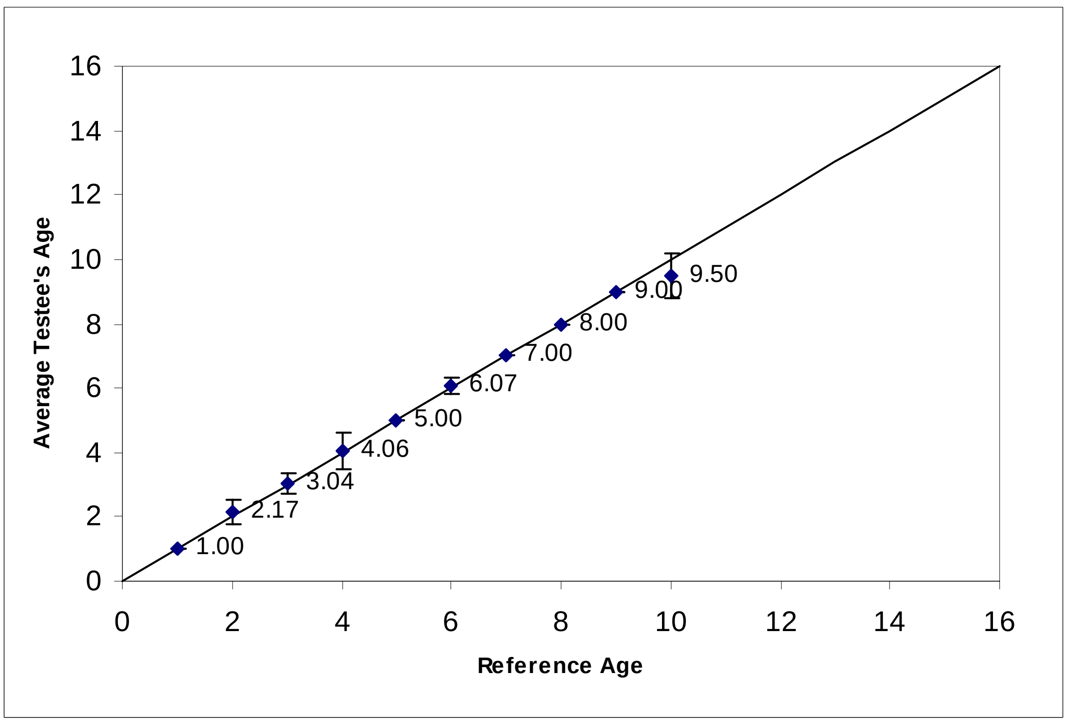

Table 6. Landings-at-age (000's) and percent at age for combined Canada and USA fishery

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1978	0	2	121	3588	1076	307	110	83	21	12	4	5323
1979	0	10	814	399	1774	545	149	22	45	4	3	3765
1980	0	1	987	1495	265	916	345	109	20	33	5	4177
1981	0	19	603	1443	1249	155	595	169	65	36	18	4352
1982	0	6	2682	1686	1429	1066	189	345	157	37	12	7609
1983	0	40	1319	3416	1474	466	283	31	71	39	6	7145
1984	0	10	269	911	1346	511	290	230	31	72	26	3697
1985	0	12	2792	1221	631	941	224	96	100	14	27	6058
1986	0	28	328	2202	516	306	403	58	39	26	4	3911
1987	0	14	3666	865	1099	144	121	167	37	24	8	6144
1988	0	10	317	3619	640	853	143	101	142	40	19	5884
1989	0	1	734	647	1823	192	312	56	25	51	12	3852
1990	0	7	680	3204	965	1198	116	122	10	14	23	6339
1991	0	11	626	783	1940	953	790	93	56	18	7	5278
1992	0	86	2353	1248	431	906	249	232	25	27	2	5559
1993	0	4	414	1968	809	215	332	110	93	23	17	3986
1994	0	2	182	486	751	246	41	59	26	20	1	1814
1995	0	0	56	235	120	89	14	4	3	2	0	523
1996	0	1	39	235	392	76	48	11	3	2	0	806
1997	0	3	108	156	288	293	71	32	10	4	1	966
1998	0	0	82	275	137	139	116	18	11	3	0	783
1999	0	2	46	422	271	80	44	41	9	1	3	920
2000	0	0	46	110	323	124	32	19	12	2	0	669
2001	0	2	17	412	195	360	93	27	16	4	0	1125
2002	0	0	8	114	363	94	139	23	7	4	1	754
2003	0	0	8	160	250	358	65	76	14	3	1	936
1978	0%	0%	2%	67%	20%	6%	2%	2%	0%	0%	0%	
1979	0%	0%	22%	11%	47%	14%	4%	1%	1%	0%	0%	
1980	0%	0%	24%	36%	6%	22%	8%	3%	0%	1%	0%	
1981	0%	0%	14%	33%	29%	4%	14%	4%	1%	1%	0%	
1982	0%	0%	35%	22%	19%	14%	2%	5%	2%	0%	0%	
1983	0%	1%	18%	48%	21%	7%	4%	0%	1%	1%	0%	
1984	0%	0%	7%	25%	36%	14%	8%	6%	1%	2%	1%	
1985	0%	0%	46%	20%	10%	16%	4%	2%	2%	0%	0%	
1986	0%	1%	8%	56%	13%	8%	10%	1%	1%	1%	0%	
1987	0%	0%	60%	14%	18%	2%	2%	3%	1%	0%	0%	
1988	0%	0%	5%	62%	11%	14%	2%	2%	2%	1%	0%	
1989	0%	0%	19%	17%	47%	5%	8%	1%	1%	1%	0%	
1990	0%	0%	11%	51%	15%	19%	2%	2%	0%	0%	0%	
1991	0%	0%	12%	15%	37%	18%	15%	2%	1%	0%	0%	
1992	0%	2%	42%	22%	8%	16%	4%	4%	0%	0%	0%	
1993	0%	0%	10%	49%	20%	5%	8%	3%	2%	1%	0%	
1994	0%	0%	10%	27%	41%	14%	2%	3%	1%	1%	0%	
1995	0%	0%	11%	45%	23%	17%	3%	1%	1%	0%	0%	
1996	0%	0%	5%	29%	49%	9%	6%	1%	0%	0%	0%	
1997	0%	0%	11%	16%	30%	30%	7%	3%	1%	0%	0%	
1998	0%	0%	10%	35%	18%	18%	15%	2%	1%	0%	0%	
1999	0%	0%	5%	46%	29%	9%	5%	4%	1%	0%	0%	
2000	0%	0%	7%	17%	48%	18%	5%	3%	2%	0%	0%	
2001	0%	0%	1%	37%	17%	32%	8%	2%	1%	0%	0%	
2002	0%	0%	1%	15%	48%	12%	18%	3%	1%	0%	0%	
2003	0%	0%	1%	17%	27%	38%	7%	8%	2%	0%	0%	
Average 1978-1990	0%	0%	21%	35%	23%	11%	5%	2%	1%	1%	0%	
Average 1991-2003	0%	0%	10%	28%	30%	18%	8%	3%	1%	0%	0%	

Table 7. Weight-at-age (kg) derived from fishery (mid-year) and from 1987-2004 DFO surveys (beginning of year) for 5Zj,m cod. (Shaded values are calculated.)

Beginning	0	1	2	3	4	5	6	7	8	9	10
1978	0.05	0.115	0.751	1.609	2.653	4.018	5.755	6.922	8.832	13.054	14.152
1979	0.05	0.115	0.751	1.609	2.653	4.018	5.755	6.922	8.832	13.054	14.152
1980	0.05	0.115	0.751	1.609	2.653	4.018	5.755	6.922	8.832	13.054	14.152
1981	0.05	0.115	0.751	1.609	2.653	4.018	5.755	6.922	8.832	13.054	14.152
1982	0.05	0.115	0.751	1.609	2.653	4.018	5.755	6.922	8.832	13.054	14.152
1983	0.05	0.115	0.751	1.609	2.653	4.018	5.755	6.922	8.832	13.054	14.152
1984	0.05	0.115	0.751	1.609	2.653	4.018	5.755	6.922	8.832	13.054	14.152
1985	0.05	0.115	0.751	1.609	2.653	4.018	5.755	6.922	8.832	13.054	14.152
1986	0.05	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307	13.864	14.152
1987	0.05	0.151	0.843	1.690	2.838	5.800	8.426	8.154	7.464	13.569	15.657
1988	0.05	0.126	0.894	1.883	3.002	4.519	6.952	9.028	9.850	13.569	15.657
1989	0.05	0.153	0.805	1.669	2.868	4.226	6.588	7.634	8.099	13.635	14.152
1990	0.05	0.204	0.787	1.896	3.075	4.581	6.336	8.307	9.491	14.919	16.104
1991	0.05	0.086	0.870	1.923	3.181	4.266	5.099	7.308	9.616	13.732	15.765
1992	0.05	0.140	0.813	1.972	3.102	4.376	6.195	7.105	8.585	17.232	14.152
1993	0.05	0.081	0.936	1.884	3.087	4.791	6.024	6.969	7.581	12.021	12.825
1994	0.05	0.076	0.655	1.439	2.865	4.340	7.591	8.091	11.428	16.162	14.152
1995	0.05	0.146	0.798	1.567	2.225	3.535	5.132	6.204	7.275	14.856	17.550
1996	0.05	0.052	0.729	1.647	2.699	4.124	6.250	5.662	11.000	14.090	15.553
1997	0.05	0.100	0.725	1.762	2.352	3.434	6.564	7.529	10.996	13.680	16.935
1998	0.05	0.102	0.620	1.349	2.461	3.312	4.811	5.931	8.386	9.896	11.509
1999	0.05	0.151	0.999	1.414	2.425	3.317	4.848	7.116	11.222	13.319	14.152
2000	0.05	0.118	0.905	1.608	2.423	3.276	4.854	6.189	7.984	14.441	14.630
2001	0.05	0.120	0.735	1.500	2.596	3.901	5.311	7.191	7.512	10.847	10.923
2002	0.05	0.120	0.423	1.175	2.306	3.592	4.412	5.952	8.436	10.001	11.842
2003[1]	0.05	0.120	0.695	1.032	1.787	3.090	3.480	5.237	6.807	7.662	14.152
2004[2]	0.05	0.015	0.228	1.455	2.340	3.668	4.263	4.592	6.774	10.535	9.030
1986-2004	0.050	0.115	0.751	1.609	2.653	4.018	5.755	6.922	8.832	13.054	14.152
2002-2004	0.050	0.085	0.449	1.221	2.144	3.450	4.052	5.260	7.339	9.399	11.675

[1] No DFO age 2 value, replaced with NEFSC spring value

[2] small size at age 1 may be due to atypical spawning event

Mid-year	0	1	2	3	4	5	6	7	8	9	10
1978	0.05	0.707	1.310	2.461	3.469	4.336	5.787	7.374	8.492	11.785	13.624
1979	0.05	0.889	1.494	2.149	4.211	4.888	7.178	9.183	10.313	11.699	14.064
1980	0.05	0.836	1.460	2.468	3.668	5.647	6.676	8.390	9.089	8.432	14.351
1981	0.05	0.882	1.495	2.358	3.415	5.213	7.222	8.565	9.888	14.170	13.574
1982	0.05	0.765	1.402	2.664	3.834	5.352	6.511	9.363	9.897	12.503	13.680
1983	0.05	0.971	1.490	2.377	3.309	4.637	6.393	7.964	10.286	11.227	12.209
1984	0.05	1.053	1.635	2.451	3.619	5.083	6.582	8.909	10.104	11.303	13.792
1985	0.05	0.907	1.418	2.086	3.887	5.087	6.412	8.097	10.236	11.418	12.724
1986	0.05	0.929	1.475	2.447	3.660	5.603	7.191	8.915	9.955	12.687	8.913
1987	0.05	0.726	1.481	2.495	4.187	5.810	7.726	8.949	10.013	11.414	13.928
1988	0.05	0.786	1.520	2.359	3.511	5.401	6.647	8.776	9.987	11.143	13.166
1989	0.05	0.809	1.617	2.269	3.772	5.396	6.694	8.222	10.718	11.665	14.143
1990	0.05	0.831	1.560	2.462	3.522	4.892	6.333	8.456	10.648	12.580	14.043
1991	0.05	1.114	1.627	2.548	3.420	4.769	5.891	7.410	10.520	9.686	14.521
1992	0.05	1.148	1.542	2.464	3.843	4.704	6.156	7.509	9.846	12.059	14.521
1993	0.05	0.883	1.571	2.308	3.079	4.496	5.729	7.075	8.884	9.699	10.858
1994	0.05	0.906	1.457	2.409	3.830	4.804	7.092	7.862	8.934	9.698	10.374
1995	0.05	0.900	1.489	2.507	3.723	5.224	6.522	11.055	10.118	10.383	14.521
1996	0.05	1.034	1.538	2.358	3.337	5.237	6.358	6.916	8.455	12.883	10.514
1997	0.05	0.978	1.498	2.232	3.339	4.254	5.797	8.048	8.330	11.870	14.521
1998	0.05	0.629	1.483	2.373	3.193	4.270	5.827	6.990	8.298	12.684	11.815
1999	0.05	0.796	1.554	2.286	3.527	4.164	6.310	6.775	8.043	12.153	13.536
2000	0.05	0.866	1.458	2.128	3.075	4.230	4.923	6.200	7.344	8.267	12.974
2001	0.05	0.880	1.488	2.334	2.998	4.053	5.122	5.081	8.019	9.224	14.812
2002	0.050	0.551	1.419	2.266	3.076	4.301	5.065	6.746	8.278	8.822	8.458
2003	0.050	0.262	1.662	2.150	2.675	3.682	4.353	5.674	7.289	7.859	9.017
1978-2003	0.050	0.848	1.505	2.362	3.507	4.828	6.250	7.866	9.307	11.051	12.794
2001-2003	0.050	0.565	1.523	2.250	2.916	4.012	4.847	5.834	7.862	8.635	10.763

Table 8. DFO and NEFSC survey indices of abundance (catch/standard tow in numbers)

DFO Feb-Mar	1	2	3	4	5	6	7	8
1986.16	1.78	8.19	7.41	0.77	1.60	1.03	0.51	0.08
1987.16	0.12	4.31	1.55	1.81	0.39	0.21	0.44	0.21
1988.16	0.36	1.08	12.85	1.36	2.02	0.23	0.19	0.43
1989.16	0.84	5.22	1.84	4.11	0.62	0.80	0.10	0.20
1990.16	0.25	1.91	8.36	4.70	10.60	1.29	2.63	0.35
1991.16	2.83	2.43	3.40	3.93	2.06	2.87	0.36	0.60
1992.16	0.11	4.93	2.94	0.99	1.55	1.09	0.72	0.22
1993.16	0.07	0.85	4.15	1.50	0.89	1.82	0.66	0.64
1994.16	0.03	1.51	1.66	3.10	1.15	0.44	0.88	0.20
1995.16	0.08	0.45	2.99	1.82	1.25	0.45	0.11	0.16
1996.16	0.22	0.49	4.20	10.44	3.45	2.49	1.07	0.26
1997.16	0.07	0.90	1.37	3.19	3.04	0.52	0.12	0.08
1998.16	0.01	1.42	2.04	0.79	0.77	0.58	0.14	0.07
1999.16	0.01	0.38	3.12	2.63	1.08	0.76	0.46	0.02
2000.16	0.00	1.02	3.12	11.96	5.19	2.48	1.23	0.76
2001.16	0.01	0.09	1.93	1.25	3.35	1.55	0.80	0.54
2002.16	0.00	0.28	1.15	5.05	1.67	3.09	1.10	0.45
2003.16	0.00	0.02	0.48	1.23	2.09	0.47	0.53	0.17
2004	1.03	0.10	0.59	0.91	1.02	0.86	0.14	0.26

NMFS fall	1	2	3	4	5
1978.69	2.64	0.26	5.10	0.73	0.11
1979.69	2.96	2.93	0.21	2.71	0.44
1980.69	1.43	0.76	1.21	0.05	0.35
1981.69	4.24	2.19	1.69	0.48	0.02
1982.69	1.05	1.29	0.08	0.12	0.00
1983.69	0.12	0.42	0.89	0.05	0.03
1984.69	2.84	0.14	1.03	1.68	0.05
1985.69	0.39	1.80	0.30	0.03	0.00
1986.69	5.20	0.11	0.35	0.00	0.00
1987.69	0.24	1.53	0.23	0.19	0.00
1988.69	1.02	0.33	2.13	0.25	0.44
1989.69	0.72	1.68	0.28	0.77	0.10
1990.69	0.72	0.79	1.49	0.21	0.37
1991.69	0.36	0.13	0.16	0.02	0.06
1992.69	0.37	1.31	0.28	0.00	0.07
1993.69	0.14	0.19	0.28	0.03	0.00
1994.69	0.14	0.54	0.39	0.28	0.14
1995.69	0.05	0.22	0.54	0.12	0.05
1996.69	0.56	0.15	0.56	0.41	0.10
1997.69	0.29	0.70	0.32	0.10	0.15
1998.69	0.32	1.29	0.90	0.12	0.20
1999.69	0.03	0.03	0.45	0.22	0.06
2000.69	0.10	0.37	0.12	0.16	0.08
2001.69	0.13	0.31	0.37	0.07	0.11
2002.69	0.26	1.24	2.29	3.44	0.35
2003.69	0.00	0.05	0.16	0.18	0.07

NMFS spring Y41	1	2	3	4	5	6	7	8
1978.29	0.27	0.00	5.10	1.12	1.61	0.34	1.37	0.19
1979.29	0.69	2.65	0.22	2.57	1.00	0.34	0.17	0.22
1980.29	0.03	2.96	2.90	0.28	3.01	0.59	0.12	0.08
1981.29	1.70	1.57	2.43	1.73	0.07	0.60	0.31	0.12

NMF Spring Y36	1	2	3	4	5	6	7	8
1982.29	0.79	11.58	24.99	22.29	16.98	0.00	5.55	1.24
1983.29	0.69	3.63	6.33	1.36	1.06	0.66	0.28	0.11
1984.29	0.20	0.22	0.81	1.22	0.48	0.39	0.34	0.00
1985.29	0.08	3.67	1.15	1.92	2.75	0.60	0.35	0.45
1986.29	1.13	0.62	2.05	0.55	0.78	0.98	0.05	0.21
1987.29	0.00	2.17	0.46	0.98	0.00	0.34	0.28	0.06
1988.29	0.58	0.45	5.05	0.50	0.84	0.08	0.03	0.14
1989.29	0.21	1.55	0.47	2.39	0.46	0.54	0.07	0.06
1990.29	0.13	0.62	3.14	1.09	1.18	0.29	0.30	0.03
1991.29	1.31	1.12	0.92	1.63	0.83	0.69	0.08	0.03
1992.29	0.14	1.20	0.65	0.17	0.45	0.27	0.29	0.05
1993.29	0.00	0.83	2.32	0.47	0.08	0.33	0.08	0.08
1994.29	0.10	0.37	0.29	0.36	0.09	0.02	0.06	0.00
1995.29	0.09	0.52	1.64	0.88	1.63	0.35	0.47	0.06
1996.29	0.25	0.54	1.78	2.41	0.22	0.17	0.05	0.00
1997.29	0.10	0.37	0.11	0.73	0.93	0.10	0.23	0.10
1998.29	0.00	1.99	3.80	1.91	1.88	1.17	0.06	0.06
1999.29	0.04	0.24	1.24	1.14	0.66	0.31	0.18	0.06
2000.29	0.00	0.55	1.16	2.43	0.89	0.25	0.09	0.04
2001.29	0.00	0.15	1.54	0.24	0.62	0.19	0.00	0.01
2002.29	0.01	0.20	0.93	2.03	0.39	0.40	0.12	0.00
2003.29	0.00	0.29	0.78	1.59	1.69	0.16	0.16	0.01
2004	0.99	0.05	1.51	3.79	3.72	2.40	0.43	0.67

Table 9. Statistical properties of estimates for population abundance and survey calibration constants from 1000 Bootstrap parameter estimates for 5Zj,m cod estimated from ADAPT.

Parameter	Estimate	Standard Error	Bias	Relative Error
N[1999 10]	105.9	41.8	3.8	39%
N[2000 10]	128.1	55.6	6.5	43%
N[2001 10]	62.9	29.9	4.2	48%
N[2002 10]	140.7	67.8	11.1	48%
N[2003 10]	102.2	42.1	6.0	41%
N[2004 2]	242.4	229.3	68.1	95%
N[2004 3]	507.8	195.0	36.6	38%
N[2004 4]	931.8	329.2	46.7	35%
N[2004 5]	770.2	253.6	25.6	33%
N[2004 6]	694.5	266.2	32.6	38%
N[2004 7]	192.2	75.6	10.1	39%
N[2004 8]	353.0	134.2	16.1	38%
N[2004 9]	186.7	76.3	13.1	41%
N[2004 10]	76.9	35.9	4.8	47%
DFO-2	0.0003275	0.0000699	0.0000066	
DFO-3	0.0011393	0.0002377	0.0000106	
DFO-4	0.0016810	0.0003494	0.0000369	
DFO-5	0.0023176	0.0005088	0.0000323	
DFO-6	0.0023866	0.0005338	0.0000488	
DFO-7	0.0023199	0.0005166	0.0000842	
NMFS Fall-1	0.0001088	0.0000190	0.0000014	
NMFS Fall-2	0.0001491	0.0000273	0.0000027	
NMFS Fall-3	0.0002321	0.0000406	0.0000017	
NMFS Fall-4	0.0001570	0.0000288	0.0000009	
NMFS Fall-5	0.0001773	0.0000380	0.0000044	
NMFS Y41 Spr-1	0.0000292	0.0000148	0.0000020	
NMFS Y41 Spr-2	0.0003135	0.0001981	0.0000461	
NMFS Y41 Spr-3	0.0003907	0.0001887	0.0000319	
NMFS Y41 Spr-4	0.0004341	0.0002357	0.0000608	
NMFS Y41 Spr-5	0.0006820	0.0003542	0.0000727	
NMFS Y41 Spr-6	0.0007711	0.0003949	0.0000852	
NMFS Y41 Spr-7	0.0012456	0.0005823	0.0000887	
NMFS Y41 Spr-8	0.0015995	0.0008454	0.0001831	
NMFS Y36 Spr-1	0.0000512	0.0000113	0.0000004	
NMFS Y36 Spr-2	0.0002302	0.0000451	0.0000031	
NMFS Y36 Spr-3	0.0005993	0.0001093	0.0000033	
NMFS Y36 Spr-4	0.0008518	0.0001672	0.0000074	
NMFS Y36 Spr-5	0.0010641	0.0002185	0.0000275	
NMFS Y36 Spr-6	0.0008598	0.0001766	0.0000159	
NMFS Y36 Spr-7	0.0007731	0.0001588	0.0000238	
NMFS Y36 Spr-8	0.0006775	0.0001484	0.0000219	

Table 10. Population estimates (1000 bootstrap, bias adjusted) for 5Zj,m cod derived from ADAPT.

		Age												
Pop #s Bias Adj		0	1	2	3	4	5	6	7	8	9	10	1+	3+
	1978	11541	11051	2192	10494	3483	984	305	277	56	26	9	28869	15635
	1979	11229	9449	9046	1685	5376	1887	531	151	152	27	11	28304	9820
	1980	21128	9193	7727	6672	1021	2811	1055	301	104	84	19	28969	12067
	1981	7654	17298	7526	5437	4118	598	1480	555	148	67	39	37228	12443
	1982	5580	6266	14145	5618	3156	2251	350	679	303	63	23	32832	12443
	1983	16499	4568	5125	9168	3087	1307	892	119	249	108	19	24622	14947
	1984	5531	13509	3704	3011	4447	1212	653	476	69	140	53	27220	10061
	1985	25764	4529	11051	2790	1648	2433	535	275	185	29	50	23474	7945
	1986	8532	21094	3697	6539	1193	784	1150	238	139	62	11	34896	10116
	1987	16522	6986	17245	2731	3379	515	368	580	142	79	28	32025	7823
	1988	4612	13527	5707	10822	1460	1781	293	193	325	83	43	34191	15000
	1989	7148	3776	11066	4386	5616	623	697	112	68	140	32	26484	11674
	1990	11142	5853	3090	8398	3008	2963	339	292	42	33	69	24018	15144
	1991	3121	9122	4785	1919	4006	1598	1354	173	130	26	15	23113	9220
	1992	4264	2555	7459	3354	870	1550	462	406	59	56	5	16770	6762
	1993	2753	3491	2014	3996	1628	328	464	156	126	26	22	12229	6746
	1994	1779	2254	2855	1277	1517	611	78	87	30	21	1	8729	3622
	1995	3333	1456	1843	2173	610	571	280	28	19	2	0	6984	3684
	1996	5361	2729	1192	1459	1567	391	388	216	19	13	1	7975	4054
	1997	2031	4389	2233	941	983	931	252	274	167	13	9	10184	3571
	1998	5059	1663	3591	1731	630	546	500	143	195	128	8	9126	3880
	1999	2893	4142	1361	2866	1170	392	322	304	100	150	102	10808	5407
	2000	2305	2369	3390	1073	1967	714	249	224	212	74	122	10271	4633
	2001	872	1887	1939	2734	779	1319	473	175	166	163	59	9636	5868
	2002	260	714	1544	1573	1867	462	757	304	119	122	130	7461	5333
	2003	2809	213	584	1257	1184	1201	294	495	228	91	96	5548	4847
	2004	2800	2300	174	471	885	745	662	182	337	174	72	5930	3527
Beginning of year biomass		0	1	2	3	4	5	6	7	8	9	10	1+	3 +
	1978	577	1270	1646	16882	9243	3956	1755	1917	491	344	127	37631	34714.969
	1979	561	1086	6792	2711	14265	7581	3054	1046	1345	349	159	38387	30510
	1980	1056	1056	5802	10733	2710	11295	6074	2081	918	1101	263	42032	35174
	1981	383	1988	5651	8747	10928	2403	8517	3840	1312	875	555	44815	37177
	1982	279	720	10620	9037	8373	9046	2017	4702	2672	829	323	48339	36999
	1983	825	525	3848	14748	8190	5253	5131	821	2195	1407	269	42387	38014
	1984	277	1552	2781	4844	11799	4869	3757	3295	612	1825	756	36090	31756
	1985	1288	520	8297	4488	4372	9776	3079	1905	1630	379	708	35156	26338
	1986	427	2544	2978	11114	3321	3295	7146	1738	1297	861	156	34450	28927
	1987	826	1057	14529	4614	9591	2988	3103	4732	1061	1070	433	43177	27592
	1988	231	1709	5103	20378	4382	8050	2034	1742	3204	1128	679	48410	41598
	1989	357	576	8903	7321	16107	2634	4593	857	550	1904	453	43900	34421
	1990	557	1191	2433	15921	9249	13571	2145	2428	402	498	1107	48945	45322
	1991	156	785	4165	3690	12743	6817	6902	1264	1250	352	229	38198	33247
	1992	213	358	6065	6614	2700	6780	2860	2884	504	971	75	29811	23388
	1993	138	281	1885	7528	5026	1572	2793	1086	953	310	285	21720	19554
	1994	89	172	1870	1838	4345	2652	594	700	348	339	16	12874	10832
	1995	167	213	1471	3405	1356	2020	1438	173	138	35	1	10250	8566
	1996	268	141	869	2403	4231	1613	2423	1225	209	181	9	13305	12295
	1997	102	438	1619	1658	2313	3197	1653	2065	1838	182	154	15116	13059
	1998	253	170	2228	2335	1549	1809	2403	846	1638	1266	88	14332	11934
	1999	145	627	1360	4053	2836	1300	1561	2165	1126	1998	1445	18470	16483
	2000	115	280	3068	1724	4765	2339	1208	1384	1696	1063	1778	19306	15958
	2001	44	227	1425	4100	2021	5147	2514	1257	1245	1771	641	20349	18696
	2002	13	86	653	1848	4305	1661	3340	1810	1001	1215	1535	17455	16716
	2003	140	26	406	1298	2117	3712	1024	2590	1551	698	1362	14783	14351
	2004	140	36	40	686	2072	2731	2821	836	2282	1829	650	13983	13907
F Bias Adj		0	1	2	3	4	5	6	7	8	9	10	4-6F	4-6u
	1978	0.000	0.000	0.063	0.469	0.413	0.418	0.502	0.398	0.532	0.653	0.571	0.420	31%
	1979	0.000	0.001	0.104	0.301	0.448	0.381	0.368	0.175	0.391	0.166	0.358	0.391	30%
	1980	0.000	0.000	0.151	0.282	0.335	0.442	0.443	0.505	0.238	0.565	0.385	0.374	28%
	1981	0.000	0.001	0.092	0.344	0.404	0.335	0.579	0.406	0.650	0.877	0.720	0.386	29%
	1982	0.000	0.001	0.234	0.399	0.681	0.726	0.883	0.805	0.832	1.005	0.862	0.735	48%
	1983	0.000	0.010	0.332	0.524	0.735	0.495	0.427	0.338	0.376	0.501	0.414	0.651	44%
	1984	0.000	0.001	0.083	0.403	0.403	0.617	0.663	0.748	0.670	0.828	0.776	0.549	39%
	1985	0.000	0.003	0.325	0.650	0.543	0.550	0.611	0.481	0.890	0.768	0.873	0.569	40%
	1986	0.000	0.001	0.103	0.460	0.640	0.556	0.483	0.314	0.370	0.609	0.443	0.614	42%
	1987	0.000	0.002	0.266	0.426	0.440	0.366	0.446	0.379	0.336	0.397	0.358	0.403	30%
	1988	0.000	0.001	0.063	0.456	0.651	0.738	0.758	0.844	0.645	0.755	0.668	0.674	45%
	1989	0.000	0.000	0.076	0.177	0.439	0.411	0.669	0.775	0.510	0.509	0.509	0.438	32%
	1990	0.000	0.001	0.277	0.540	0.433	0.583	0.472	0.611	0.301	0.632	0.447	0.472	34%
	1991	0.000	0.001	0.155	0.591	0.750	1.042	1.004	0.880	0.636	1.380	0.759	0.959	57%
	1992	0.000	0.038	0.423	0.520	0.775	1.006	0.886	0.973	0.623	0.729	0.675	0.840	52%
	1993	0.000	0.001	0.254	0.764	0.768	1.232	1.476	1.433	1.592	2.913	1.817	0.934	56%
	1994	0.000	0.001	0.072	0.531	0.753	0.549	0.822	1.291	2.362	5.992	-0.426	0.674	45%
	1995	0.000	0.000	0.033	0.125	0.237	0.175	0.053	0.178	0.176	1.218	0.286	0.194	16%
	1996	0.000	0.000	0.036	0.192	0.313	0.229	0.132	0.052	0.153	0.138	0.149	0.254	20%
	1997	0.000	0.001	0.054	0.196	0.378	0.402	0.337	0.121	0.059	0.333	0.078	0.373	28%
	1998	0.000	0.000	0.025	0.188	0.263	0.312	0.267	0.129	0.053	0.022	0.044	0.274	22%
	1999	0.000	0.000	0.038	0.174	0.283	0.236	0.150	0.135	0.086	0.008	0.030	0.259	21%
	2000	0.000	0.000	0.015	0.117	0.194	0.199	0.138	0.089	0.051	0.020	0.002	0.186	15%
	2001	0.000	0.001	0.009	0.176	0.309	0.340	0.221	0.158	0.095	0.024	0.006	0.290	23%
	2002	0.000	0.000	0.005	0.079	0.229	0.236	0.209	0.078	0.050	0.028	0.008	0.230	19%
	2003	0.000	0.001	0.014	0.137	0.243	0.359	0.251	0.162	0.062	0.025	0.012	0.283	22%

Table 11. Projection results for the 2004-2008 population using bootstrap bias adjusted point estimates with a 2004 yield = the TAC of 1,300t and a fishing mortality of F_{ref}=0.18 for 2005-2008.

	Age												
Population Numbers	0	1	2	3	4	5	6	7	8	9	10		
2004	2800	2300	174	471	885	745	662	182	337	174	72		
2005	2800	2292	1883	142	357	623	520	481	140	266	140		
2006	2800	2292	1877	1530	106	246	426	372	367	110	214		
2007	2800	2292	1877	1525	1146	73	168	304	284	287	88		
2008	2800	2292	1877	1525	1142	790	50	120	232	222	231		
2009	2800	2292	1877	1525	1142	787	540	36	92	182	179		
Fishing Mortality													
2004	0	0	0.007	0.078	0.151	0.158	0.119	0.063	0.038	0.015	0.003		
2005-2008	0	0	0.008	0.089	0.172	0.18	0.136	0.071	0.043	0.017	0.004		
Natural mortality													
2004-2008	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		
Partial Recruitment													
2004-2008	0	0	0.04	0.49	0.96	1	0.75	0.4	0.24	0.09	0.02		
Begyear Weight													
2004	0.05	0.02	0.23	1.45	2.34	3.67	4.26	4.59	6.77	10.54	9.03		
2005-2009	0.05	0.09	0.45	1.22	2.14	3.45	4.05	5.26	7.34	9.4	11.67		
Projected Biomass												0+	3+
2004	140	36	40	686	2072	2731	2821	836	2282	1829	650	14123	13907
2005	140	196	845	173	765	2149	2108	2530	1028	2496	1635	14064	12883
2006	140	196	842	1867	228	848	1726	1957	2691	1032	2496	14022	12844
2007	140	196	842	1861	2457	252	681	1601	2081	2702	1032	13846	12669
2008	140	196	842	1861	2449	2724	203	632	1703	2090	2702	15543	14365
2009	140	196	842	1861	2449	2715	2188	188	673	1711	2090	15052	13874
Projected Catch Numbers													
2004	0	0	1	32	113	99	68	10	11	2	0		
2005	0	0	13	11	51	93	60	30	5	4	0		
2006	0	0	13	118	15	37	49	23	14	2	1		
2007	0	0	13	118	165	11	19	19	11	4	0		
2008	0	0	13	118	164	118	6	8	9	3	1		
Midyear Weight													
2004-2008	0.05	0.56	1.52	2.25	2.92	4.01	4.85	5.83	7.86	8.64	10.76		
Projected Catch												0+	3+
2004	0	0	2	72	330	398	328	59	90	20	2	1300	1298
2005	0	0	20	25	150	374	291	175	42	35	5	1117	1096
2006	0	0	20	266	45	148	238	135	111	14	8	985	964
2007	0	0	20	265	480	44	94	111	86	38	3	1141	1121
2008	0	0	20	265	479	474	28	44	70	29	9	1418	1398

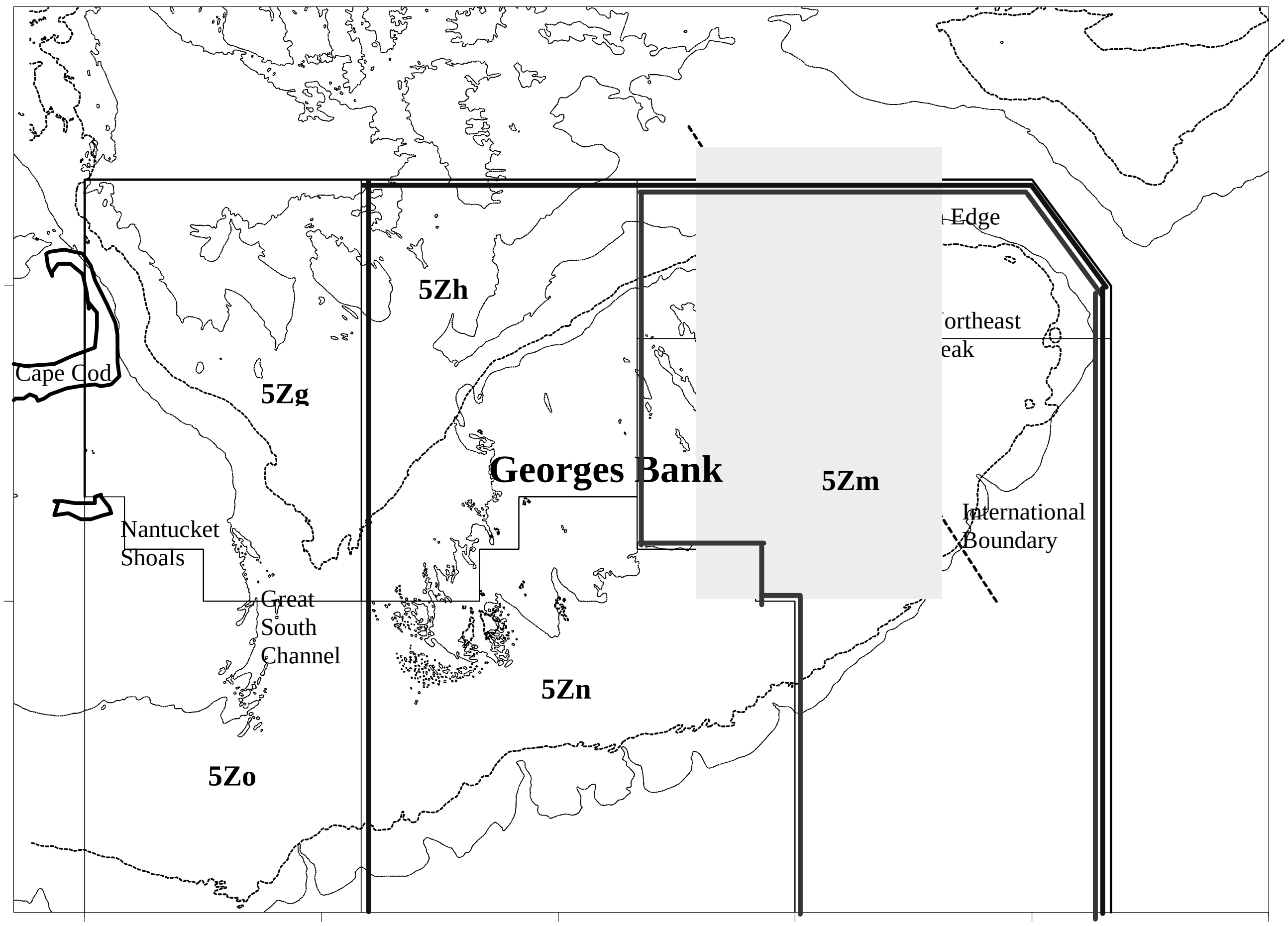

Figure 1a. Map of the Georges Bank area showing the 5Zj,m management unit. Shaded area indicates USA closed area II.

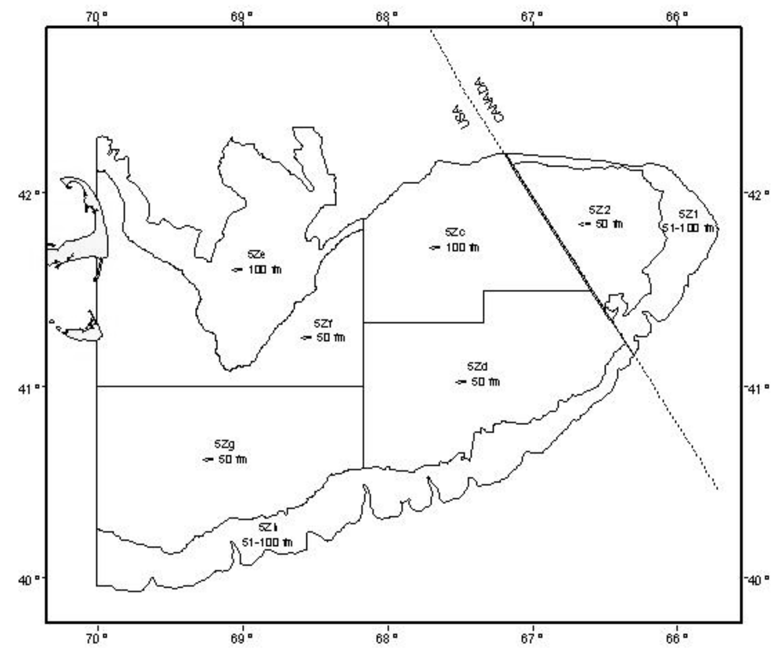

Figure 1b. DFO survey strata on Georges Bank.

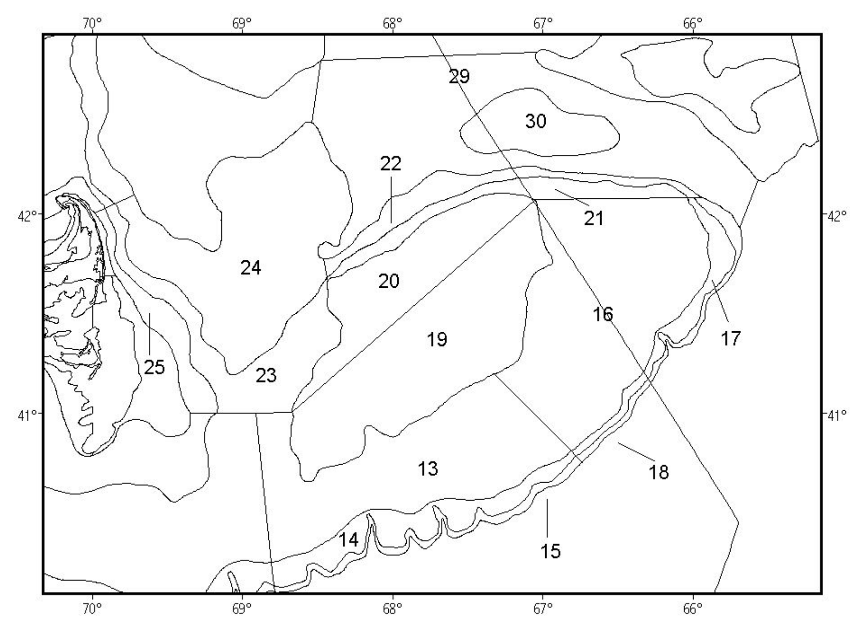

Figure 1c. NEFSC survey strata on Georges Bank.

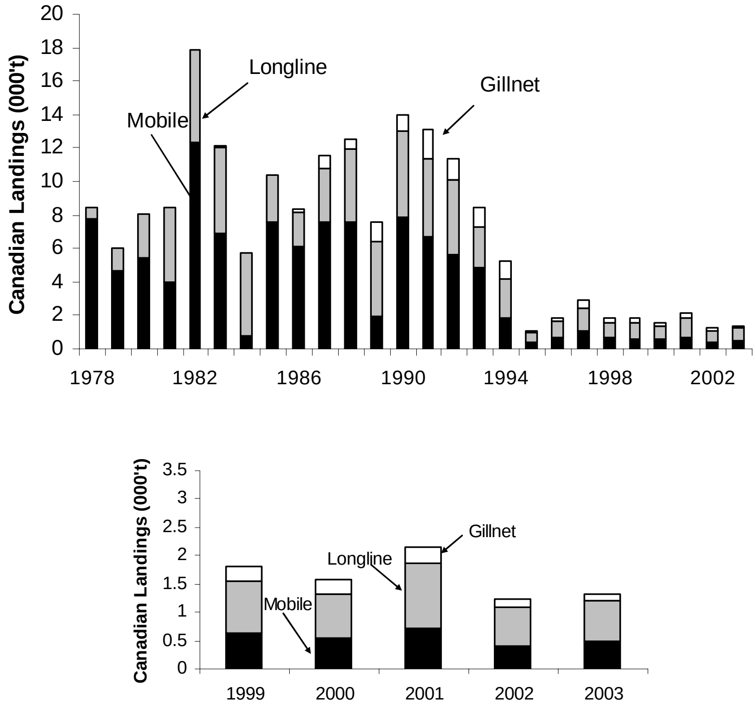

Figure 2. Landings of 5Zj,m cod by Canada gear sectors.

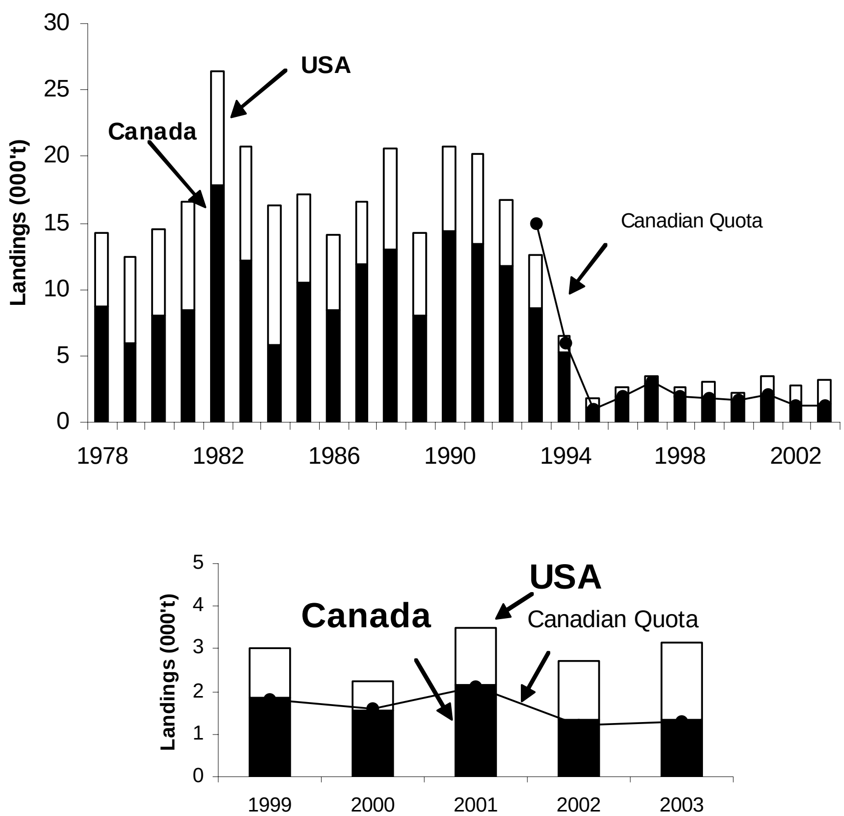

Figure 3. Landings of 5Zj,m cod by Canadian and USA fisheries.

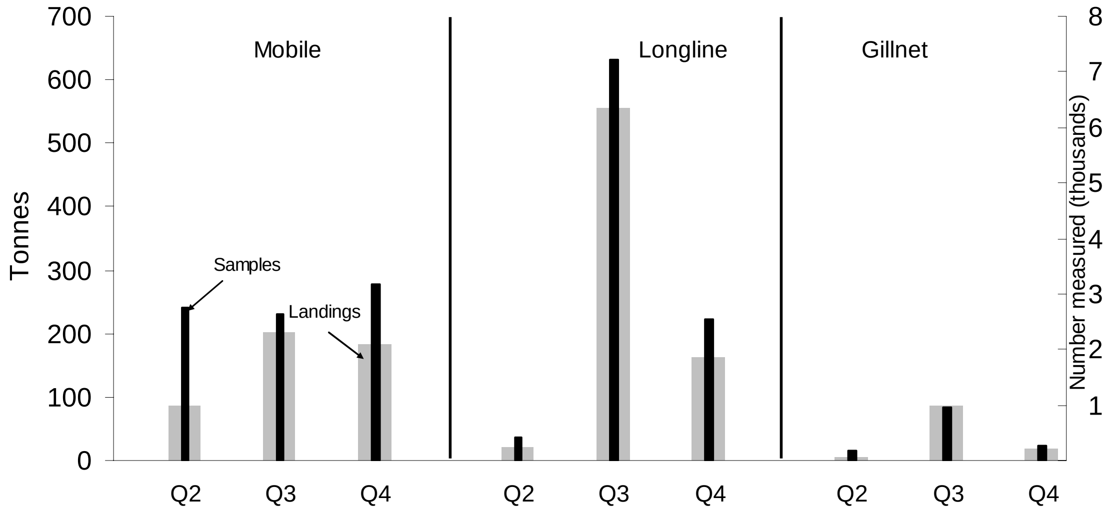

Figure 4a. Summary of Canadian landings by gear sector and corresponding length samples used in determining catch at age for 2003.

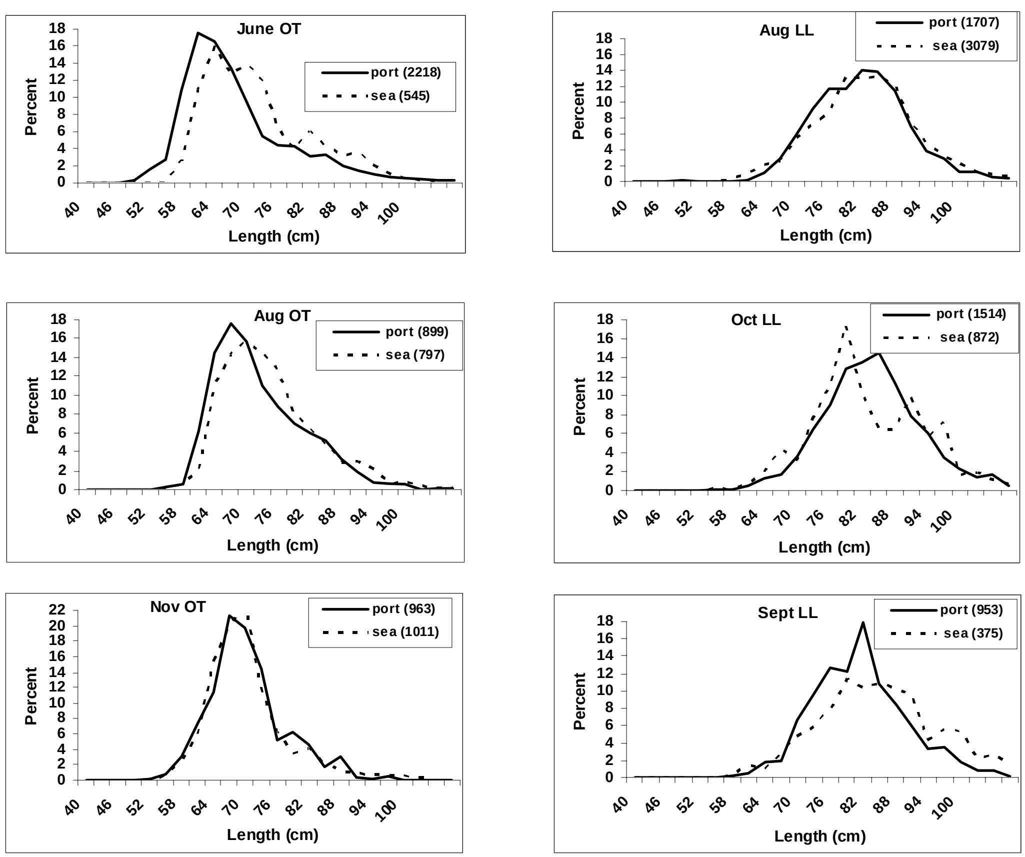

Figure 4b. Comparison of Canadian 2003 length frequency distributions from sea (catch) and on-shore (landings) samples.

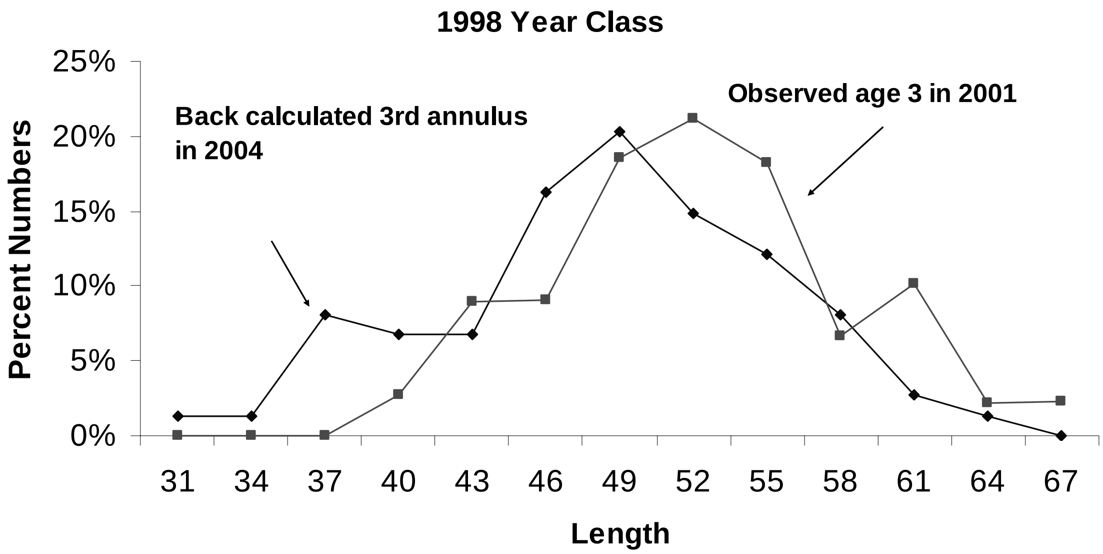

Figure 5. A back calculated analysis of the February 2004 Georges Bank research survey otoliths used to quantify aging results.

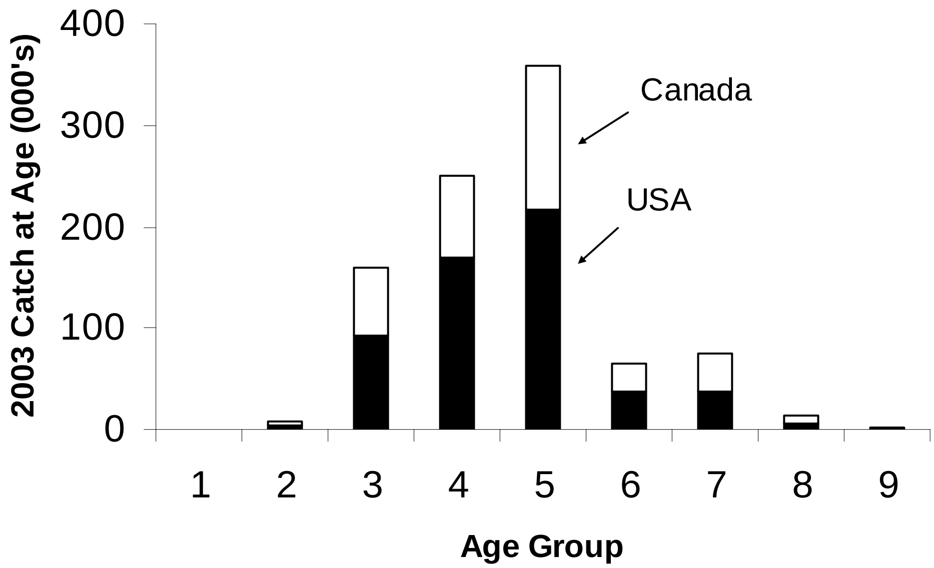

Figure 6. Catch at age in the 2003 combined Canadian and USA 5Zj,m cod fishery.

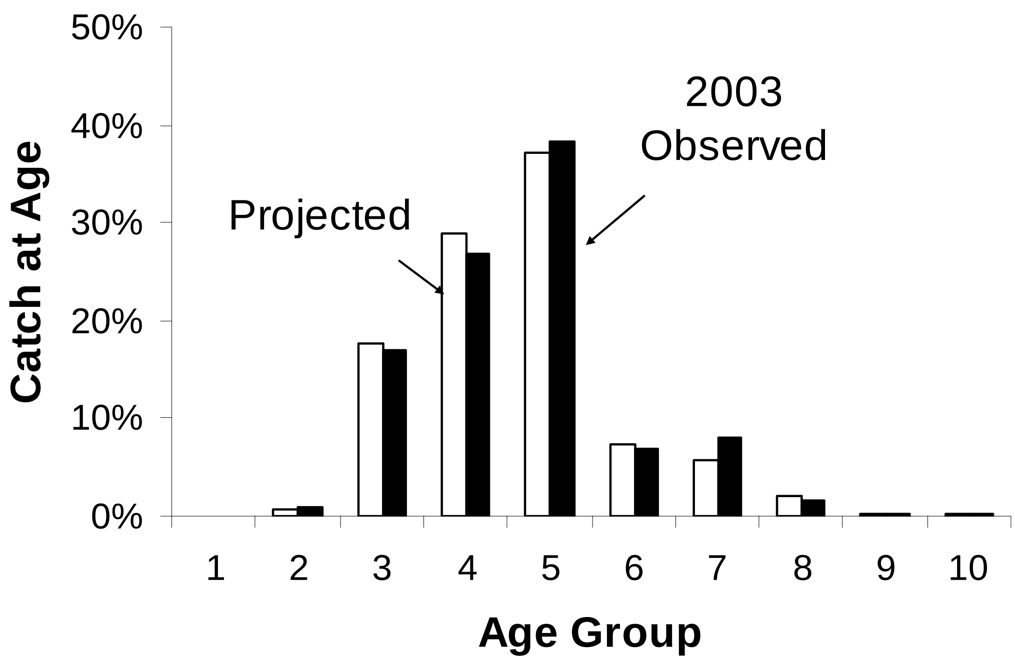

Figure 7. Observed and predicted percent catch at age for the 5Zj,m cod fishery in 2003.

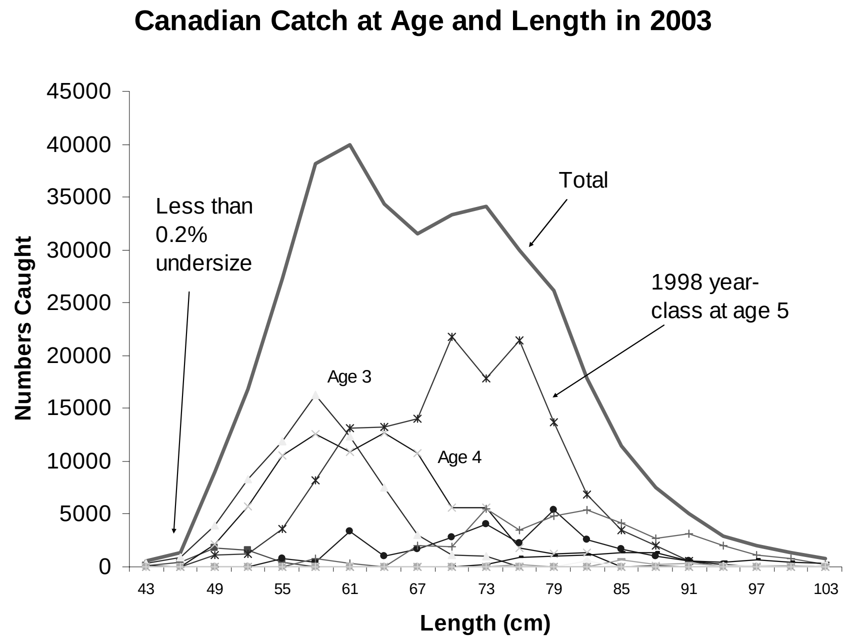

Figure 8a. Length composition by age group for the 2003 Canadian 5Zj,m cod fishery.

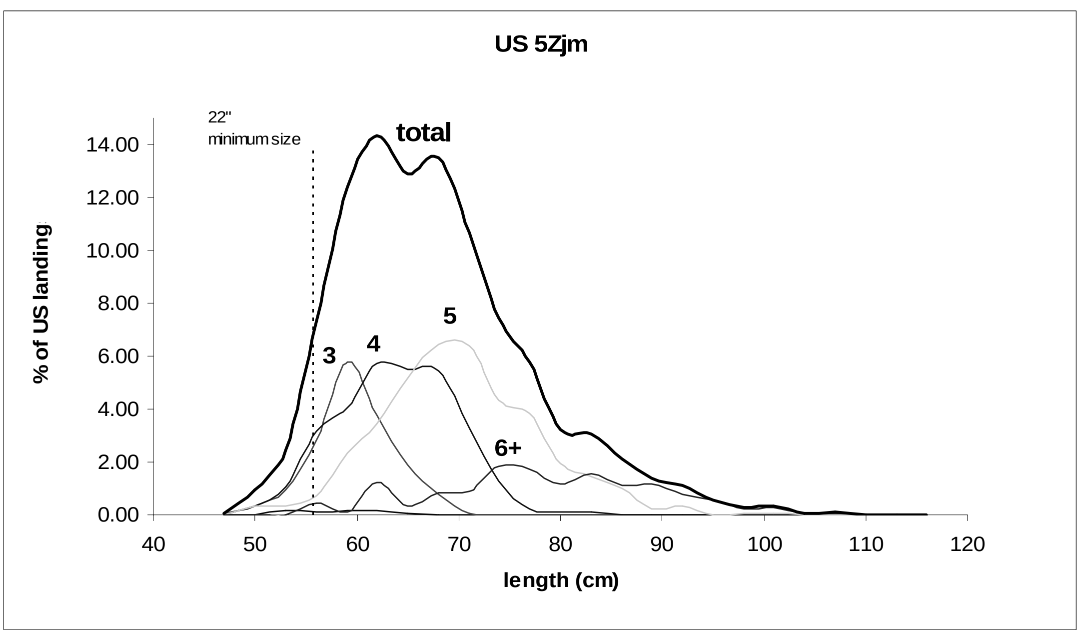

Figure 8b. Length composition by age group for the 2003 USA 5Zj,m cod fishery.

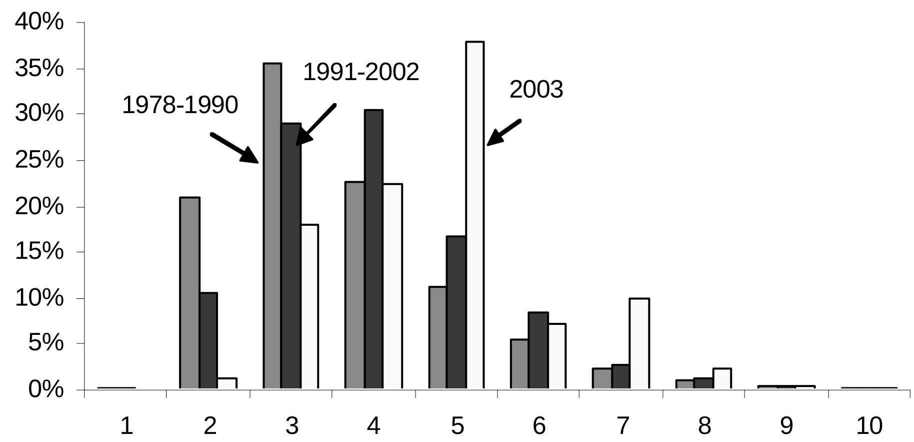

Figure 9. Comparison of the observed percent catch at age (Canada + USA) in 2003 with the percent catch at age from earlier time periods.

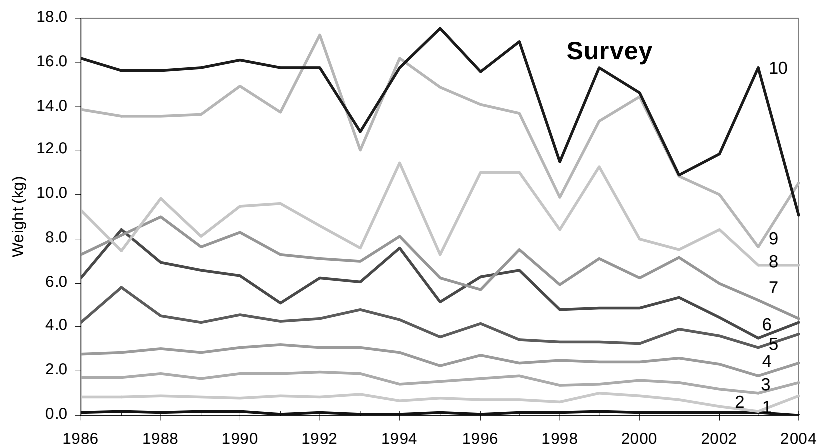

Figure 10. Beginning of year mean weight (kg) at age for cod derived from DFO research surveys.

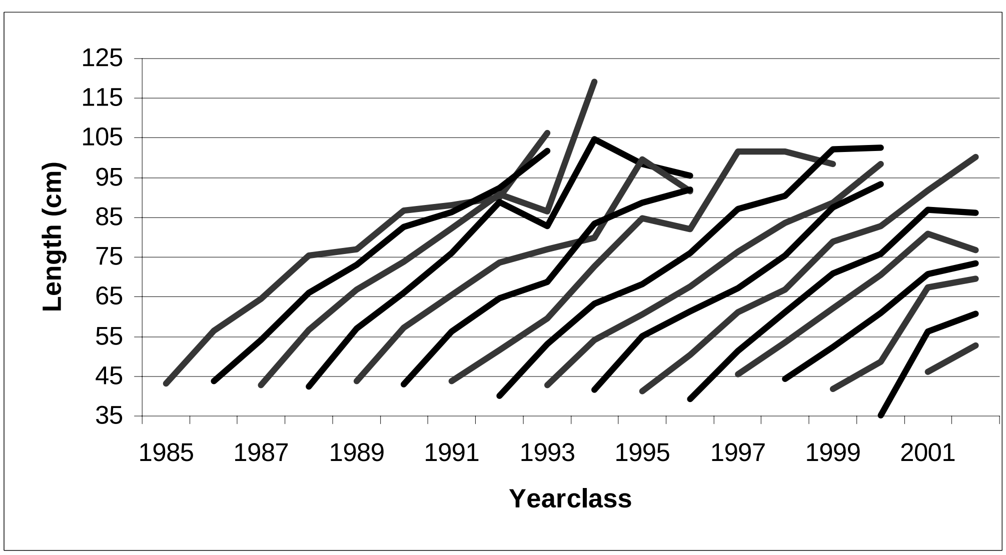

Figure 11. Mean size at age for cod derived from DFO research surveys.

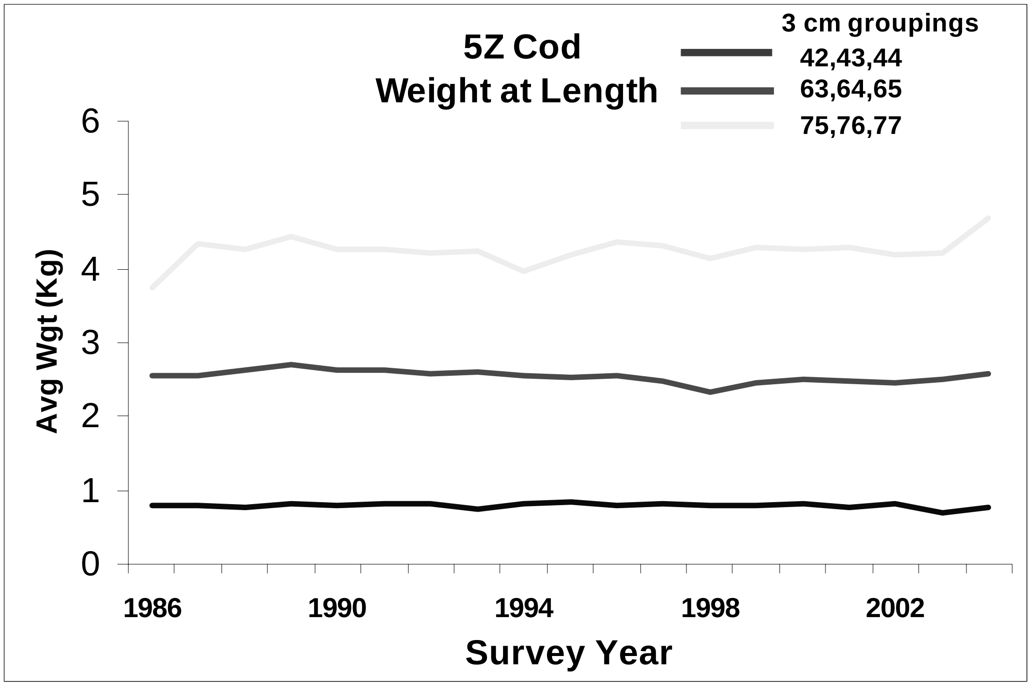

Figure 12. Condition factor for Georges Bank cod.

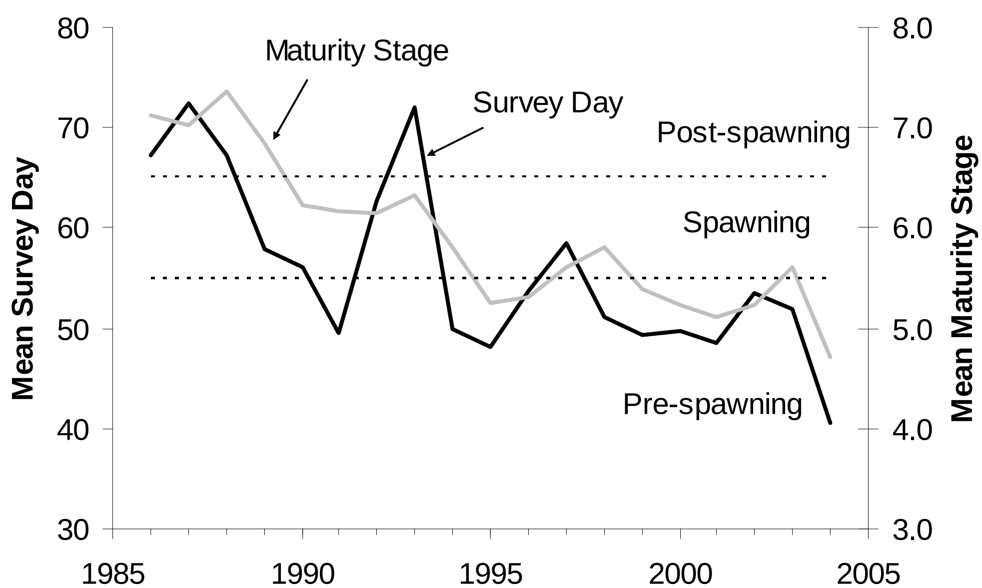

Figure 13. DFO survey timing and average maturity stage for adult cod.

Cod Distribution (kg/tow), 1999-2003 density and 2004

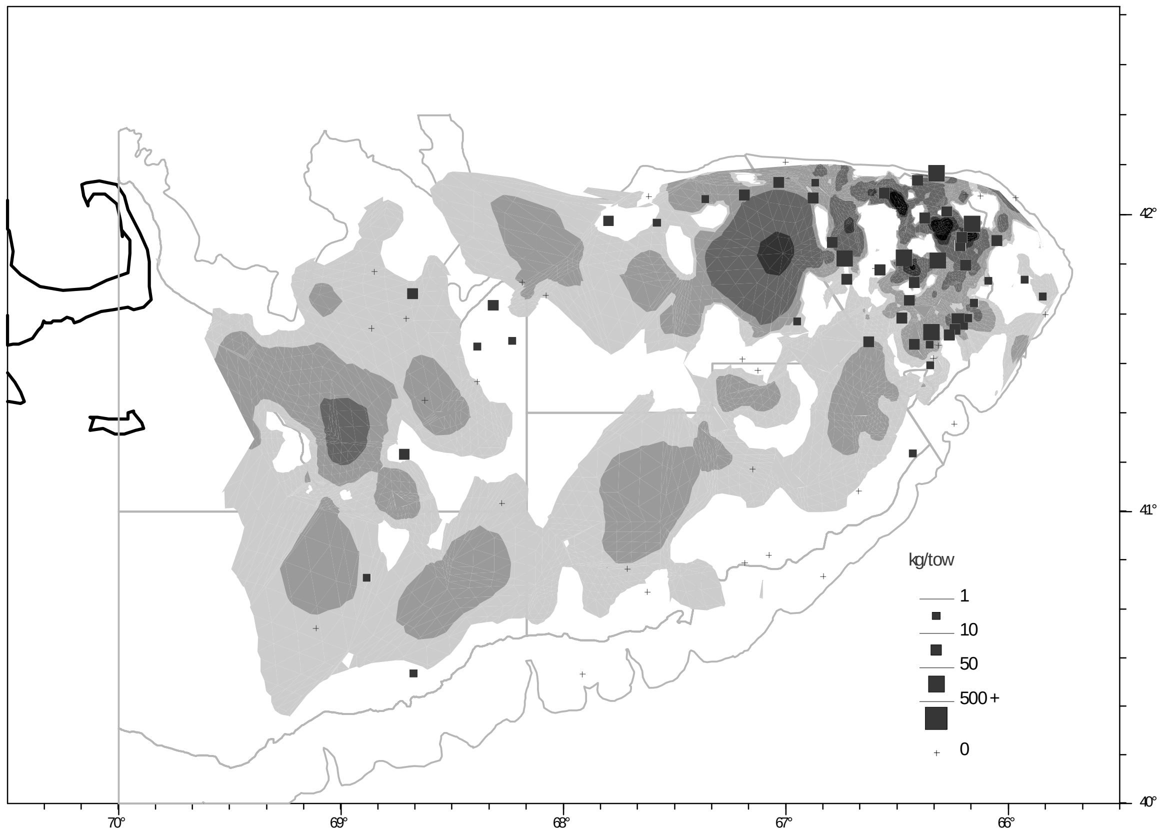

Figure 14a. Comparison of cod per standard tow (kg/tow) from the 2004 DFO research survey (box symbol) with average density gradient distribution for the 1999-2003 surveys.

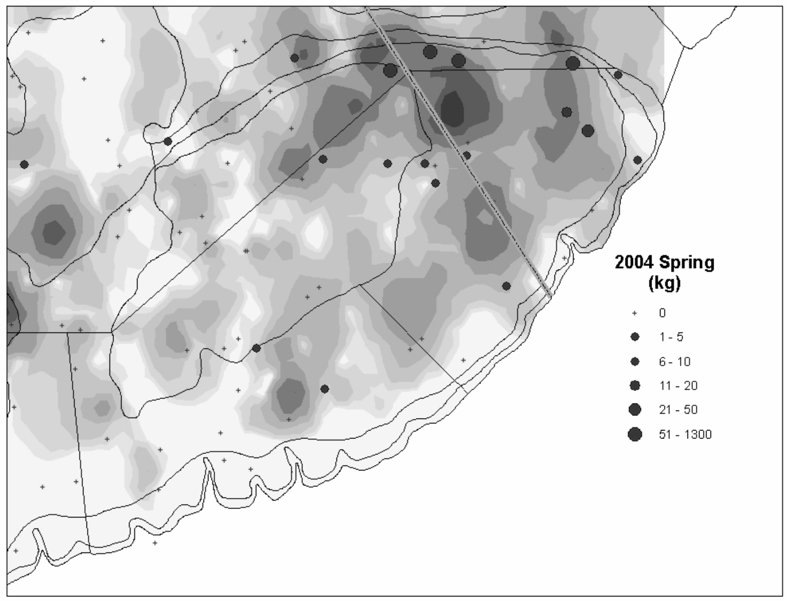

Figure 14b. Comparison of Atlantic cod per standard tow (kg/tow) from the 2004 NEFSC spring research survey (box symbol) with average density gradient distribution for the 1999-2003 NEFSC spring surveys.

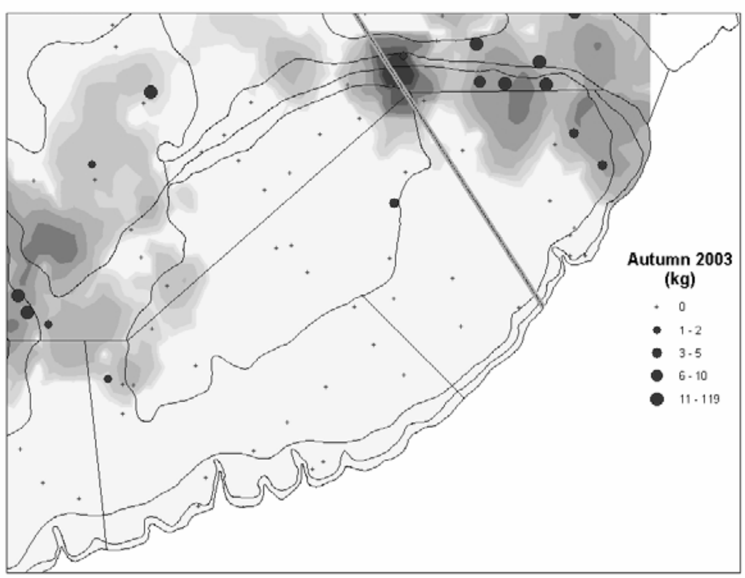

Figure 14c. Comparison of Atlantic cod per standard tow (kg/tow) from the 2003 NEFSC autumn research survey (box symbol) with average density gradient distribution for the 1998-2002 NEFSC autumn surveys.

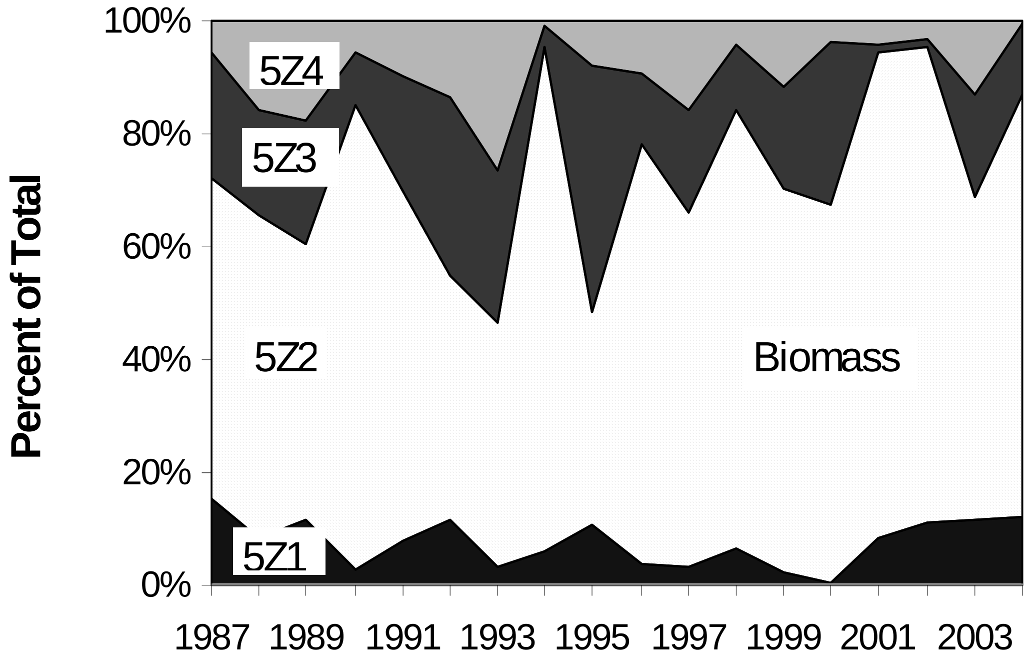

Figure 15a. DFO spring survey biomass index for 1987-2004 by stratum.

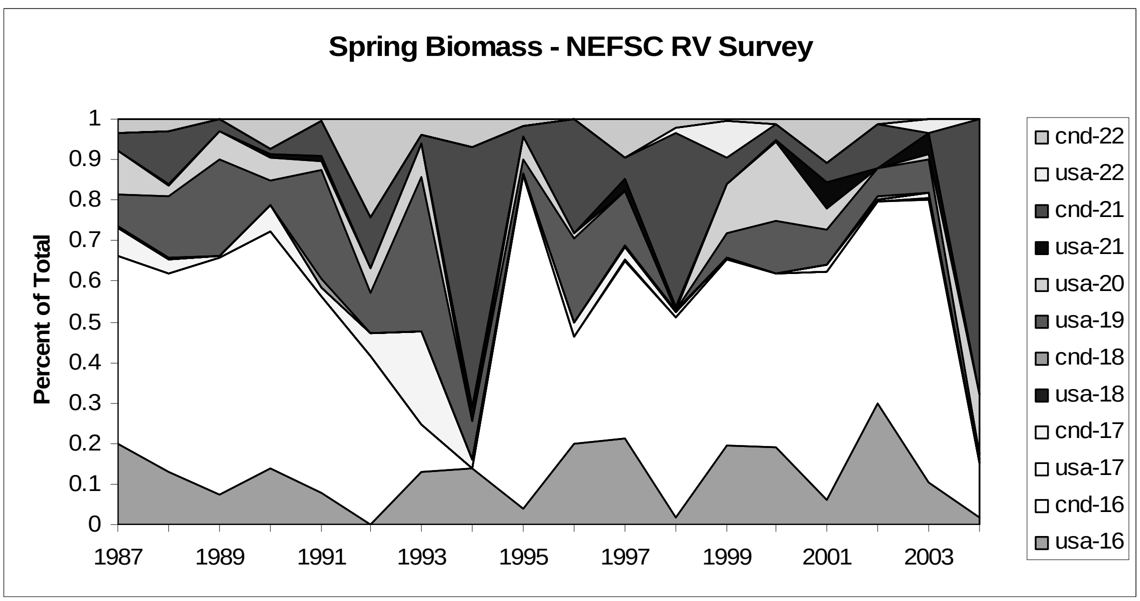

Figure 15b. NEFSC spring survey biomass index for 1987-2004 by stratum (strata 16-18, 21-22 are split by International Boundary) within area 5Zjm.

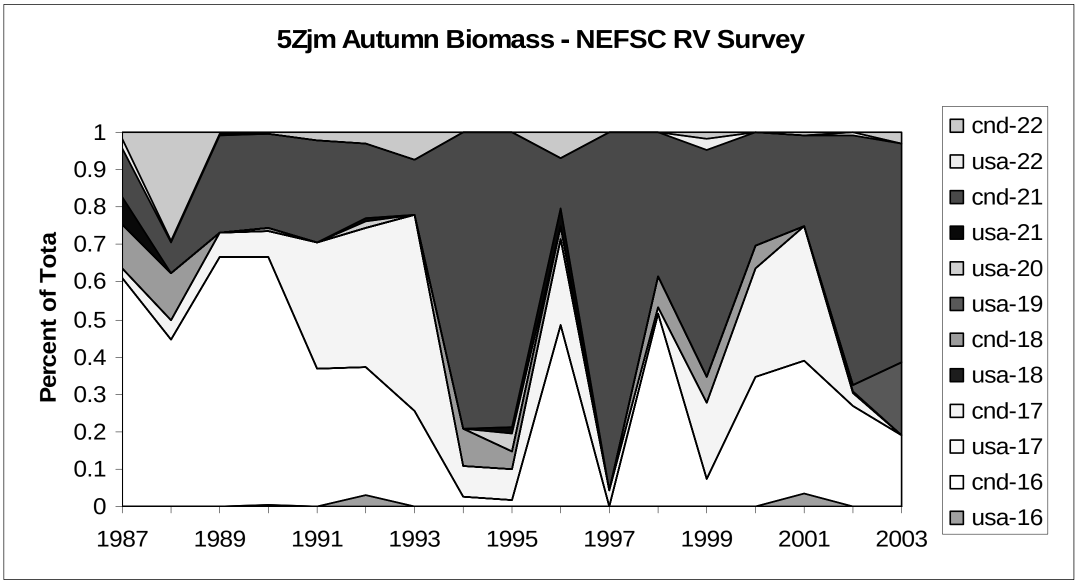

Figure 15c. NEFSC autumn survey biomass index for 1987-2003 by stratum (strata 16-18, 21-22 are split by International Boundary) within area 5Zjm.

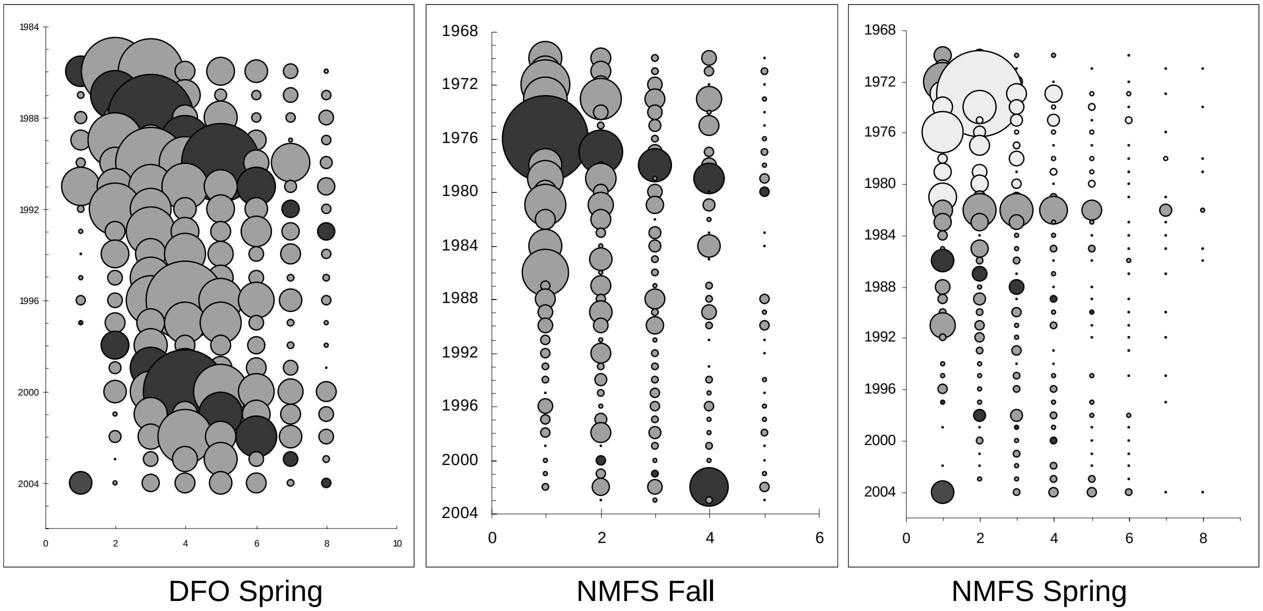

Figure 16. Catch per tow in numbers at age, adjusted by estimated average catchability at age from ADAPT, for 5Zj,m cod from the DFO spring and NMFS spring and fall surveys in 5Zj,m.

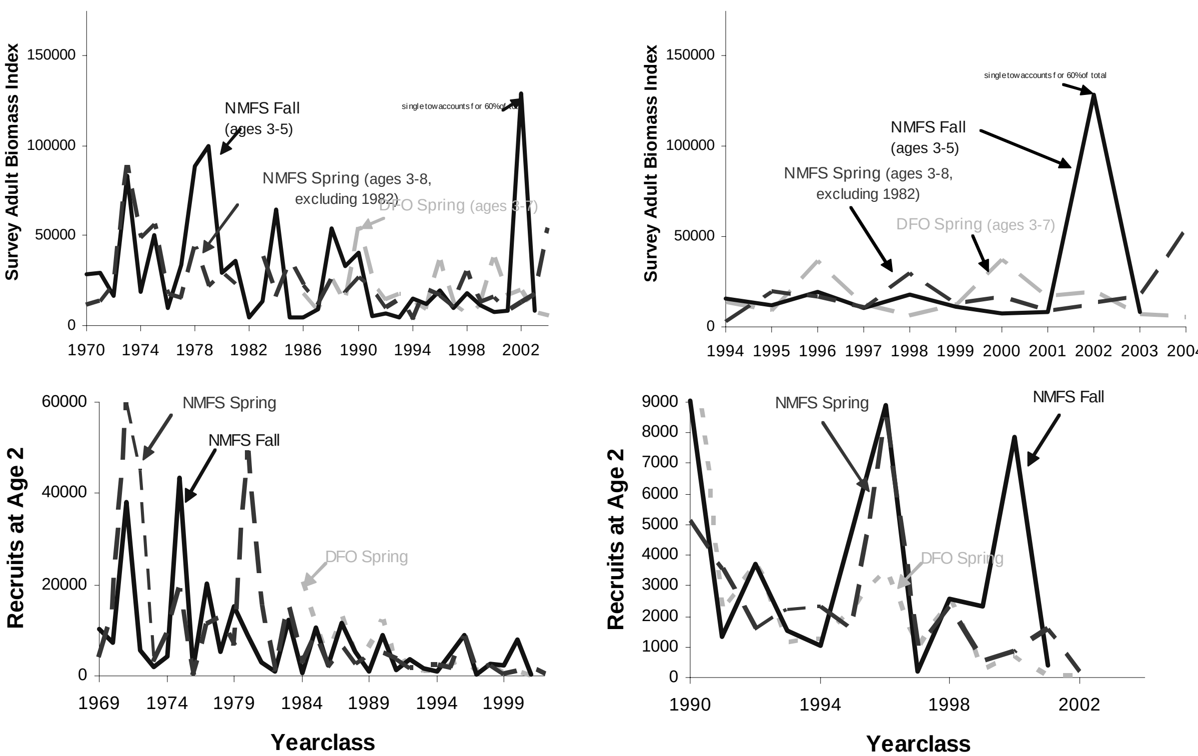

Figure 17. Estimates of adult biomass (ages 3+) (upper panel) and recruitment indices at age 2 (lower panel) for 5Zj,m cod from the DFO spring and NMFS spring and fall surveys in 5Zj,m.

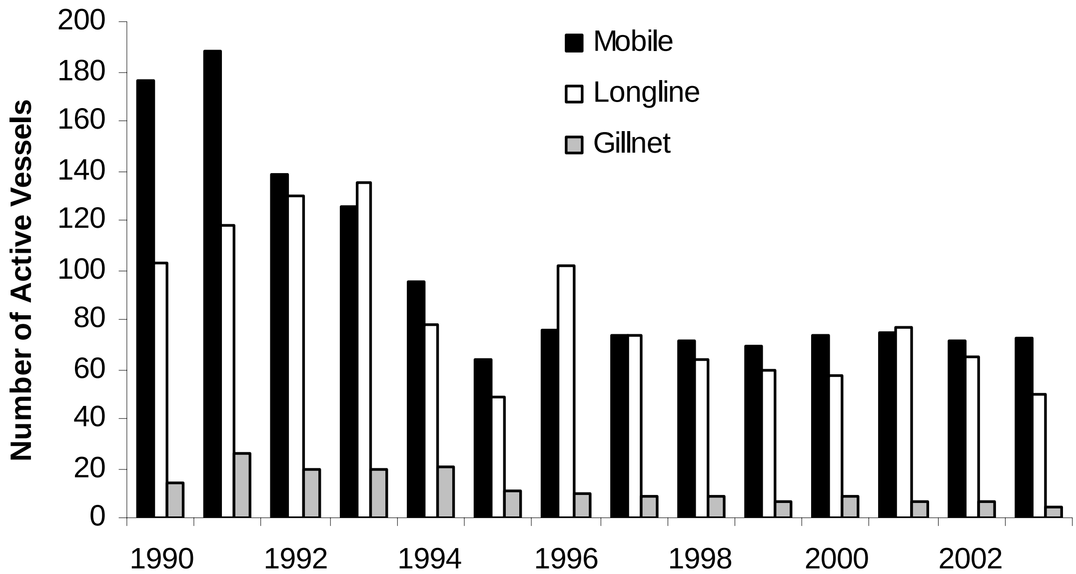

Figure 18. Number of Canadian fishing vessels by gear type.

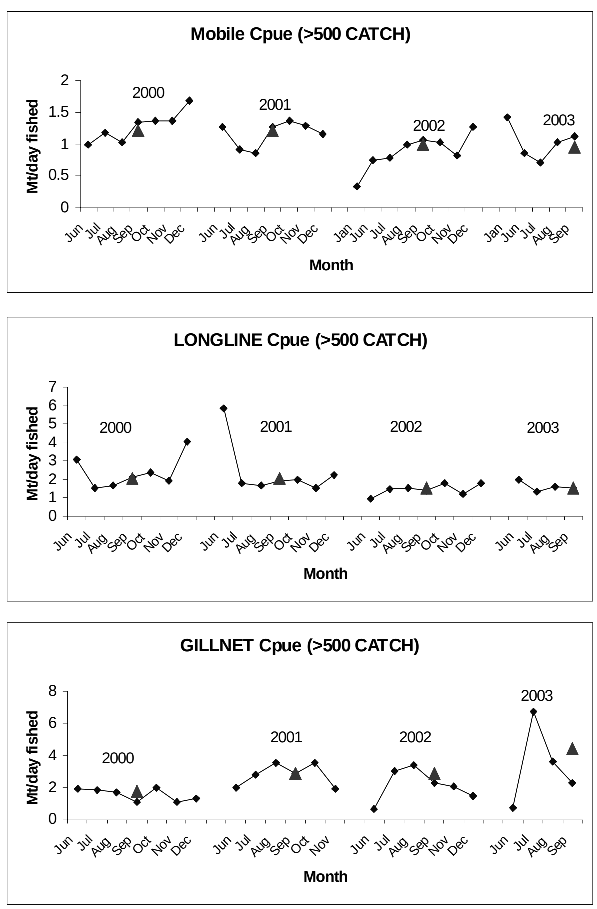

Figure 19a. Landings per day fished by gear type for trips with >500kg cod landings.

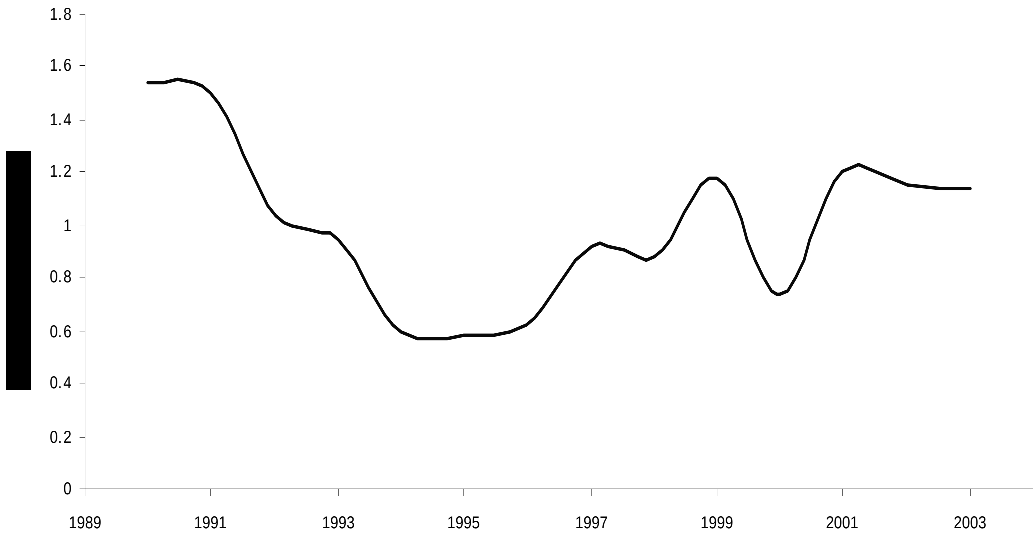

Figure 19b. Fishery performance(ton/day fished) of USA otter trawl gear for trips with >500 kg of cod landings during 1990-2003.

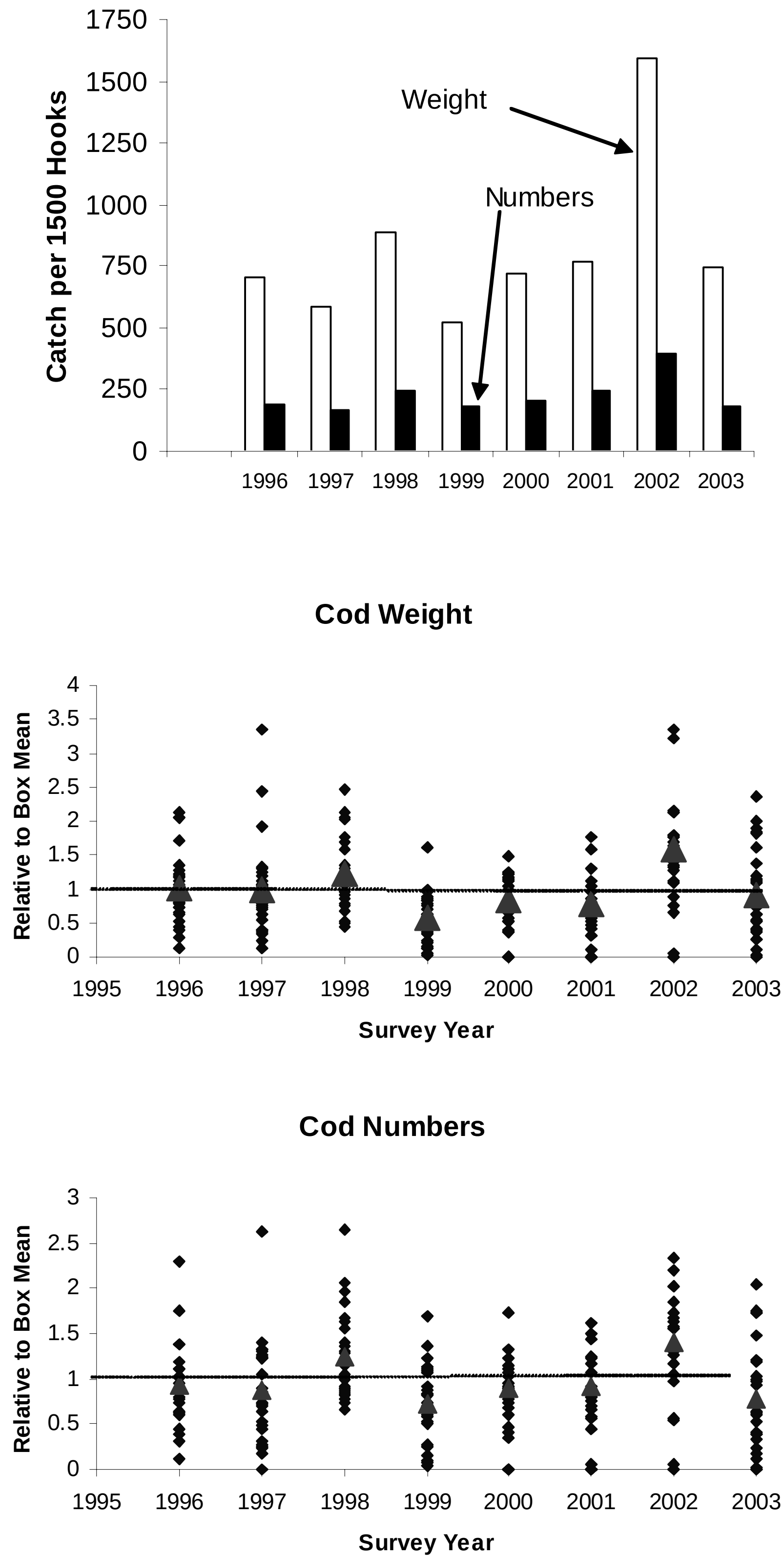

Figure 20. Results of Canadian longline industry survey showing the annual average weight and number caught per 1500 hooks and annual catch rate relative to mean of sampling units.

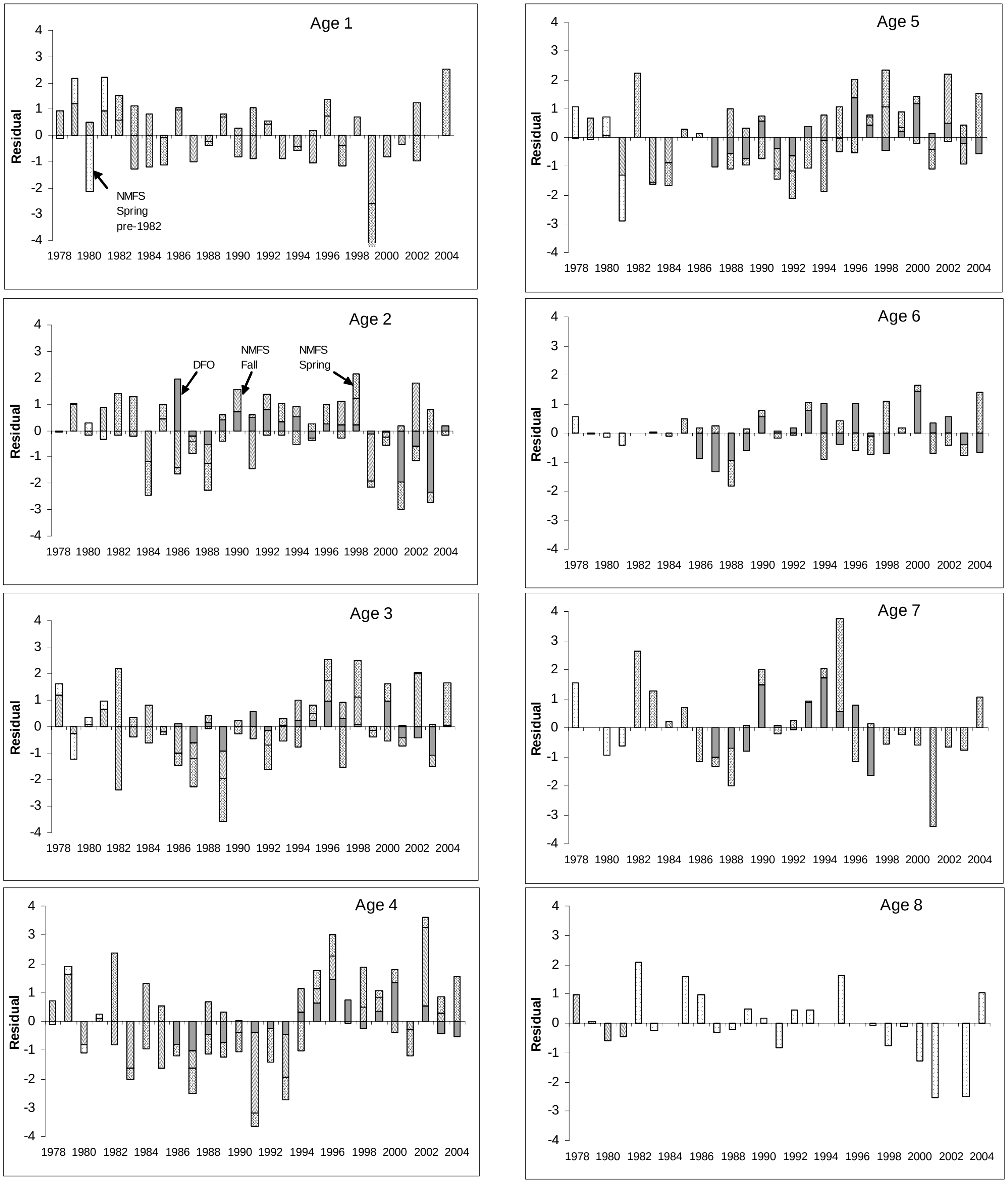

Figure 21. Standardized residuals at age from ADAPT for the DFO spring 1986-2004), NMFS fall (1977-2003), NMFS spring (1978-81,Yankee 41) and NMFS spring (1982-2004, Yankee 36) research indices.

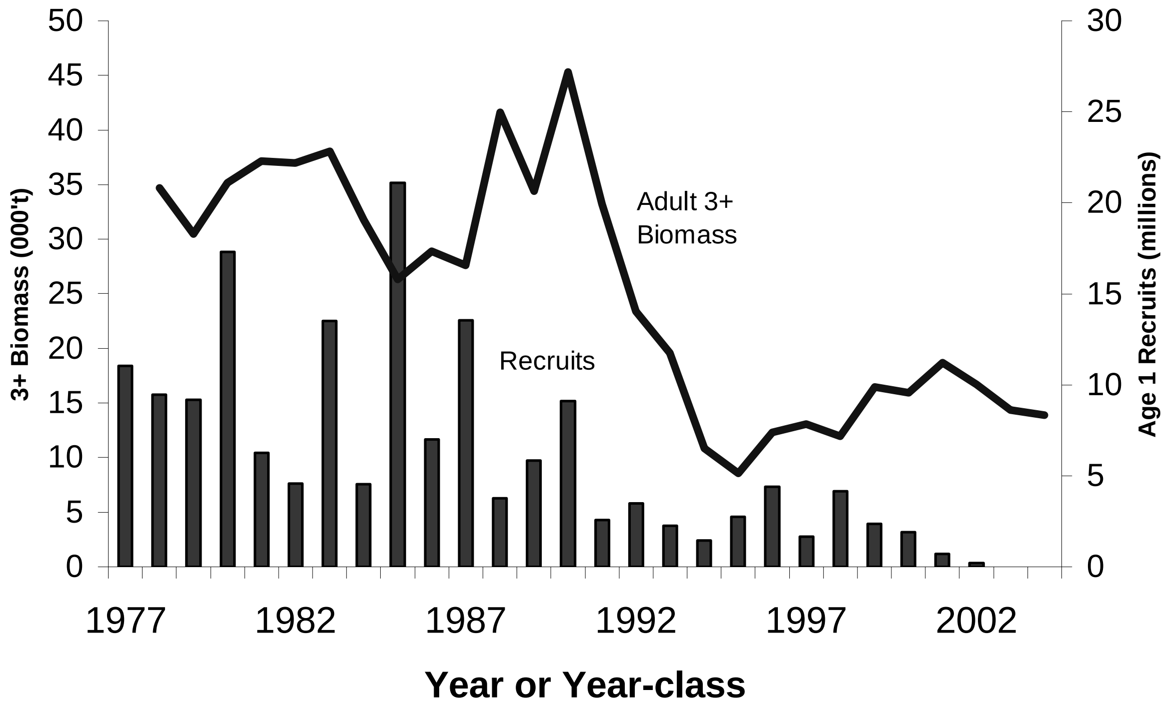

Figure 22. Spawning stock biomass and recruits at age one from ADAPT for 5Zj,m cod.

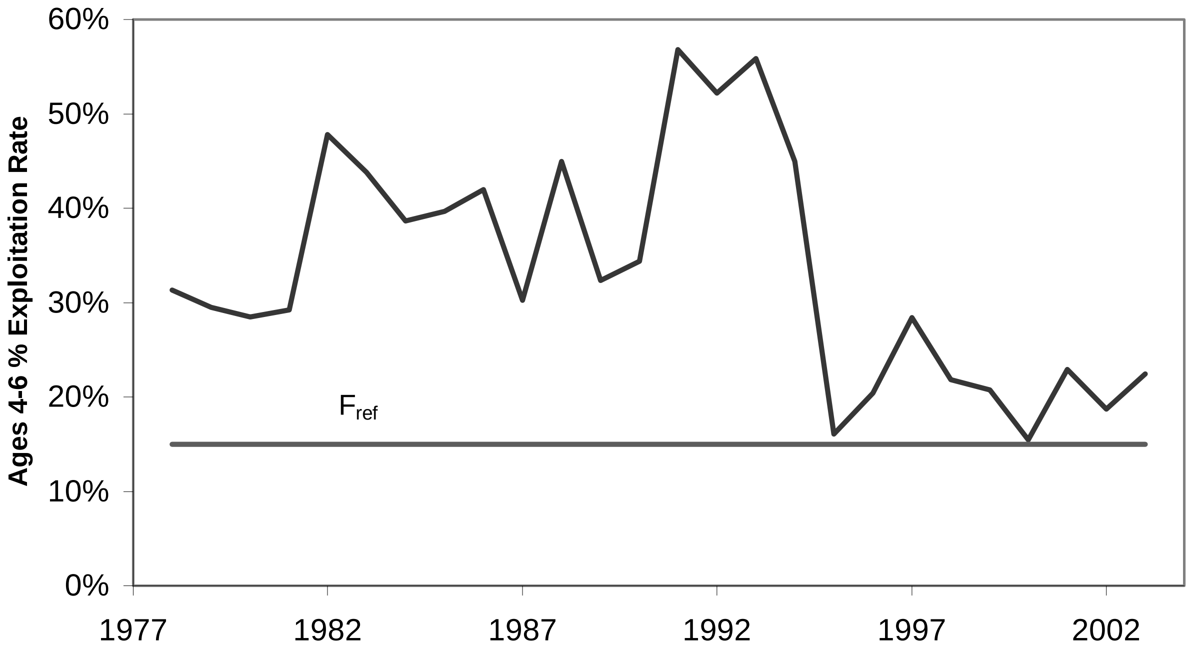

Figure 23. Exploitation rate at ages 4-6 cod derived from ADAPT.

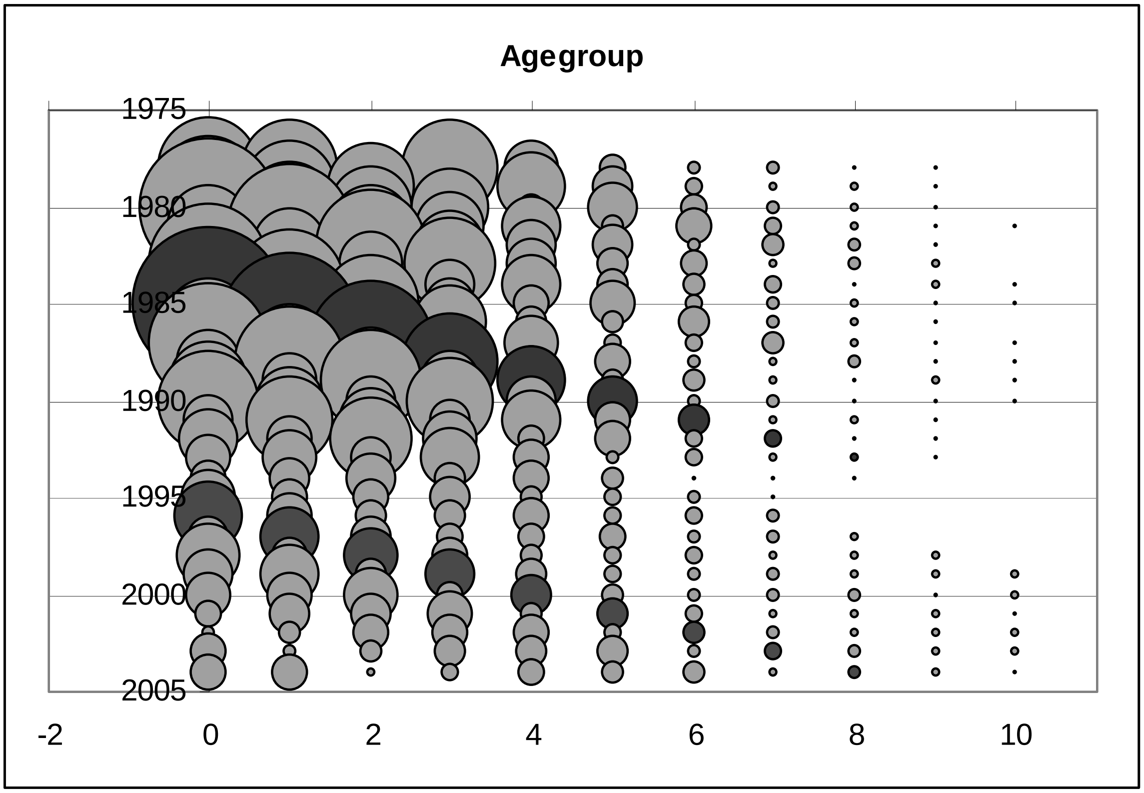

Figure 24: Relative abundance at age for 5Zj,m cod for 1978-2004.

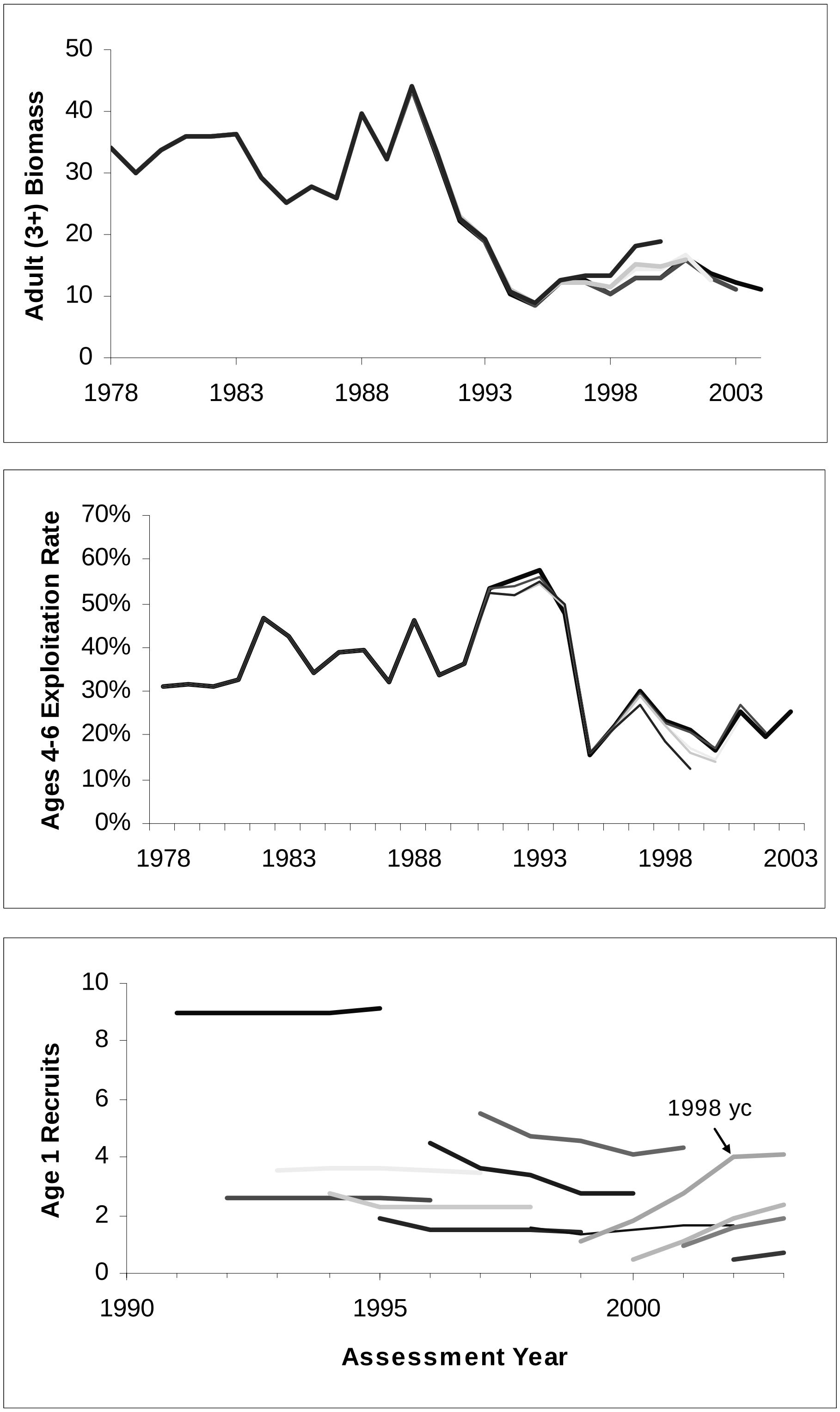

Figure 25. Retrospective pattern in population biomass (upper panel), exploitation rates on ages 4-6 (middle panel), and recruitment (lower panels) for 5Zj,m cod from ADAPT.

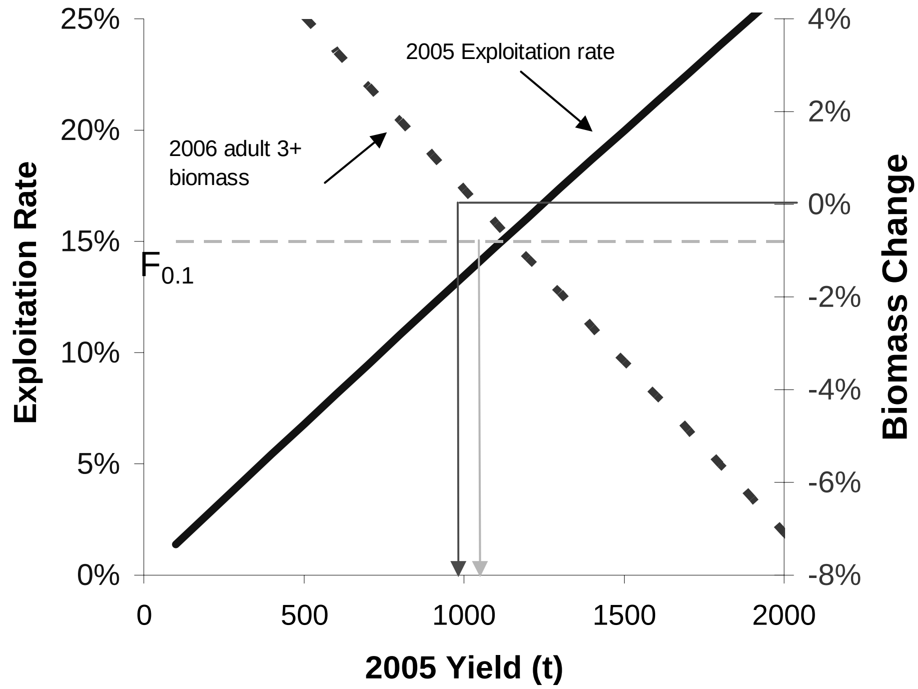

Figure 26. Projected exploitation rate and the % change in 3+ biomass in 2006 relative to 2005 at different levels of yield in 2005.

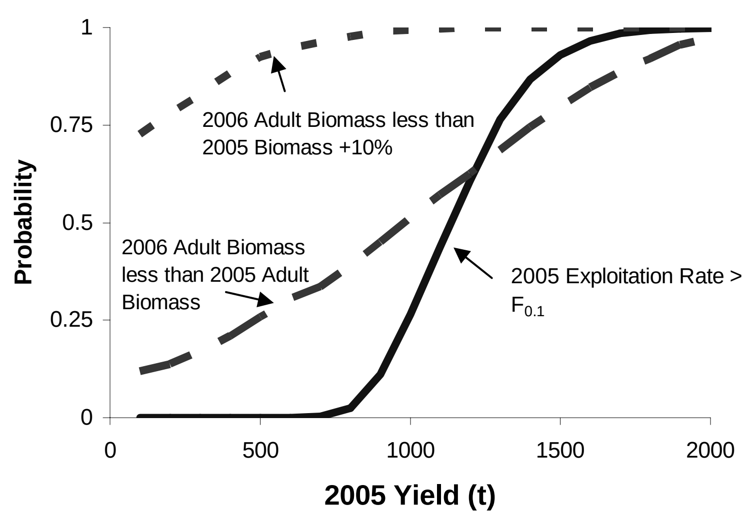

Figure 27. Probability of projected change in 5Zj,m cod adult stock biomass from 2005 to 2006 and exploitation rate in 2005 at different yields in 2005 and assuming a 2004 yield of 1,300 t.

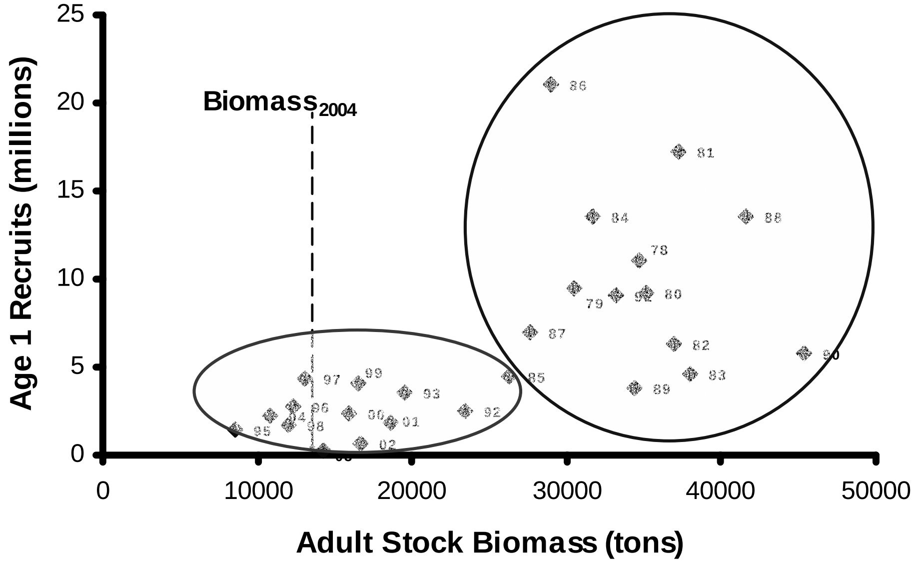

Figure 28. Comparison of recruits at age 1 and adult stock biomass for 5Zj,m cod, 1978-2004.

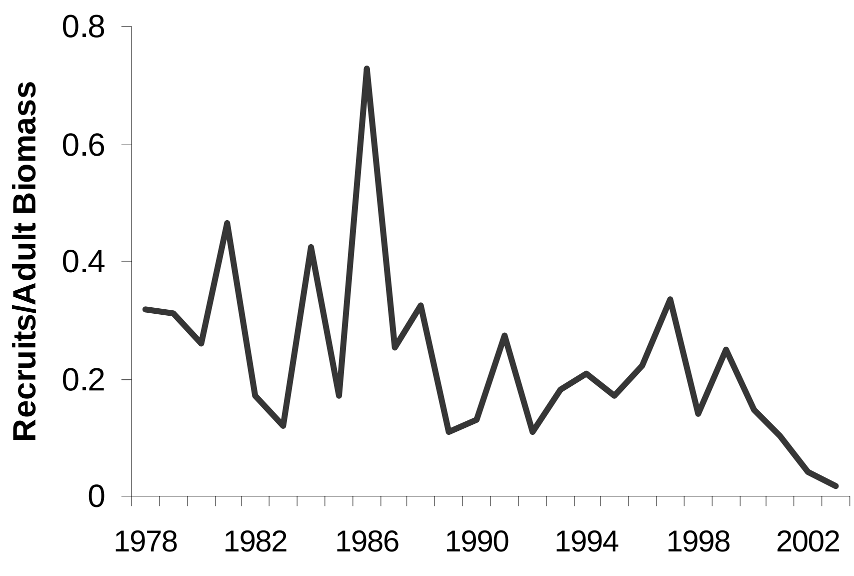

Figure 29. Relationship between recruits and spawning stock biomass (R/SSB) for 5Zj,m cod, 1978-2004.

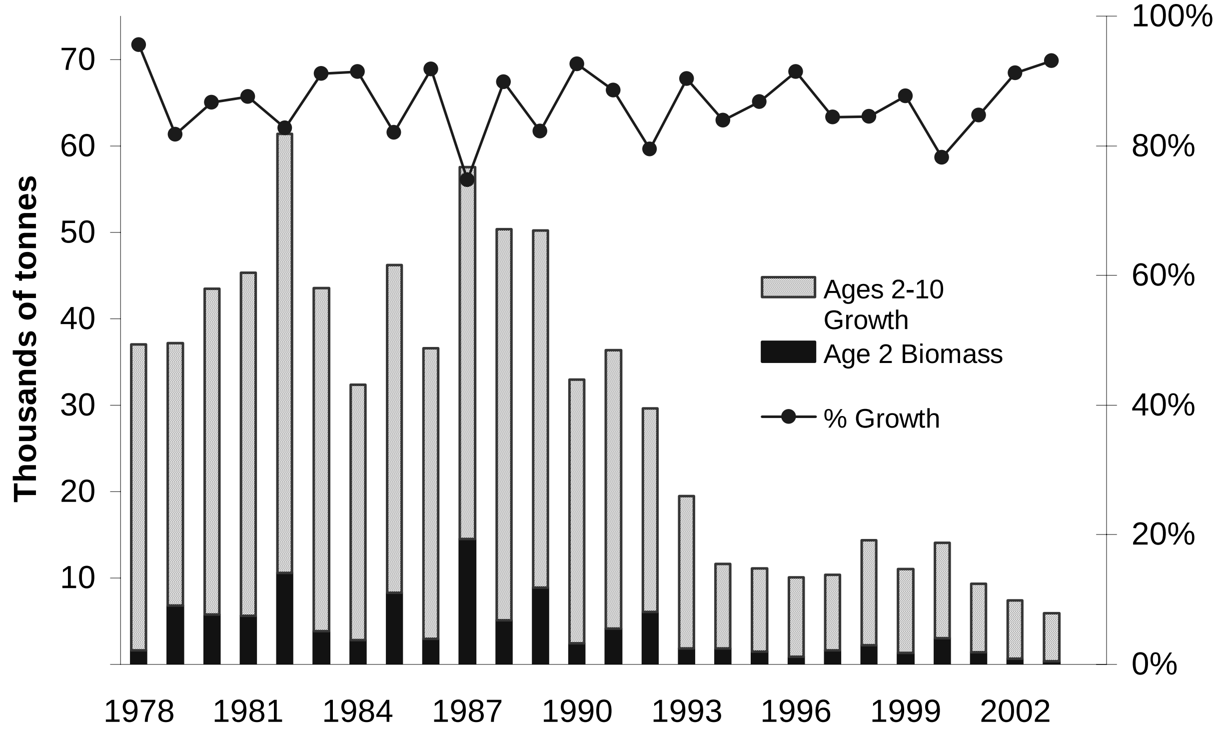

Figure 30. Comparison of stock production derived from growth and from recruitment for 5Zj,m cod, 1978-2003.

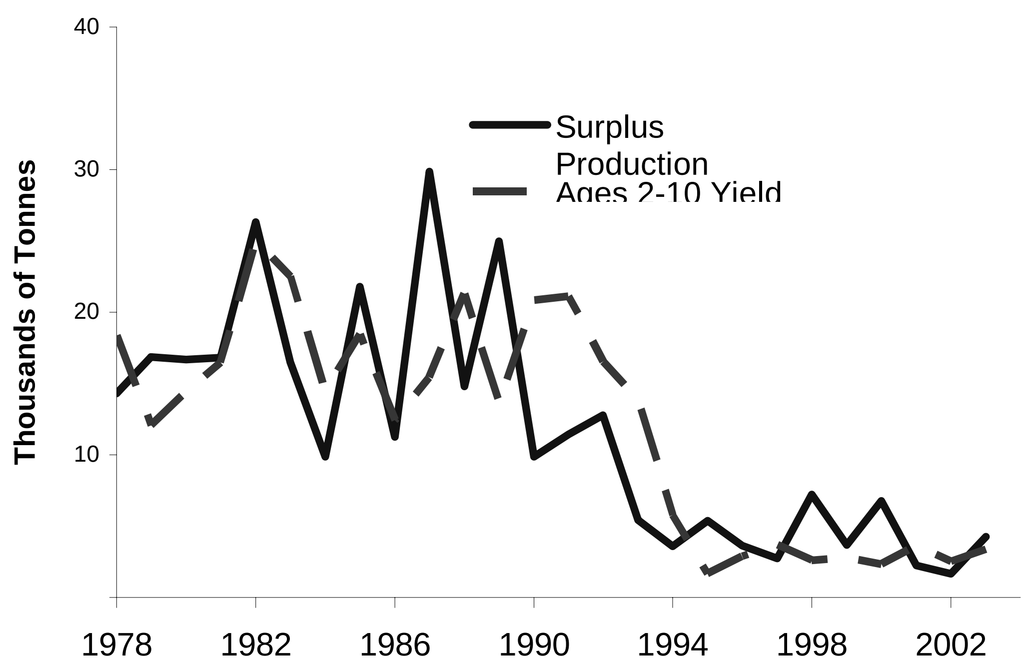

Figure 31. Comparison of surplus production and yields for 5Zj,m cod, 1978-2003.