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Population Status of Eastern Georges Bank Cod (Unit Areas 5Zj,m) for 1978-2006

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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. Estimates of cod discards were included in the catch at age for the first time. Results of the assessment provided statistically significant parameter estimates for the 2005 beginning-of-year population at ages 3 through 10**;** the estimate for age 2 in 2005 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 8,700 t in 1995 to about 19,000t 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 14,281t at the beginning of 2005. Exploitation rate on ages 4-6 decreased from more than 50% in the early 1990s to about the F_{ref} level (F=0.18, 16% exploitation rate) in 1995 but has since been higher, ranging between 16%-25%. The exploitation rate declined in 2004 (14%). 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**.** Assessment results suggest improved recruitment from the 2003 year-class. With an expected 1,000 t total catch in 2005, projections for 2006 indicate an increase in yield to about 2,200 t at F_{ref} and an increase in stock biomass between 2005 and 2006. The adult stock biomass remains below a threshold of 25,000 t, above which chances of good recruitment are improved.

RÉSUMÉ

Nous avons effectué une évaluation analytique du stock de morue du banc Georges dans 5Zjm à partir de données à jour des prises par âge des individus de 1 à 10 ans et d'indices de relevé de recherche pour les individus de 1 à 8 ans. Nous avons caractérisé la population en appliquant une formulation ADAPT de référence fondée sur les recommandations du CERT. Des estimations des prises rejetées en mer sont incluses dans les données sur les prises par âge pour la première fois. L'évaluation a donné des estimations statistiquement significatives de paramètres de la population de morues âgées de 3 à 10 ans au début de 2005, mais l'estimation pour les morues de 2 ans ne l'était pas. Le biais et la précision des estimations se situaient dans les limites acceptables (écart-type de 39 à 48 %). La biomasse d'adultes (3 ans et plus) a augmenté, du creux de 8 700 t en 1995 à environ 19 000 t au début de 2001, en grande partie grâce à la survie et à la croissance des classes d'âge 1995, 1996 et 1998. Depuis 2001, la biomasse des adultes a diminué; elle se chiffrait à environ 14 281 t au début de 2005. Le taux d'exploitation des morues de 4 à 6 ans a baissé, passant de plus de 50 % au début des années 90 à environ le niveau de référence (F = 0,18, taux d'exploitation = 16 %) en 1995, puis a augmenté, jusqu'à entre 16 et 25 %, pour diminuer à nouveau, se chiffrant à 14 % en 2004. Étant donné la capturabilité réduite des morues de 5 ans et plus, le recrutement partiel a changé depuis 1994, ce qui s'explique par le fait qu'il s'agit d'une pêche accessoire au Canada et par les mesures de gestion qui ont réduit l'accès à la ressource, tant sur le plan spatial que temporel, pour les pêcheurs canadiens et étatsuniens. Ces dernières années, le recrutement a été faible. Bien que les classes d'âge 1996 et 1998 soient plus fortes que la moyenne des années récentes, elles se chiffrent au-dessous de la moyenne à long terme. Les résultats de l'évaluation suggèrent une hausse du recrutement grâce à l'entrée de la classe d'âge 2003. Compte tenu des prises totales prévues en 2005 (1 000 t), les prévisions pour 2006 indiquent que le rendement augmentera jusqu'à environ 2 200 t pour une exploitation à Fref et que la biomasse du stock augmentera de 2005 à 2006. 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.

INTRODUCTION

This report incorporates commercial catch data and research survey results for the 1978-2004 time period to estimate the stock status of cod on eastern Georges Bank, Fisheries and Oceans statistical unit areas 5Zj and 5Zm (5Zj,m) (Figure 1a), or equivalently National Marine Fisheries Service statistical areas 551, 552, 561 and 562. Definition of this management unit was based largely on analysis of tagging results and commercial and survey catch distribution (Hunt, 1989). Hunt *et al*. (2004) 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 (O'Boyle, R.N. and W.J. Overholtz (eds.), 2002) and a new ADAPT model formulation was recommended. This new model differed from the previously used model in that some 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

Total combined USA and Canada catches during 1978-2004 are shown in Table 1 and Figure 2. Landings were 3,400 t in 2003, a 23% increase from 2002, but declined to about 2,300 t in 2004.

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 2, Figure 2). Landings since 1995 have fluctuated between 1,000 t and 3,000 t. The 2004 fishery opened in June and resulted in a 1,100 t catch. Landings by gear sector in the Canadian fishery (Table 2, Figure 3) shows a consistent pattern in recent years.

Prior to 1996, incidental Canadian landings by other than the primary gear sectors were reported as 'miscellaneous' gear and these landings were included in the determination of catch at age. Most of this incidental catch was taken in the Canadian offshore sea scallop fishery as an allowed by-catch. Since 1996, no landings of groundfish (excepting monkfish) by the scallop fishery have been allowed and the by-catch has been discarded. Also, some groundfish by-catch for years prior to 1996 was discarded by the scallop fishery. Estimated discards of cod from the scallop fishery for 1960-2004 were derived by Van Eeckhaute *et al.* (2005). Those shown in Table 1, ranging from 57 t to 200 t, and used in this assessment were from preliminary analyses. Though the differences will not greatly impact assessment results, the catch at age will be updated in future assessments. Additional discards from the mobile gear fishery in 1997 – 1999 were estimated (Van Eeckhaute and Gavaris, 2004) and ranged from 253 t to 428 t. Similar calculations of discards from the mobile gear fishery for the years since 1999 indicated that a hypothesis of no discarding could not be rejected.

Between 1978-1984, USA landings increased from 5,500 t to 10,500 t then declined and remained stable at about 6,000 t during 1985-1993 (Table 1, Figure 2). Closed Area II was implemented in December 1994 and US cod landings during 1994-2000 ranged from between 560 t to 1,230 t and averaged about 800 t. USA landings of cod from areas 5Zj,m in both 2001 and 2002 were about 1,400 t, the highest since 1993, and increased to about 1,800 t in 2003. USA landings declined by almost 50% in 2004 to about 1,000 t, due to the imposition of a

restrictive and enforced hard TAC. Almost all of the USA catches in 5Zj,m was taken by otter trawl gear.

Length composition data from samples of landings and catches obtained by commercial port samples and at-sea Observer sampling were used to estimate catch at length and age composition in the Canadian fishery. A summary of the number of length and age samples used in the analyses is presented in Table 3. The fishery was adequately sampled and about 18,000 Canadian cod length observations and 1,400 age determinations were available to construct the 2004 catch-at-age (Table 4, Figure 4a). Comparison of length frequency distributions between at-sea and on-shore samples by gear sector and month show 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 in areas fished and cod size frequency composition between large offshore trawlers and tonnage classes 2 and 3 trawlers.

Precision estimates of intra-reader age determinations by the Canadian age reader were completed and results were acceptable and indicated overall agreement of about 90% between first and second aging readings, with a CV of 1.69 (Table 5).

Catch at age for Canadian mobile gear discards in 1997-1999 was assumed to have the same relative age composition as sampled landings. Catch at age derived for landings was therefore prorated to account for the additional discarded catch.

Sampling for lengths of cod discards in the Canadian scallop fishery was limited to Observer samples collected in 2001 and 2002; no information was available for other years. To provide estimates for unsampled years, an average proportional catchability relative to the RV catch at length for 2001 and 2002 was calculated. The average of the annual proportional catch at length for the DFO, NMFS spring and NMFS fall RV surveys was used to represent the population at length available to the scallop fishery. The derived catchability was applied to the RV lengths for 1996-2004 and resultant annual proportional catch at length prorated to the equivalent weight associated with the discard tonnage. Details of the method used to estimate discard catch at age are given in Stone and Gavaris (2005).

Catch-at-age for reported USA landings during 1994-2004 was estimated from USA length and age samples. For 1996-2004, 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).

Discards-at-age for the USA otter trawl fleet were estimated from observed trips in the NEFSC Observer Data Base System (OBDBS) for 1989-2004. Discard to kept ratios were estimated quarterly and applied to quarterly landings to estimate annual discards.

Annual length-weight relationships were derived from OBDBS length samples to estimate discards-at-length and discards-at-age were then derived by applying both commercial and NEFSC research survey age data.

Total removals-at-age and percent-at-age are given in Table 6 and in Figure 5. Average fishery weight-at-age and average beginning-of-year weights are given in Table 7. Calculations

of population biomass were made using weights-at-age obtained from DFO survey data (Hunt and Johnson, 1999). The data collected during surveys most adequately represent the entire population, while fishery data represent that portion of the population available to commercial gear, that is, the larger fish of the partially recruited ages.

Comparisons between the observed catch-at-age in 2004 and the projected catch-at-age in 2004 from last year's assessment are depicted in Figure 6, and show good correspondence. In 2004, the 1998 year-class accounted for about 21% of the catch in numbers and the 2000 year-class was dominant at about 24%. Canadian (Figure 7a) and USA (Figure 7b) catch-at-length and age contributions for 2004 indicate considerable overlap in length for adjacent age groups. Comparison of the 2004 percent catch at age with the short term and long term average (Figure 8) shows a continuing increase in the contribution of ages 5+ in 2004 over the long-term average.

DFO survey weight-at-age shows a declining trend in recent years (Table 7, Figure 9) and all weights remain below the long term average. Mean size at age was examined and showed a less pronounced decline in length at younger ages in recent years (Figure 10).

Condition factor was examined to determine if this was affecting the decline in weight at age. The average weight of fish in 3 cm groupings at 43, 64 and 76 cm was calculated using data from 1986-2005 DFO Georges Bank surveys. No trend in condition factor is evident for any of the three groupings (Figure 11).

Hunt *et al.* (2004) examined average maturity stage and mean survey date and concluded that the decline in weight at age was not due to 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

The approach used to estimate mean catch per tow specific to the 5Zj,m area for DFO and NMFS surveys is described in Hunt (1990). Only sets within the 5Zj,m area are 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 NMFS surveys conducted by the RV *Delaware II* to RV *Albatross IV* equivalents and to account for a change in trawl doors in 1985 The DFO survey was initiated in 1986, while the NMFS autumn survey started in 1963 and the NMFS spring survey began in 1968. The NMFS spring survey has used two different bottom trawls over the 1978-2004 time period. A Yankee #41 trawl was used between 1978 and 1981, and a 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 standardized numbers per tow (Table 8) show a decrease for the 2001-2005 DFO surveys from that observed in 2000 and previous. The 2005 catch distribution pattern (shown as box symbols in Figure 12a) was similar to the average (shown as density contours in Figure 12a). The highest catch rates occurred in the Canadian zone in the 5Zj area along the northern edge, however DFO stratum 5Z2 (Figure 1b) accounts for most of the survey biomass. A substantial variation exists in the contribution of DFO stratum 5Z2 (Figure 13a). 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. Above average sets in stratum 5Z4 in 2005 resulted in this stratum accounting for an unusually high proportion of the total biomass estimate.

Total catch in numbers for the 2005 NEFSC spring survey decreased between 2004 and 2005 (Table 8). The high index observed in 2004 appears to be a year effect. The 2005 catch distribution was fairly dispersed with larger catches occurring in NEFSC strata 16 and 21 (Figure 12b and Figure 1c). The highest percent of total biomass of cod in the 5Zj,m strata occurred in the eastern part of stratum 16 (Figure 13b). Total catch in numbers in the 2004 NEFSC autumn survey increased from 2003 for all age groups (Table 8). The 2004 autumn catch distribution was primarily along the Northern Edge (Figure 12c) and similar to the average (1999-2003) density. The highest biomass occurred in stratum 16, which has been seen historically (Figure 13c).

Each research vessel surveys was assigned a decimal year value (DFO=0.16, NMFS spring 0.29, NMFS fall 0.69) to correspond to the season in which that survey was conducted. This eliminated the requirement to lag the NMFS fall survey forward as an index of beginning of year abundance as done in previous ADAPT formulations.

Catch per tow in numbers at age for the three surveys is shown in Figure 14. 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.

The three survey indices for ages 3+ biomass, adjusted by the estimated average catchability at age from recent ADAPT formulations are shown in Figure 15. 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 2005 index was above the recent average. 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 and was above the recent average in 2004. The NMFS spring survey has been increasing slightly since 2001 with a substantial increase between 2003 and 2004 but declined to a low level in 2005.

Estimates of recruitment at age two from the surveys are shown in the lower right panels of Figure 15 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 long term average but the 2003 year-class is above the recent average and may be similar in size to the 2000 year-class.

Commercial Fishery Catch Rates

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.

The number of Canadian vessels, by gear sector, for the 1990-2003 time period are shown in Figure 16. Overall, the number of vessels participating in the fishery declined between 1990 and 1995 increased in 1996. Most of this increase was due to the addition of about 20 tonnage class one longline vessels. The number of vessels has remained relatively stable since 1996.

Canadian 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 2nd calendar quarter (O'Brien *et al.*, 2002). Since 1994, the majority of USA vessels fish near the northwest corner of Closed Area II, and since 2000, also near the southwest corner of Closed Area II. A preliminary measure of fishery performance by otter trawl vessels was estimated by summing catch and effort for vessels in this area during 1990-2004. The data were not standardized for any variable, i.e. tonnage class, season, depth. Fishery performance (t/day fished) shows a declining trend from 1990 to 1995, a increasing trend from 1996 to 2003 and a subsequent decline (Figure 17). 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 Survey

A longline survey of the Canadian portion of Georges Bank area was initiated in 1995 using a fixed set design with one set in each selected box. A detailed description of the survey methods, results and a comparison with Sequential Population Analysis (SPA) population estimates are reported in Johnston and Hunt (1999) and in Hunt *et al.* (2004). Results from the longline surveys conducted during 1996-2004 are shown in Figure 18 and indicate little change between 2003 and 2004.

This survey has been discontinued and will not be completed in 2005.

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 2004

$I_{1,a,y}$ = NMFS fall survey
a=1 to 5 y=1978.69 to 2004.69

$I_{2,a,y}$ = NMFS spring survey (Yankee #41 trawl)
a=1 to 8, y=1978.29 to 1981.29

$I_{3,a,y}$ = NMFS spring survey (Yankee #36 trawl)
a=1 to 8, y=1982.29 to 2005.29 (includes the current year results)

$I_{4,a,y}$= DFO survey
a=2 to 7, y=1986.16 to 2005.16 (includes the current year results)

$\theta_{a,t'} = \ln$ population abundance for ages *a* = 2, 3 ... 10 at time $t' =$ 2005 and age *a*=11 at time $t' =$ 2000-2004

$\kappa_{s,a} = \ln$ 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:

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

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:

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

The survey indices were compared to population abundance at the decimal time of year designated. Natural mortality was assumed constant and equal to 0.2 for all age groups. Beginning of year 2005 population estimates were dervied for ages 2-10 with the population number at ages 0 and 1 set equal the average of 1993 to 2004 values. The fishing mortality rate on age 10 for 1999-2004 was based on estimated abundance at age 11 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). Associated precision and bias of parameter estimates were derived using a bootstrap (1,000 replicates) statistical technique.

ASSESSMENT RESULTS

To determine the effect of the addition of the discard data in the assessment, the assessment from 2004 was replicated and estimates of exploitation rate and population biomass were compared. Results when discards are included are given in Figure 19. Only a nominal change in adult biomass values is apparent. However, the exploitation rate in years with substantial discarding is higher.

Parameter estimates, bias adjustment and standard error derived from the above ADAPT formulation are given in Table 9. Population parameter estimates for 2005 have a relative error of 33% to 47% for ages 3 to 10. The estimate of the 2003 year-class at age 2 was very imprecise. 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.

Some year effects are apparent in the residuals for the survey indices (Figure 20), most recently 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.

Adult (3+) stock biomass markedly declined from about 45,400 mt in 1990 to a low of about 8,700 mt in 1995 (Figure 21, Table 10). Adult biomass increased to 18,800 mt in 2001 but subsequently declined to 14,300 mt at the beginning of 2005 (80% Confidence Interval: 12,200 t – 17,500 t). Most of the increase in the late 1990s was due to the growth and survival to ages 5+ of the 1992, 1995 and 1996 year-classes. Lower weights-at-age in the population in recent years and the continuing low recruitment have contributed to the recent decline.

Average fishing mortality for ages 4-6 (weighted by population size in numbers) increased rapidly between 1990 and 1991 to over 0.9, much greater than the fishing mortality reference, F_{ref} = 0.18 (Figure 22). By 1995, F had declined to near F_{ref} due to restrictive management measures. Since 1995, fishing mortalities have been greater than the F_{ref} but the F_{2004}=0.16 (80% Confidence Interval: 0.13 – 0.20) was slightly below F_{ref}.

Reduced fishing mortality in recent years enchanced the survival of the 1992 and 1995 year-classes and increased the relative contribution of ages 5 and older (Figure 23). The higher mean weight-at-age and survival associated with these cohorts has generated most of the increase in stock biomass between 1995 and 2000 but reflects growth rather than improved recruitment.

Recruitment at age 1 has been below the average of 6.5 million since 1991 (Figure 21 and Table 10). The 1996 and 1998 year-classes, at about 4.5 million, appear to be the strongest since the 1990 year-class. Recruitment of the 2002 year-class, at less than 1 million is the lowest on record. However, the 2003 year-class at about 9.3 million fish at age 1, is the largest since the 1990 cohort, but there is considerable uncertainty in the estimate. This year-class will make a large contribution to the adult stock and fishery over the next several years.

RETROSPECTIVE ANALYSIS

Retrospective analyses of exploitation rate and adult biomass indicate that in the mid-1990s, exploitation was under-estimated and biomass over-estimated relative to current estimates (Figure 24), but the magnitude is moderate. The retrospective pattern in this assessment is similar to that seen in previous assessment results (Hunt *et al*., 2004) and does not apear to indicate a strong or persistent trend.

YIELD PER RECRUIT ANALYSIS

Hunt and Johnson (1999) reported results of a yield per recruit analysis which used 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. Bi-lateral discussions with the USA recommended a value of F_{ref} of 0.18 and this has been used as the reference level.

PROGNOSIS

Catch projections were completed using the bias-adjusted beginning year population abundance values for 2005 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 (average of 2002-2004 fishery) and beginning of year (average of 2003-2005 DFO survey) weights-at-age were used to reflect the recent weights-at-age. Recruitment for 2005 age one was set to the 2000-2004 average of 4 million fish at age 1 (Table 11).

Assuming a 2005 catch equal to the 1,000 mt quota, the projection indicates that a combined Canada/USA yield of about 2,200 mt in 2006 has a neutral risk, about 50%, of exceeding F_{ref}. (Figure 26). At a yield of 2,200 mt in 2006, there is a low risk of a decline in biomass and about a 25% risk of not achieving a 10% increase in biomass from the beginning of year 2006 to the beginning of year 2007. A 2006 yield of about 1,900 mt would reduce the risk of exceeding F_{ref} to about 20% and enhance stock rebuilding prospects (lower risk of not achieving 10% biomass increase) (Figure 25). The 2003 year-class at age 3 is projected to contribute about 1,000 mt to the F_{ref} catch in 2006 (Table 11).

Medium term projections assumed that the stock could be exploited at a constant fishing mortality rate of 0.18 and that recruitment was average. The previous 10-year average recruitment, with the 2003 year-class included, is 4.0 million. However, the 2003 year-class is not well estimated and has considerable uncertainty and an average (2.3 million) with this year-class excluded may be more consistent with recent recruitment trends.

Adult biomass levels and subsequent **recruitment** at age 1 are depicted in Figure 27 for the 1978-2004 time period. Recruitment levels appear to have a positive correlation with biomass and the probability of good recruitment increases at higher biomass levels. The projected 2005 adult biomass of 15,000 t is well below the threshold stock size (25,000 t) 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 28) shows a decline since 1996 indicating poorer survivorship, with the exception of the 2003 year-class.

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 29) has been derived from growth and the rest from recruitment. In recent years, due to weak recruitment, the amount of production 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 30), particularly in the early 1990s. Low productivity since 2001 and current catches have resulted in yield exceeding production.

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. With current fishing practices and catch ratios, the achievement of rebuilding objectives for this cod stock may constrain the harvesting of haddock.

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Table 1. Summary of total landings (t) by Canada and the USA in unit areas 5Zj,m for 1978-2004, including derived estimates of discards.

	Canada			USA			Total		
Year	Landings	Discards	Catch	Landings	Discards	Catch	Landings	Discards	Catch
1978	8778		8778	5502		5502	14280		14280
1979	5978	100	6078	6408		6408	12386	100	12486
1980	8063	60	8123	6418		6418	14481	60	14541
1981	8499	84	8583	8094		8094	16593	84	16677
1982	17824	71	17895	8565		8565	26389	71	26460
1983	12130	31	12161	8572		8572	20702	31	20733
1984	5763	35	5798	10551		10551	16314	35	16349
1985	10443	48	10491	6641		6641	17084	48	17132
1986	8504	9	8513	5696		5696	14200	9	14209
1987	11844		11844	4792		4792	16636		16636
1988	12741	10	12751	7645		7645	20386	10	20396
1989	7895		7895	6182	158	6340	14077	158	14234
1990	14364		14364	6378	61	6439	20742	61	20803
1991	13462		13462	6777	144	6921	20239	144	20383
1992	11673		11673	5080	129	5209	16753	129	16882
1993	8524	30	8554	4019	66	4085	12543	96	12638
1994	5278	12	5290	1228	6	1234	6506	18	6524
1995	1100		1100	665	1	666	1765	1	1766
1996	1926	57	1984	773	2	775	2699	60	2759
1997	2919	496	3415	557	1	558	3476	497	3973
1998	1907	396	2304	795	2	797	2702	399	3101
1999	1818	351	2169	1150	7	1157	2968	358	3327
2000	1572	73	1645	661	11	672	2233	84	2317
2001	2143	143	2286	1361	83	1444	3504	226	3730
2002	1279	94	1373	1379	37	1416	2658	131	2789
2003	1325	200	1525	1813	87	1900	3138	287	3425
2004	1111	145	1257	980	74	1053	2091	219	2310
Minimum	1100	9	1100	557	1	558	1765	1	1766
Maximum	17824	496	17895	10551	158	10551	26389	497	26460
Average	6995	122	7086	4396	54	4428	11391	133	11513

Table 2. Nominal landings (t) of cod by year, gear and month for Canada in unit areas 5Zj,m for 1996-2004. (see Hunt and Hatt (2001) for 1978-1995 landings detail).

Year	Gear	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Discards	Total
1996	Gillnet						26	138	81						245
	Longline						29	389	290	91	137	66	21		1023
	Mobile	2					217	96	100	58	42	40	103		659
	Discards[1]													57	57
1996	Total	2					272	623	472	149	179	106	125	57	1984
1997	Gillnet						133	133	107	51	47				470
	Longline						177	432	385	255	132	15	21		1416
	Mobile						360	166	210	135	56	52	53	428	1461
	Discards[1]													68	68
1997	Total						670	731	703	440	235	67	74	496	3415
1998	Gillnet						76	90	63	25	46				300
	Longline						74	345	221	197	87	21	18		963
	Mobile						178	71	138	95	99	39	27	273	918
	Discards[1]													123	123
1998	Total					0	328	505	422	316	232	60	45	396	2304
1999	Gillnet						59	100	48	15	36	7	6		270
	Longline						95	288	244	152	107	27	17		929
	Mobile	3					226	156	47	72	59	38	19	253	872
	Discards[1]													98	98
1999	Total	3					379	544	339	239	201	71	42	351	2169
2000	Gillnet						55	76	28	24	41	9	4		238
	Longline						41	191	177	222	138	15	16		800
	Mobile	0					102	140	82	73	70	38	30		535
	Discards[1]													73	73
2000	Total	0					197	407	287	318	248	63	51	73	1645
2001	Gillnet						37	75	48	60	43	21			284
	Longline						62	212	273	282	229	62	16		1137
	Mobile						160	84	58	104	134	111	72		722
	Discards[1]													143	143
2001	Total						259	371	379	446	406	193	89	143	2286
2002	Gillnet						3	45	51	23	1	9	7		140
	Longline						2	151	199	162	127	31	30		700
	Mobile						38	87	34	78	62	55	86		439
	Discards[1]													94	94
2002	Total						43	283	283	263	190	95	123	94	1373
2003	Gillnet						6	30	31	24	3	14	1		110
	Longline						22	181	238	138	121	28	14		742
	Mobile						88	84	54	64	69	70	45		474
	Discards[1]													200	200
2003	Total						116	295	324	227	193	112	59	200	1525
2004	Gillnet						4	2	14	21	0	11	0		52
	Longline						6	85	231	168	88	96	14		688
	Mobile						78	82	50	47	56	42	16		371
	Discards[1]													145	145
2004	Total						88	169	294	236	144	149	30	145	1257

[1] derived estimate of cod discards in the Canadian scallop fishery

Table 3. Canadian and USA 5Zj,m commercial landings samples for 1978-2004. 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 1996-2004. USA 5Zj,m age samples were supplemented with DFO 5Zj,m age samples for 1996-2004.

	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
4	31	1872	439 (1481)	127	17859	1370

Table 4. Summary of 2004 Canadian commercial and Observer samples used to estimate catch-at-age. USA catch-at-age for 1994-2004 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	78	2210	122	78
	Jul	82	1623	72	
	Aug	50	744	33	
	Sep	47	1180	66	179
	Oct	56	1794	106	
	Nov	42	1182	108	
	Dec+Jan/03	16	1176	47	114
Total		371	9909	554	371
Longline	Jan				
	Feb				
	Mar				
	Apr				
	May				
	Jun	6	35		6
	Jul	85	1293	195	
	Aug	231	1586	171	
	Sep	168	697	110	484
	Oct	88	1260	72	
	Nov	97	882	111	
	Dec	14	579		199
Total		689	6332	659	689
Gillnet	Jan				
	Feb				
	Mar				
	Apr				
	May				
	Jun	4	541	75	4
	Jul	2			
	Aug	14			
	Sep	21	605	13	37
	Oct				
	Nov	11	472	69	
	Dec				11
Total		52	1618	157	52
Age Keys	Q1				
	Q2	88	2786	197	
	Q3	700	7728	660	
	Q4	324	7345	513	

Table 5. Results of 2004 intra-reader aging agreements.

1st Age BH	2nd Age - CAN BH								
	1	2	3	4	5	6	7	8	Total
1	10	1							11
2		9							9
3		1	78	4					83
4			3	76					79
5				12	63	1			76
6					5	27	1		33
7						2	32	4	38
8							1	11	12
Total									341

CV=1.69
90% Agreement

DIFF		
-1	0	+1
25	307	10

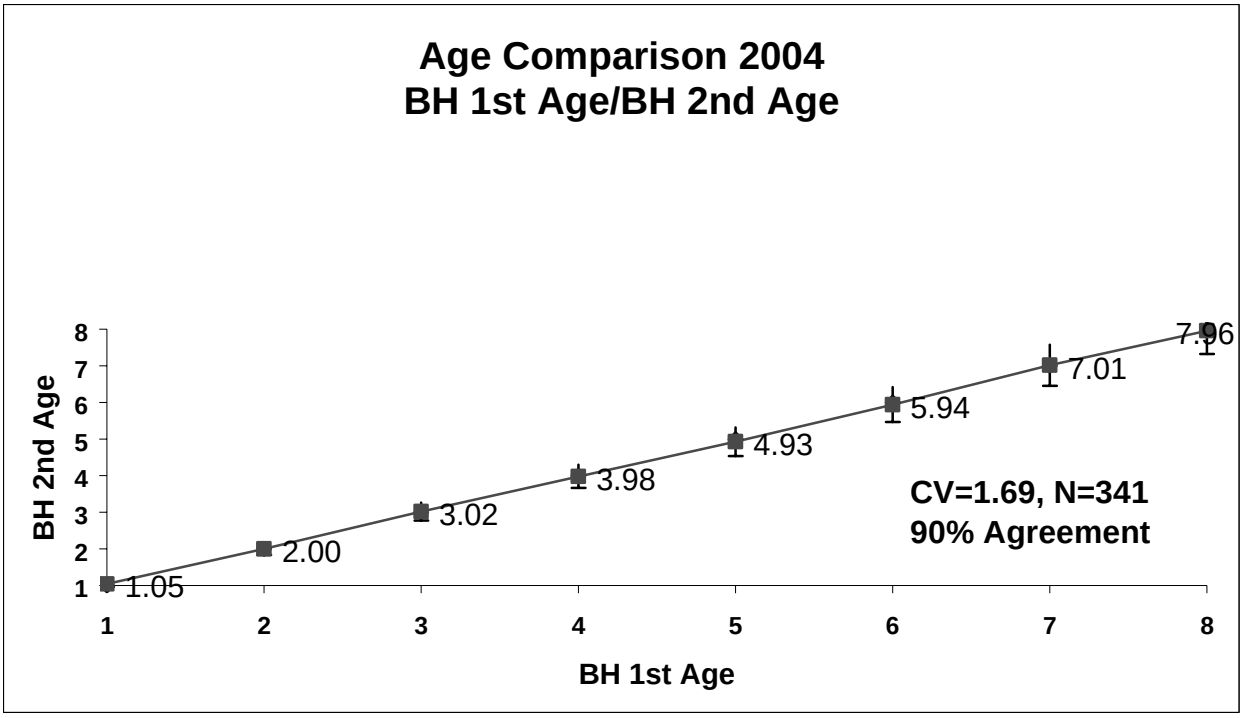


Table 6. Catch-at-age (000s) and percent at age for combined Canada and USA fishery with discards included.

Numbers CDN+USA	0	1	2	3	4	5	6	7	8	9	10	Total
1978	0.0	2.0	121.0	3588.0	1076.0	307.0	110.0	83.0	21.0	11.6	3.6	5323.1
1979	0.0	10.2	827.6	405.7	1803.7	554.1	151.5	22.4	45.8	3.8	3.1	3827.8
1980	0.0	1.0	994.3	1506.1	267.0	922.8	347.6	109.8	20.1	33.6	5.4	4207.8
1981	0.0	19.2	609.0	1457.3	1261.3	156.5	600.9	170.7	65.6	36.4	18.6	4395.5
1982	0.0	6.0	2692.7	1692.7	1434.7	1070.2	189.8	346.4	157.6	37.2	12.2	7639.5
1983	0.0	40.1	1322.4	3424.7	1477.8	467.2	283.7	31.1	71.2	38.9	5.9	7163.0
1984	0.0	10.1	270.6	916.5	1354.2	514.1	291.8	231.4	31.2	72.8	26.6	3719.2
1985	0.0	12.1	2804.8	1226.6	633.9	945.3	225.0	96.4	100.5	14.4	26.9	6085.9
1986	0.0	28.2	328.5	2204.8	516.9	306.3	403.1	58.4	39.3	25.9	3.6	3915.1
1987	0.0	14.0	3665.8	864.9	1098.9	144.0	121.0	167.0	37.0	23.6	7.6	6143.8
1988	0.0	9.9	317.3	3621.9	640.5	853.7	142.8	101.1	141.8	40.5	19.4	5888.9
1989	0.0	48.8	820.1	667.0	1827.6	191.8	311.7	55.6	24.8	50.9	11.7	4010.0
1990	0.0	9.0	719.5	3215.2	965.9	1199.1	116.4	122.3	10.0	14.3	22.6	6394.4
1991	0.0	33.3	724.1	802.4	1944.5	953.3	790.4	93.0	56.0	17.8	7.1	5422.0
1992	0.0	96.9	2456.9	1252.0	432.1	906.9	249.8	232.8	25.0	26.8	2.4	5681.5
1993	0.0	7.6	458.9	1986.2	812.3	216.1	333.7	110.6	93.6	23.2	17.4	4059.5
1994	0.0	2.9	187.5	488.5	753.0	246.5	40.7	58.8	26.0	20.3	1.1	1825.0
1995	0.0	2.0	56.5	235.2	120.1	89.1	14.4	4.2	3.0	1.5	0.0	525.9
1996	0.0	4.4	41.7	238.5	400.3	78.8	49.8	11.8	2.7	1.8	0.1	830.0
1997	0.0	3.0	136.2	213.7	412.0	461.1	111.8	55.7	18.5	3.7	0.7	1416.6
1998	0.1	0.6	103.2	381.1	198.1	201.2	167.0	26.2	14.9	4.7	1.1	1098.3
1999	0.0	3.3	63.0	540.4	364.4	110.1	61.7	52.1	12.1	2.1	4.6	1213.9
2000	0.0	1.8	59.6	115.8	335.9	129.5	34.6	20.2	12.2	1.8	0.3	711.7
2001	0.0	1.9	112.9	471.5	201.2	375.3	98.4	29.3	17.1	5.4	0.5	1313.7
2002	0.0	3.9	16.5	130.5	377.6	98.0	145.7	25.8	7.5	3.8	1.5	810.7
2003	0.0	1.8	31.6	177.9	276.5	393.6	73.0	81.9	15.9	3.1	1.2	1056.5
2004	0.0	2.9	13.7	132.2	152.8	134.0	128.8	32.9	22.1	4.3	0.8	624.5
Percent												
1978	0.0	0.0	2.3	67.4	20.2	5.8	2.1	1.6	0.4	0.2	0.1	100.0
1979	0.0	0.3	21.6	10.6	47.1	14.5	4.0	0.6	1.2	0.1	0.1	100.0
1980	0.0	0.0	23.6	35.8	6.3	21.9	8.3	2.6	0.5	0.8	0.1	100.0
1981	0.0	0.4	13.9	33.2	28.7	3.6	13.7	3.9	1.5	0.8	0.4	100.0
1982	0.0	0.1	35.2	22.2	18.8	14.0	2.5	4.5	2.1	0.5	0.2	100.0
1983	0.0	0.6	18.5	47.8	20.6	6.5	4.0	0.4	1.0	0.5	0.1	100.0
1984	0.0	0.3	7.3	24.6	36.4	13.8	7.8	6.2	0.8	2.0	0.7	100.0
1985	0.0	0.2	46.1	20.2	10.4	15.5	3.7	1.6	1.7	0.2	0.4	100.0
1986	0.0	0.7	8.4	56.3	13.2	7.8	10.3	1.5	1.0	0.7	0.1	100.0
1987	0.0	0.2	59.7	14.1	17.9	2.3	2.0	2.7	0.6	0.4	0.1	100.0
1988	0.0	0.2	5.4	61.5	10.9	14.5	2.4	1.7	2.4	0.7	0.3	100.0
1989	0.0	1.2	20.5	16.6	45.6	4.8	7.8	1.4	0.6	1.3	0.3	100.0
1990	0.0	0.1	11.3	50.3	15.1	18.8	1.8	1.9	0.2	0.2	0.4	100.0
1991	0.0	0.6	13.4	14.8	35.9	17.6	14.6	1.7	1.0	0.3	0.1	100.0
1992	0.0	1.7	43.2	22.0	7.6	16.0	4.4	4.1	0.4	0.5	0.0	100.0
1993	0.0	0.2	11.3	48.9	20.0	5.3	8.2	2.7	2.3	0.6	0.4	100.0
1994	0.0	0.2	10.3	26.8	41.3	13.5	2.2	3.2	1.4	1.1	0.1	100.0
1995	0.0	0.4	10.7	44.7	22.8	16.9	2.7	0.8	0.6	0.3	0.0	100.0
1996	0.0	0.5	5.0	28.7	48.2	9.5	6.0	1.4	0.3	0.2	0.0	100.0
1997	0.0	0.2	9.6	15.1	29.1	32.6	7.9	3.9	1.3	0.3	0.1	100.0
1998	0.0	0.1	9.4	34.7	18.0	18.3	15.2	2.4	1.4	0.4	0.1	100.0
1999	0.0	0.3	5.2	44.5	30.0	9.1	5.1	4.3	1.0	0.2	0.4	100.0
2000	0.0	0.2	8.4	16.3	47.2	18.2	4.9	2.8	1.7	0.2	0.0	100.0
2001	0.0	0.1	8.6	35.9	15.3	28.6	7.5	2.2	1.3	0.4	0.0	100.0
2002	0.0	0.5	2.0	16.1	46.6	12.1	18.0	3.2	0.9	0.5	0.2	100.0
2003	0.0	0.2	3.0	16.8	26.2	37.3	6.9	7.8	1.5	0.3	0.1	100.0
2004	0.0	0.5	2.2	21.2	24.5	21.5	20.6	5.3	3.5	0.7	0.1	100.0

Table 7. Weight-at-age (kg) derived from fishery (mid-year) and from 1987-2005 DFO surveys (beginning of year) for 5Zj,m cod. (Shaded values are calculated).

Midyear

	0	1	2	3	4	5	6	7	8	9	10	11
1978	0.05	0.707	1.310	2.461	3.469	4.336	5.787	7.374	8.492	11.785	13.624	16.024
1979	0.05	0.889	1.494	2.149	4.211	4.888	7.178	9.183	10.313	11.699	14.064	12.454
1980	0.05	0.836	1.460	2.468	3.668	5.647	6.676	8.390	9.089	8.432	14.351	17.522
1981	0.05	0.882	1.495	2.358	3.415	5.213	7.222	8.565	9.888	14.170	13.574	22.500
1982	0.05	0.765	1.402	2.664	3.834	5.352	6.511	9.363	9.897	12.503	13.680	16.803
1983	0.05	0.971	1.490	2.377	3.309	4.637	6.393	7.964	10.286	11.227	12.209	17.258
1984	0.05	1.053	1.635	2.451	3.619	5.083	6.582	8.909	10.104	11.303	13.792	17.068
1985	0.05	0.907	1.418	2.086	3.887	5.087	6.412	8.097	10.236	11.418	12.724	17.517
1986	0.05	0.929	1.475	2.447	3.660	5.603	7.191	8.915	9.955	12.687	8.913	11.746
1987	0.05	0.726	1.481	2.495	4.187	5.810	7.726	8.949	10.013	11.414	13.928	18.224
1988	0.05	0.786	1.520	2.359	3.511	5.401	6.647	8.776	9.987	11.143	13.166	15.388
1989	0.05	0.809	1.617	2.269	3.772	5.396	6.694	8.222	10.718	11.665	14.143	16.577
1990	0.05	0.831	1.560	2.462	3.522	4.892	6.333	8.456	10.648	12.580	14.043	16.170
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	15.649
1994	0.05	0.906	1.457	2.409	3.830	4.804	7.092	7.862	8.934	9.698	10.374	12.896
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	12.454
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	15.635
1999	0.05	0.796	1.554	2.286	3.527	4.164	6.310	6.775	8.043	12.153	13.536	15.780
2000	0.05	0.866	1.458	2.128	3.075	4.230	4.923	6.200	7.344	8.267	12.974	11.428
2001	0.05	0.880	1.488	2.334	2.998	4.053	5.122	5.081	8.019	9.224	14.812	14.846
2002	0.050	0.551	1.419	2.266	3.076	4.301	5.065	6.746	8.278	8.822	8.458	13.835
2003	0.050	0.262	1.662	2.150	2.675	3.682	4.353	5.674	7.289	7.859	9.017	12.091
2004	0.050	0.699	1.368	2.033	2.862	3.454	4.566	5.504	7.346	9.030	8.857	11.536
1978-2004	0.050	0.842	1.500	2.350	3.483	4.777	6.188	7.778	9.234	10.976	12.649	15.278
2002-2004	0.050	0.504	1.483	2.150	2.871	3.812	4.661	5.975	7.637	8.570	8.778	

Beginning

	0	1	2	3	4	5	6	7	8	9	10
1978	0.05	0.110	0.743	1.588	2.603	3.958	5.638	6.771	8.734	13.053	14.152
1979	0.05	0.110	0.743	1.588	2.603	3.958	5.638	6.771	8.734	13.053	14.152
1980	0.05	0.110	0.743	1.588	2.603	3.958	5.638	6.771	8.734	13.053	14.152
1981	0.05	0.110	0.743	1.588	2.603	3.958	5.638	6.771	8.734	13.053	14.152
1982	0.05	0.110	0.743	1.588	2.603	3.958	5.638	6.771	8.734	13.053	14.152
1983	0.05	0.110	0.743	1.588	2.603	3.958	5.638	6.771	8.734	13.053	14.152
1984	0.05	0.110	0.743	1.588	2.603	3.958	5.638	6.771	8.734	13.053	14.152
1985	0.05	0.110	0.743	1.588	2.603	3.958	5.638	6.771	8.734	13.053	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	0.05	0.120	0.695	1.032	1.787	3.090	3.480	5.237	6.807	7.662	14.152
2004	0.05	0.015	0.228	1.455	2.340	3.668	4.263	4.592	6.774	10.535	9.030
2005	0.05	0.011	0.591	1.201	1.645	2.819	3.405	3.914	6.857	13.036	14.152
1986-2005	0.050	0.110	0.743	1.588	2.603	3.958	5.638	6.771	8.734	13.053	14.152
2003-2005	0.050	0.049	0.505	1.229	1.924	3.192	3.716	4.581	6.813	10.411	12.445

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

DFO Feb-Mar	0	1	2	3	4	5	6	7	8	Total
1986.16		1.78	8.19	7.41	0.77	1.60	1.03	0.51	0.08	21.37
1987.16		0.12	4.31	1.55	1.81	0.39	0.21	0.44	0.21	9.04
1988.16		0.36	1.08	12.85	1.36	2.02	0.23	0.19	0.43	18.52
1989.16		0.84	5.22	1.84	4.11	0.62	0.80	0.10	0.20	13.73
1990.16		0.25	1.91	8.36	4.70	10.60	1.29	2.63	0.35	30.09
1991.16		2.83	2.43	3.40	3.93	2.06	2.87	0.36	0.60	18.48
1992.16		0.11	4.93	2.94	0.99	1.55	1.09	0.72	0.22	12.55
1993.16		0.07	0.85	4.15	1.50	0.89	1.82	0.66	0.64	10.58
1994.16		0.03	1.51	1.66	3.10	1.15	0.44	0.88	0.20	8.97
1995.16		0.08	0.45	2.99	1.82	1.25	0.45	0.11	0.16	7.31
1996.16		0.22	0.49	4.20	10.44	3.45	2.49	1.07	0.26	22.62
1997.16		0.07	0.90	1.37	3.19	3.04	0.52	0.12	0.08	9.29
1998.16		0.01	1.42	2.04	0.79	0.77	0.58	0.14	0.07	5.82
1999.16		0.01	0.38	3.12	2.63	1.08	0.76	0.46	0.02	8.46
2000.16		0.00	1.02	3.12	11.96	5.19	2.48	1.23	0.76	25.76
2001.16		0.01	0.09	1.93	1.25	3.35	1.55	0.80	0.54	9.52
2002.16		0.00	0.28	1.15	5.05	1.67	3.09	1.10	0.45	12.80
2003.16		0.00	0.02	0.48	1.23	2.09	0.47	0.53	0.17	4.98
2004.16		1.03	0.10	0.59	0.91	1.02	0.86	0.14	0.26	4.90
2005		0.06	2.47	3.37	17.21	4.25	1.97	1.78	0.15	31.26
NMFS spring										
Y41										
1978.29		0.27	0.00	5.10	1.12	1.61	0.34	1.37	0.19	10.00
1979.29		0.69	2.65	0.22	2.57	1.00	0.34	0.17	0.22	7.86
1980.29		0.03	2.96	2.90	0.28	3.01	0.59	0.12	0.08	9.97
1981.29		1.70	1.57	2.43	1.73	0.07	0.60	0.31	0.12	8.53
NMF Spring										
Y36										
1982.29		0.79	11.58	24.99	22.29	16.98	0.00	5.55	1.24	83.42
1983.29		0.69	3.63	6.33	1.36	1.06	0.66	0.28	0.11	14.12
1984.29		0.20	0.22	0.81	1.22	0.48	0.39	0.34	0.00	3.66
1985.29		0.08	3.67	1.15	1.92	2.75	0.60	0.35	0.45	10.97
1986.29		1.13	0.62	2.05	0.55	0.78	0.98	0.05	0.21	6.37
1987.29		0.00	2.17	0.46	0.98	0.00	0.34	0.28	0.06	4.29
1988.29		0.58	0.45	5.05	0.50	0.84	0.08	0.03	0.14	7.67
1989.29		0.21	1.55	0.47	2.39	0.46	0.54	0.07	0.06	5.75
1990.29		0.13	0.62	3.14	1.09	1.18	0.29	0.30	0.03	6.78
1991.29		1.31	1.12	0.92	1.63	0.83	0.69	0.08	0.03	6.61
1992.29		0.14	1.20	0.65	0.17	0.45	0.27	0.29	0.05	3.22
1993.29		0.00	0.83	2.32	0.47	0.08	0.33	0.08	0.08	4.19
1994.29		0.10	0.37	0.29	0.36	0.09	0.02	0.06	0.00	1.29
1995.29		0.09	0.52	1.64	0.88	1.63	0.35	0.47	0.06	5.64
1996.29		0.25	0.54	1.78	2.41	0.22	0.17	0.05	0.00	5.42
1997.29		0.10	0.37	0.11	0.73	0.93	0.10	0.23	0.10	2.67
1998.29		0.00	1.99	3.80	1.91	1.88	1.17	0.06	0.06	10.87
1999.29		0.04	0.24	1.24	1.14	0.66	0.31	0.18	0.06	3.87
2000.29		0.00	0.55	1.16	2.43	0.89	0.25	0.09	0.04	5.41
2001.29		0.00	0.15	1.54	0.24	0.62	0.19	0.00	0.01	2.74
2002.29		0.01	0.20	0.93	2.03	0.39	0.40	0.12	0.00	4.08
2003.29		0.00	0.29	0.78	1.59	1.69	0.16	0.16	0.01	4.68
2004.29		1.20	0.02	1.86	4.70	4.48	2.67	0.50	0.67	16.10
2005		0.03	0.62	0.13	1.34	0.51	0.33	0.24	0.06	3.25
NMFS fall										
1978.69	0.21	2.64	0.26	5.10	0.73	0.11				8.84
1979.69	0.32	2.96	2.93	0.21	2.71	0.44				9.25
1980.69	0.60	1.43	0.76	1.21	0.05	0.35				3.80
1981.69	0.60	4.24	2.19	1.69	0.48	0.02				8.62
1982.69	0.00	1.05	1.29	0.08	0.12	0.00				2.54
1983.69	1.47	0.12	0.42	0.89	0.05	0.03				1.51
1984.69	0.06	2.84	0.14	1.03	1.68	0.05				5.74
1985.69	2.24	0.39	1.80	0.30	0.03	0.00				2.52
1986.69	0.22	5.20	0.11	0.35	0.00	0.00				5.66
1987.69	0.29	0.24	1.53	0.23	0.19	0.00				2.19
1988.69	0.18	1.02	0.33	2.13	0.25	0.44				4.17
1989.69	0.41	0.72	1.68	0.28	0.77	0.10				3.55
1990.69	0.36	0.72	0.79	1.49	0.21	0.37				3.58
1991.69	0.00	0.36	0.13	0.16	0.02	0.06				0.73
1992.69	0.00	0.37	1.31	0.28	0.00	0.07				2.03
1993.69	0.00	0.14	0.19	0.28	0.03	0.00				0.64
1994.69	0.02	0.14	0.54	0.39	0.28	0.14				1.49
1995.69	0.40	0.05	0.22	0.54	0.12	0.05				0.98
1996.69	0.02	0.56	0.15	0.56	0.41	0.10				1.78
1997.69	0.00	0.29	0.70	0.32	0.10	0.15				1.56
1998.69	0.00	0.32	1.29	0.90	0.12	0.20				2.83
1999.69	0.00	0.03	0.03	0.45	0.22	0.06				0.79
2000.69	0.00	0.10	0.37	0.12	0.16	0.08				0.83
2001.69	0.04	0.13	0.31	0.37	0.07	0.11				0.99
2002.69	0.22	0.26	1.24	2.29	3.44	0.35				7.57
2003.69	0.17	0.00	0.05	0.16	0.18	0.07				0.47
2004.69	0.20	0.76	0.12	1.51	0.70	0.98				4.07

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	Stnd Error	Relative Error	Bias	Relative Bias
N[2000 11]	79.2	34.2	43.1%	4.6	5.8%
N[2001 11]	97.1	41.9	43.1%	5.6	5.8%
N[2002 11]	47.9	26.0	54.2%	4.7	9.8%
N[2003 11]	103.0	51.4	49.8%	6.3	6.1%
N[2004 11]	75.4	36.6	48.5%	6.4	8.4%
N[2005 2]	8570.0	5130.0	59.9%	993.0	11.6%
N[2005 3]	415.0	196.0	47.1%	43.0	10.4%
N[2005 4]	926.0	326.0	35.2%	63.5	6.9%
N[2005 5]	907.0	318.0	35.0%	53.6	5.9%
N[2005 6]	698.0	232.0	33.2%	33.1	4.7%
N[2005 7]	486.0	196.0	40.4%	32.8	6.8%
N[2005 8]	125.0	52.9	42.4%	6.0	4.8%
N[2005 9]	272.0	122.0	44.9%	17.1	6.3%
N[2005 10]	139.0	61.1	44.1%	8.7	6.3%
N[2005 11]	57.0	28.3	49.7%	5.1	9.0%
DFO 2	0.00028400	0.00005990	21.1%	0.00000623	2.2%
DFO 3	0.00115000	0.00023800	20.7%	0.00000133	0.1%
DFO 4	0.00182000	0.00037800	20.8%	0.00002420	1.3%
DFO 5	0.00234000	0.00049900	21.3%	0.00001650	0.7%
DFO 6	0.00238000	0.00051700	21.7%	0.00004740	2.0%
DFO 7	0.00235000	0.00054300	23.1%	0.00004850	2.1%
NMFS Fall 1	0.00009960	0.00001830	18.4%	0.00000142	1.4%
NMFS Fall 2	0.00014200	0.00002570	18.1%	0.00000192	1.3%
NMFS Fall 3	0.00024000	0.00004350	18.1%	0.00000415	1.7%
NMFS Fall 4	0.00016300	0.00003020	18.5%	0.00000207	1.3%
NMFS Fall 5	0.00019300	0.00004100	21.2%	0.00000520	2.7%
NMFS Y41 Spr 1	0.00002900	0.00001460	50.5%	0.00000273	9.4%
NMFS Y41 Spr 2	0.00031200	0.00019900	63.7%	0.00004400	14.1%
NMFS Y41 Spr 3	0.00038800	0.00020100	51.7%	0.00003520	9.1%
NMFS Y41 Spr 4	0.00043100	0.00021300	49.5%	0.00003060	7.1%
NMFS Y41 Spr 5	0.00067700	0.00034900	51.6%	0.00006770	10.0%
NMFS Y41 Spr 6	0.00076600	0.00043800	57.1%	0.00010700	14.0%
NMFS Y41 Spr 7	0.00124000	0.00061600	49.8%	0.00013300	10.8%
NMFS Y41 Spr 8	0.00159000	0.00085900	54.1%	0.00020800	13.1%
NMFS Y36 Spr 1	0.00003950	0.00000815	20.7%	0.00000063	1.6%
NMFS Y36 Spr 2	0.00018900	0.00003660	19.4%	0.00000238	1.3%
NMFS Y36 Spr 3	0.00054600	0.00010500	19.2%	0.00000628	1.1%
NMFS Y36 Spr 4	0.00085000	0.00016400	19.3%	0.00000760	0.9%
NMFS Y36 Spr 5	0.00102000	0.00019900	19.5%	0.00000470	0.5%
NMFS Y36 Spr 6	0.00083500	0.00017300	20.7%	0.00001680	2.0%
NMFS Y36 Spr 7	0.00075700	0.00014700	19.4%	0.00001330	1.8%
NMFS Y36 Spr 8	0.00067800	0.00015100	22.3%	0.00002870	4.2%

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

Pop #s Bias (Bootstrap)	0	1	2	3	4	5	6	7	8	9	10	0+	3+
1978	11608	11131	2210	10563	3506	991	307	279	56	26	9	40687	15737
1979	11275	9504	9112	1700	5432	1905	536	152	154	27	11	39809	9918
1980	21198	9231	7772	6714	1028	2830	1062	303	105	85	19	50346	12145
1981	7679	17356	7557	5467	4143	601	1490	558	149	68	39	45107	12516
1982	5596	6287	14192	5638	3167	2260	352	682	304	64	23	38565	12489
1983	16529	4582	5142	9197	3097	1312	895	119	250	108	19	41249	14996
1984	5536	13533	3715	3022	4463	1217	655	478	70	140	54	32882	10098
1985	25795	4532	11071	2797	1652	2439	536	276	185	29	50	49362	7964
1986	8586	21119	3700	6544	1194	785	1150	238	139	62	11	43528	10124
1987	16708	7029	17265	2733	3381	516	368	581	142	79	28	48831	7828
1988	4865	13680	5743	10839	1462	1783	293	193	325	83	43	39308	15021
1989	7285	3983	11191	4415	5627	624	698	112	68	140	32	34175	11716
1990	11339	5964	3217	8423	3014	2968	339	293	42	33	69	35701	15181
1991	3228	9283	4875	1987	4017	1602	1357	173	130	26	15	26693	9307
1992	4441	2643	7570	3339	909	1554	465	409	59	57	5	21451	6796
1993	2887	3636	2076	3995	1613	358	466	158	128	26	23	15365	6766
1994	1903	2363	2970	1287	1499	596	101	87	32	22	1	10863	3626
1995	3558	1558	1932	2262	617	556	267	47	20	3	1	10820	3772
1996	5638	2913	1274	1531	1640	397	375	206	34	13	1	14023	4198
1997	2118	4616	2381	1005	1039	983	254	262	158	26	9	12851	3736
1998	5454	1734	3777	1834	658	555	502	137	182	119	18	14969	4005
1999	3734	4465	1419	3004	1209	393	310	293	93	139	95	15154	5536
2000	3076	3057	3653	1108	2022	713	239	208	200	67	112	14455	4668
2001	2237	2519	2502	2937	803	1353	467	164	152	152	53	13339	6081
2002	703	1832	2060	1946	1980	476	771	294	108	109	120	10398	5804
2003	11303	575	1496	1672	1476	1281	302	500	217	82	86	18989	5615
2004	4886	9254	469	1196	1209	959	696	181	335	164	64	19413	4804
2005	5000	4000	7574	372	862	854	665	453	119	255	130	20283	3709
Biomass													
1978	580	7781	3633	21913	10218	3596	1434	1509	418	235	80	51395	39402
1979	564	6643	14975	3528	15831	6913	2506	825	1150	239	100	53274	31091
1980	1060	6452	12773	13928	2995	10271	4967	1638	782	754	164	55784	35499
1981	384	12132	12420	11342	12074	2183	6966	3019	1117	599	347	62583	37647
1982	280	4395	23325	11696	9231	8202	1645	3690	2269	566	202	65500	37500
1983	826	3202	8451	19079	9026	4760	4186	644	1865	960	168	53167	40687
1984	277	9460	6105	6269	13006	4415	3065	2588	520	1246	472	47423	31581
1985	1290	3168	18195	5803	4814	8850	2508	1493	1383	258	441	48203	25550
1986	429	2547	2981	11122	3323	3298	7151	1739	1298	861	156	34906	28949
1987	835	1063	14546	4617	9596	2990	3104	4735	1062	1070	433	44053	27608
1988	243	1728	5135	20410	4387	8057	2036	1744	3206	1129	680	48755	41649
1989	364	608	9003	7370	16139	2638	4598	858	551	1906	453	44489	34513
1990	567	1214	2532	15968	9268	13595	2148	2433	402	499	1108	49736	45423
1991	161	799	4243	3821	12778	6832	6920	1267	1254	353	230	38657	33454
1992	222	370	6156	6586	2819	6800	2878	2903	507	977	75	30293	23545
1993	144	293	1943	7525	4979	1717	2810	1101	967	313	289	22080	19699
1994	95	180	1946	1853	4295	2586	770	708	361	355	17	13168	10947
1995	178	228	1542	3544	1372	1965	1372	290	143	47	10	10690	8742
1996	282	151	928	2522	4427	1637	2343	1166	378	189	19	14041	12681
1997	106	460	1726	1771	2443	3376	1667	1973	1736	352	158	15769	13477
1998	273	177	2343	2474	1619	1838	2414	810	1529	1181	204	14863	12070
1999	187	675	1418	4248	2932	1304	1503	2084	1042	1847	1342	18581	16301
2000	154	361	3306	1781	4899	2336	1160	1285	1594	970	1640	19485	15665
2001	112	303	1839	4405	2084	5278	2481	1182	1140	1654	583	21061	18807
2002	35	221	872	2287	4565	1711	3400	1749	913	1089	1420	18261	17134
2003	565	69	1040	1726	2637	3958	1050	2618	1479	627	1213	16983	15309
2004	244	143	107	1741	2829	3519	2965	833	2272	1723	580	16956	16461
2005	250	43	4475	447	1418	2406	2265	1772	814	3319	1840	19049	14281
F Bias Adj.												4-6F	4-6u
1978	0.000	0.000	0.062	0.465	0.410	0.415	0.499	0.395	0.529	0.648	0.567	0.417	31.1%
1979	0.000	0.001	0.105	0.304	0.452	0.384	0.371	0.176	0.394	0.167	0.361	0.394	29.7%
1980	0.000	0.000	0.152	0.283	0.336	0.442	0.444	0.506	0.238	0.566	0.385	0.375	28.5%
1981	0.000	0.001	0.093	0.346	0.406	0.336	0.581	0.408	0.653	0.880	0.723	0.388	29.3%
1982	0.000	0.001	0.234	0.399	0.682	0.726	0.883	0.805	0.832	1.005	0.862	0.736	47.8%
1983	0.000	0.010	0.332	0.523	0.734	0.494	0.427	0.337	0.375	0.501	0.413	0.650	43.8%
1984	0.000	0.001	0.084	0.404	0.404	0.619	0.665	0.749	0.671	0.830	0.777	0.551	38.7%
1985	0.000	0.003	0.326	0.651	0.544	0.551	0.613	0.482	0.892	0.770	0.875	0.570	39.8%
1986	0.000	0.001	0.103	0.460	0.640	0.556	0.484	0.314	0.370	0.609	0.443	0.614	42.0%
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	30.2%
1988	0.000	0.001	0.063	0.456	0.651	0.738	0.758	0.844	0.645	0.755	0.668	0.673	44.9%
1989	0.000	0.014	0.084	0.182	0.440	0.410	0.668	0.774	0.509	0.508	0.509	0.438	32.4%
1990	0.000	0.002	0.282	0.540	0.432	0.583	0.471	0.609	0.301	0.630	0.446	0.472	34.4%
1991	0.000	0.004	0.178	0.582	0.750	1.038	1.000	0.877	0.633	1.376	0.756	0.955	56.6%
1992	0.000	0.041	0.438	0.526	0.730	1.003	0.879	0.964	0.619	0.724	0.670	0.813	51.1%
1993	0.000	0.002	0.276	0.775	0.783	1.055	1.472	1.408	1.558	2.859	1.779	0.898	54.5%
1994	0.000	0.001	0.071	0.528	0.771	0.567	0.562	1.269	2.096	3.474	2.664	0.644	43.5%
1995	0.000	0.001	0.032	0.120	0.233	0.182	0.055	0.101	0.170	0.736	0.246	0.195	16.1%
1996	0.000	0.002	0.036	0.185	0.306	0.234	0.144	0.058	0.084	0.146	0.103	0.255	20.5%
1997	0.000	0.001	0.060	0.219	0.415	0.453	0.382	0.142	0.069	0.160	0.082	0.417	31.1%
1998	0.000	0.000	0.028	0.212	0.304	0.360	0.307	0.155	0.062	0.025	0.052	0.316	24.7%
1999	0.000	0.001	0.047	0.192	0.317	0.279	0.180	0.153	0.094	0.010	0.033	0.295	23.3%
2000	0.000	0.001	0.018	0.120	0.196	0.210	0.156	0.097	0.054	0.015	0.002	0.196	16.2%
2001	0.000	0.001	0.049	0.190	0.313	0.345	0.239	0.184	0.107	0.023	0.001	0.299	23.5%
2002	0.000	0.002	0.008	0.074	0.227	0.245	0.213	0.088	0.061	0.029	0.003	0.233	18.9%
2003	0.000	0.003	0.022	0.116	0.218	0.385	0.284	0.171	0.070	0.028	0.011	0.292	23.1%
2004	0.000	0.000	0.027	0.115	0.134	0.152	0.203	0.192	0.061	0.024	0.003	0.160	13.5%

Table 11. Projection results for the 2004-2010 population using bootstrap bias adjusted point estimates with a 2005 yield = the TAC of 1,000t and a fishing mortality of F_{ref}=0.18 for 2006-2009.

Population Numbers

	0	1	2	3	4	5	6	7	8	9	10	11
2005	5000	4000	7574	372	862	854	665	453	119	255	130	52
2006	5000	4094	3275	6172	288	635	625	501	355	95	206	106
2007	5000	4094	3351	2660	4623	199	434	447	382	278	76	168
2008	5000	4094	3351	2722	1993	3186	136	310	341	300	224	62
2009	5000	4094	3351	2722	2039	1373	2179	97	237	267	241	183
2010	5000	4094	3351	2722	2039	1405	939	1557	74	186	215	197

Fishing Mortality

2005	0.000	0.000	0.005	0.055	0.106	0.111	0.084	0.044	0.027	0.010	0.002	0.002
2006 2009	0.000	0.000	0.008	0.089	0.172	0.180	0.136	0.071	0.043	0.017	0.004	0.004

Natural Mortality

2005 2009	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

Partial Recruitment

2005 2009	0.00	0.00	0.04	0.49	0.96	1.00	0.75	0.40	0.24	0.09	0.02	0.02

Beginning of Year Weights

2005	0.05	0.01	0.59	1.20	1.65	2.82	3.41	3.91	6.86	13.04	14.15	14.15
2006-2009	0.05	0.05	0.50	1.23	1.92	3.19	3.72	4.58	6.81	10.41	12.44	12.44

Population Biomass

	0	1	2	3	4	5	6	7	8	9	10	11	0+	3+
2005	250	44	4476	447	1418	2406	2265	1772	814	3319	1840	734	19785	15015
2006	250	200	1652	7587	555	2027	2324	2295	2417	985	2567	1322	24181	22079
2007	250	200	1691	3270	8894	634	1613	2048	2602	2896	948	2094	27142	25001
2008	250	200	1691	3347	3834	10170	505	1422	2322	3118	2787	773	30420	28278
2009	250	200	1691	3347	3924	4384	8096	445	1612	2783	3001	2273	32005	29864
2010	250	200	1691	3347	3924	4486	3490	7134	504	1932	2678	2447	32083	29942

Projected Catch Numbers

	0	1	2	3	4	5	6	7	8	9	10	11
2005	0	0	33	18	79	81	48	18	3	2	0	0
2006	0	1	23	477	41	95	72	31	14	1	1	0
2007	0	1	23	206	665	30	50	28	15	4	0	1
2008	0	1	23	210	287	477	16	19	13	5	1	0
2009	0	1	23	210	293	206	251	6	9	4	1	1

Midyear Weights

2005 2009	0.05	0.50	1.48	2.15	2.87	3.81	4.66	5.97	7.64	8.57	8.78	8.78

Catch Biomass

	0	1	2	3	4	5	6	7	8	9	10	11	0+	3+
2005	0	0	48	39	226	310	226	105	22	20	2	1	1000	951
2006	0	0	34	1025	119	362	336	187	104	12	6	3	2189	2155
2007	0	0	35	442	1908	113	233	167	112	36	2	5	3054	3019
2008	0	0	35	452	823	1819	73	116	100	39	7	2	3465	3430
2009	0	0	35	452	842	784	1171	36	69	35	7	6	3437	3402

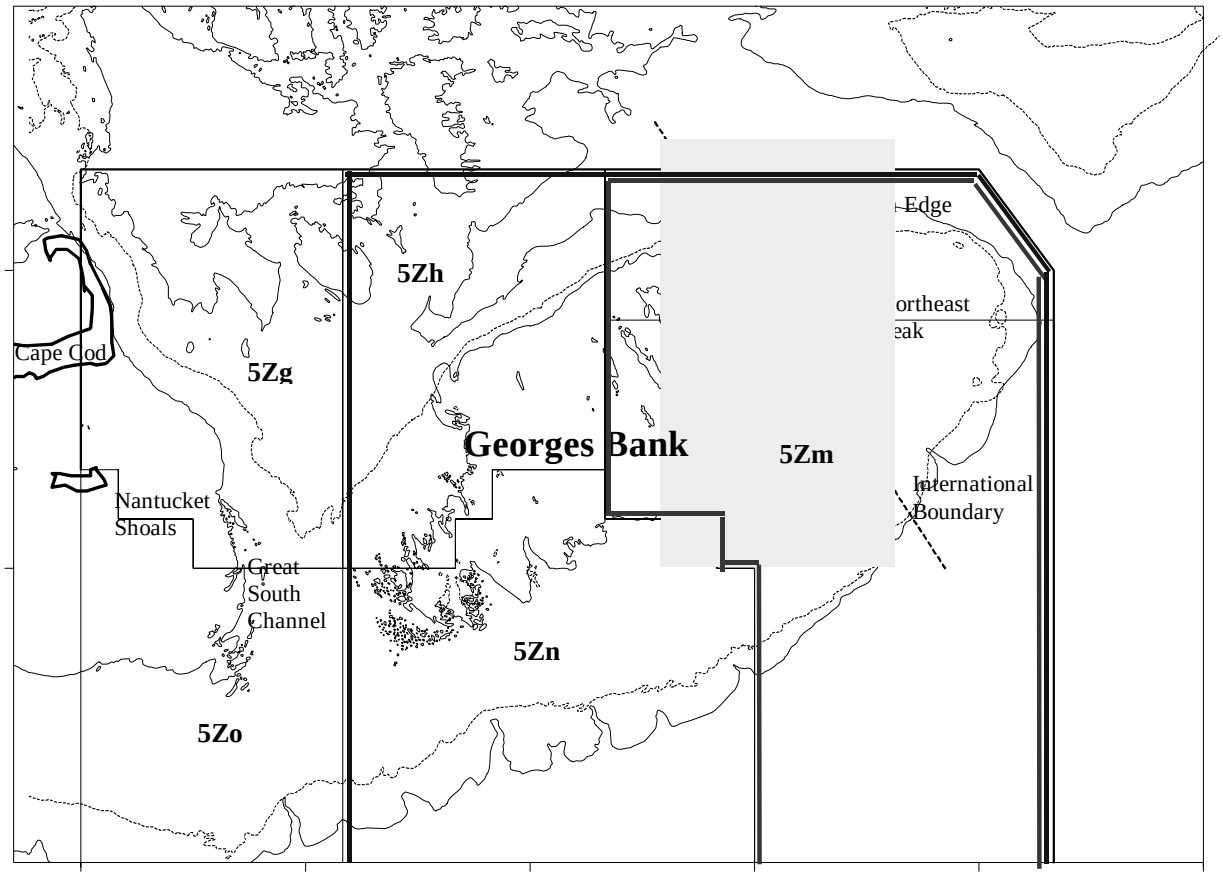


Figure 1a. Map of the Georges Bank area showing the 5Zj,m management unit. Shaded area indicates USA closed area II.

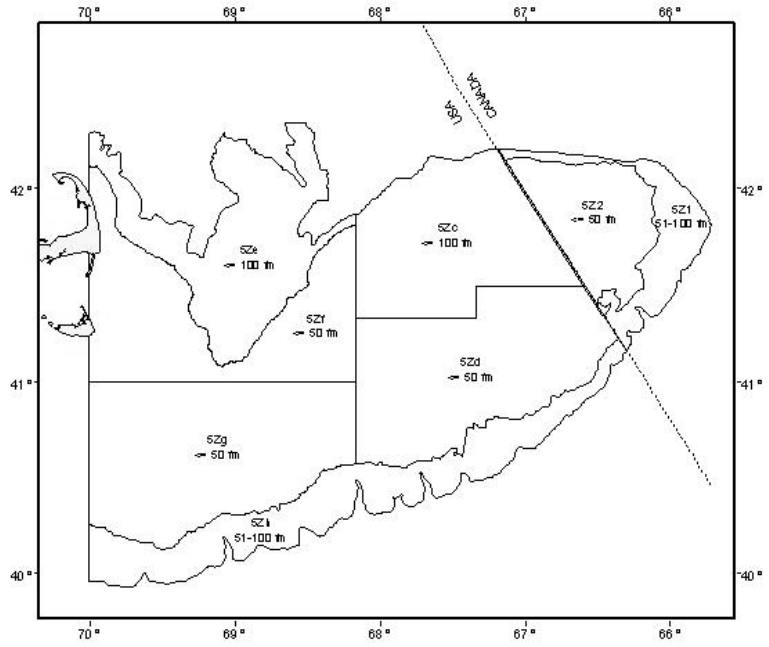


Figure 1b. DFO survey strata on Georges Bank.

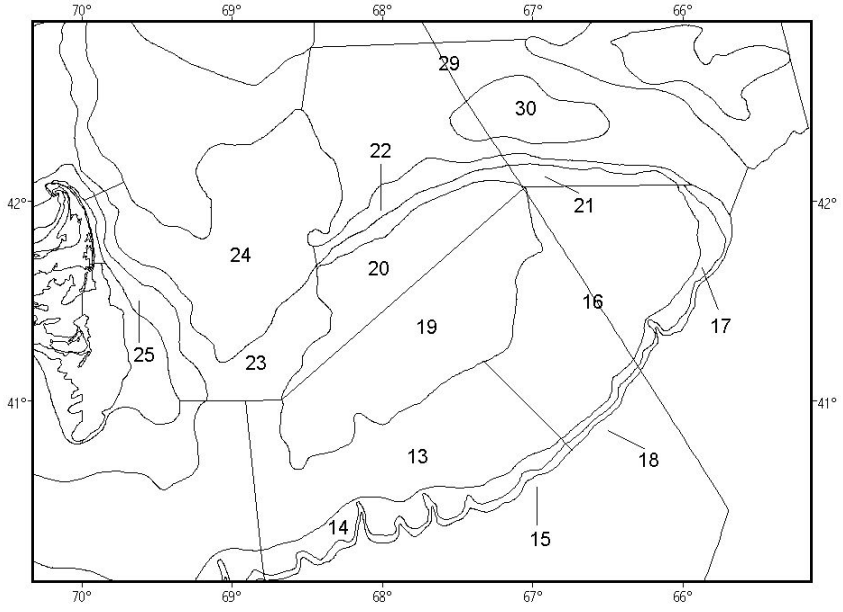


Figure 1c. NEFSC survey strata on Georges Bank.

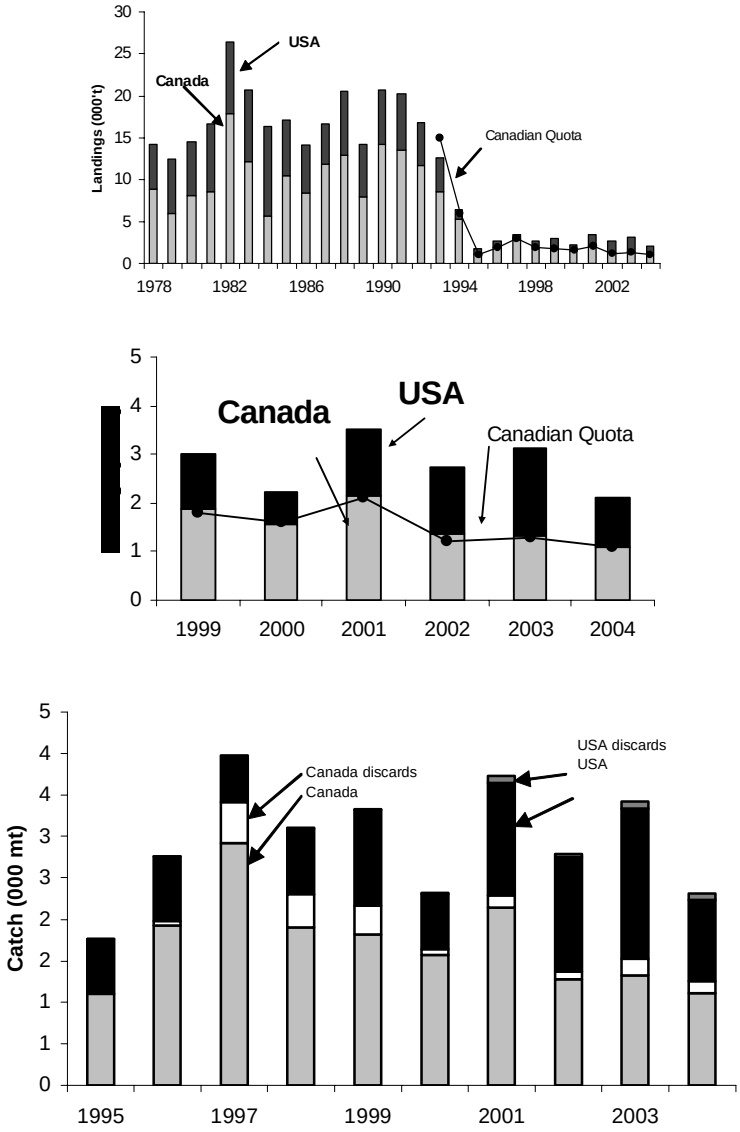


Figure 2. Landings of 5Zj,m cod by Canadian and USA fisheries.

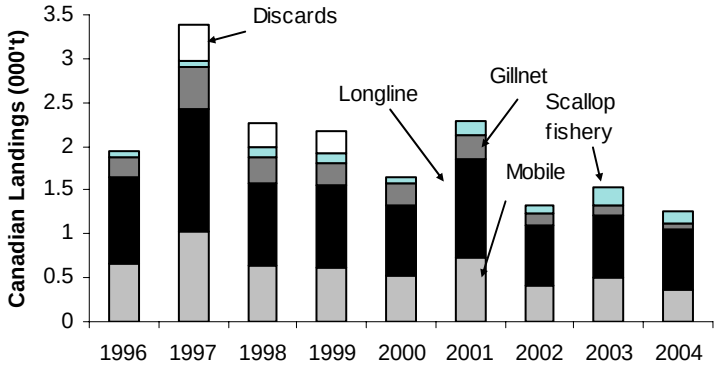


Figure 3. Landings of 5Zj,m cod by Canada gear sectors.

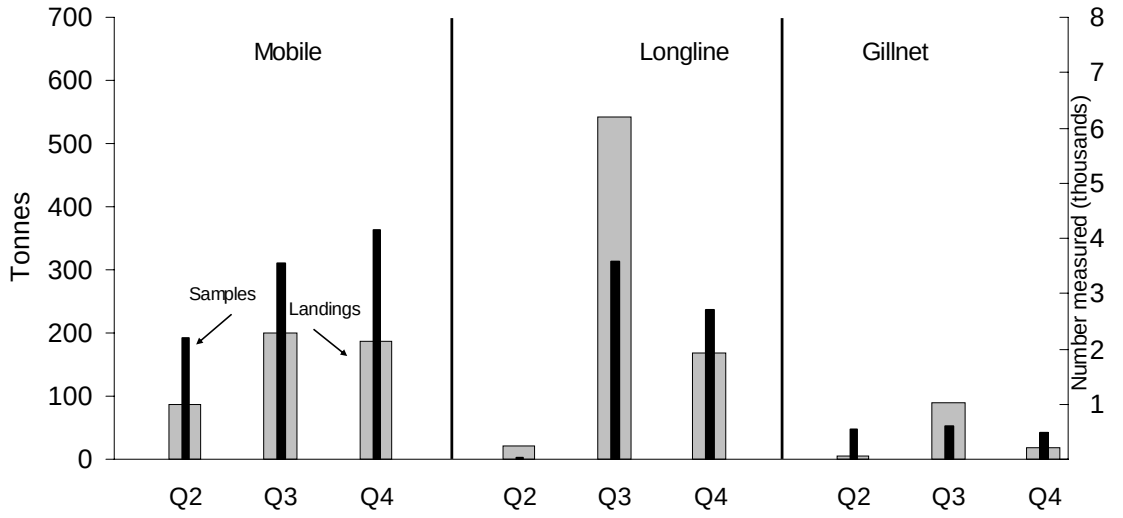


Figure 4a. Summary of Canadian landings by gear sector and corresponding length samples used in determining catch at age for 2004.

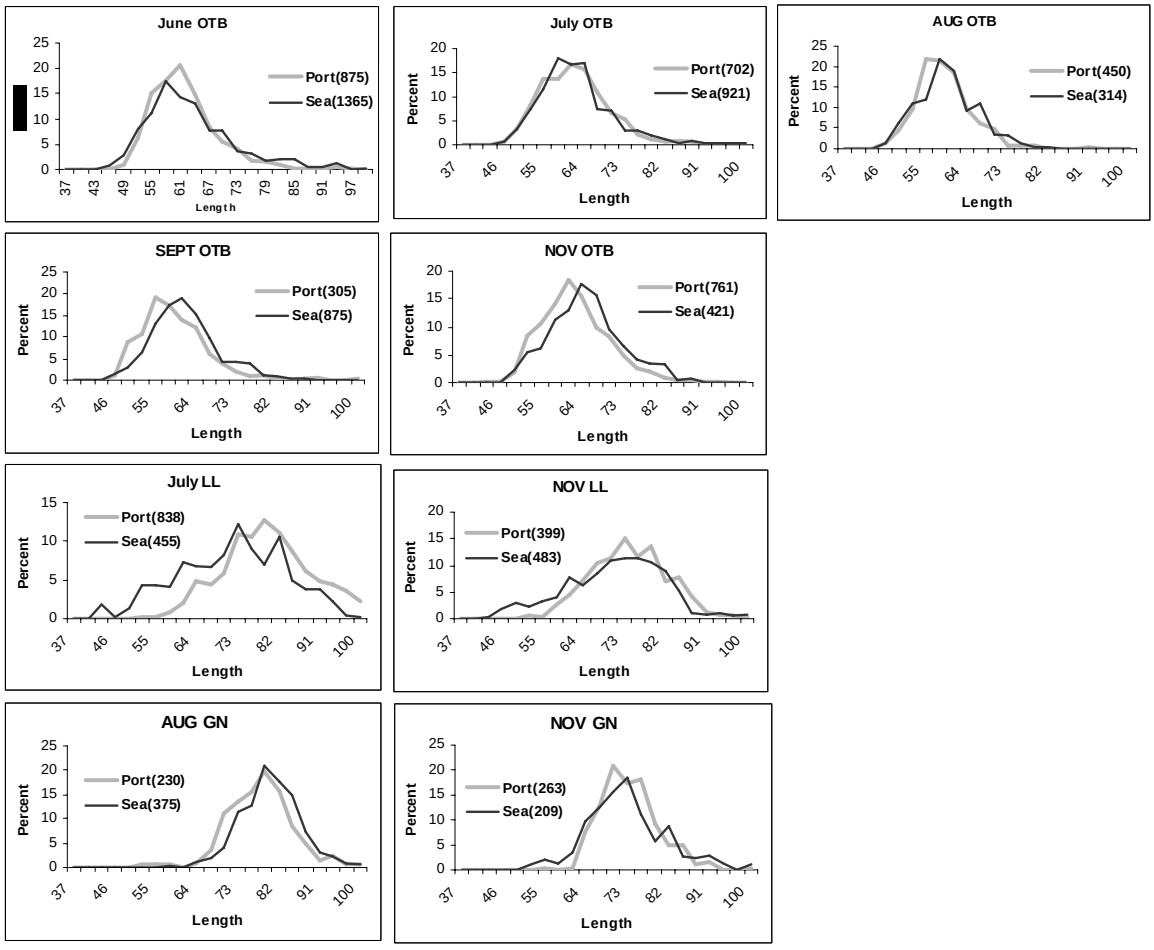


Figure 4b. Comparison of Canadian 2004 length frequency distributions from sea (catch) and on-shore (landings) samples.

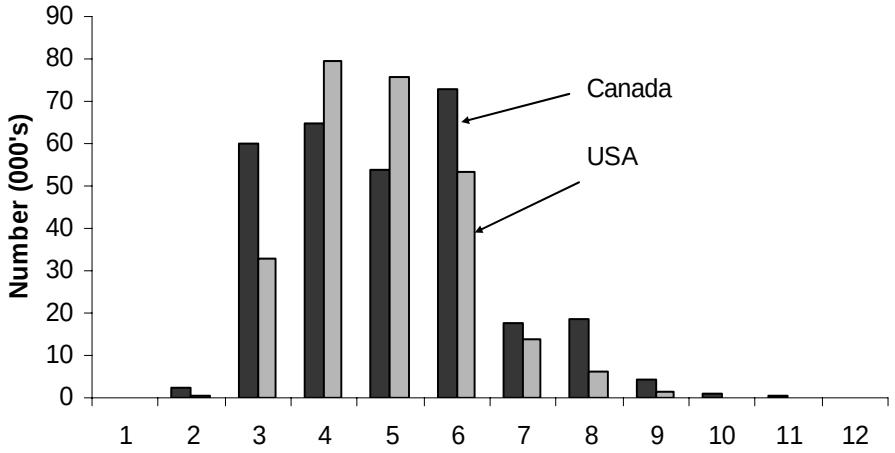


Figure 5. Catch at age in the 2004 combined Canadian and USA 5Zj,m cod fishery.

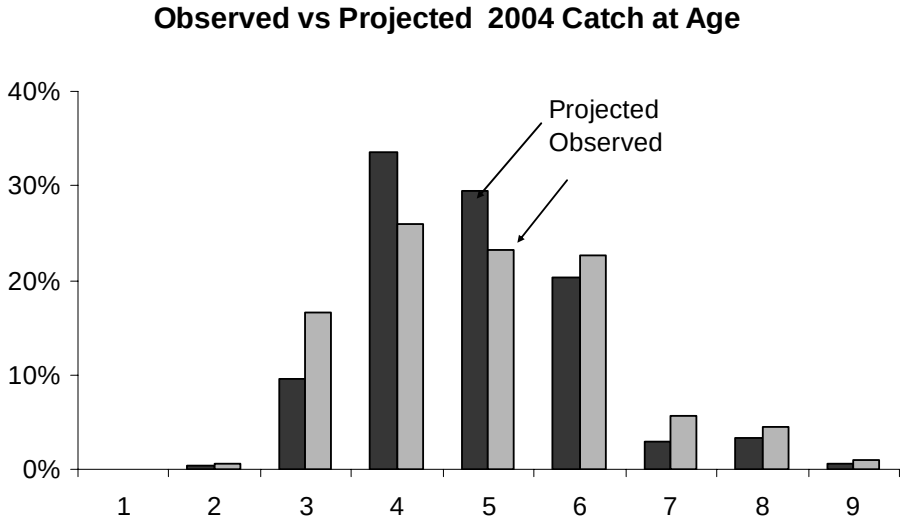


Figure 6. Observed and predicted percent catch at age for the 5Zj,m cod fishery in 2004

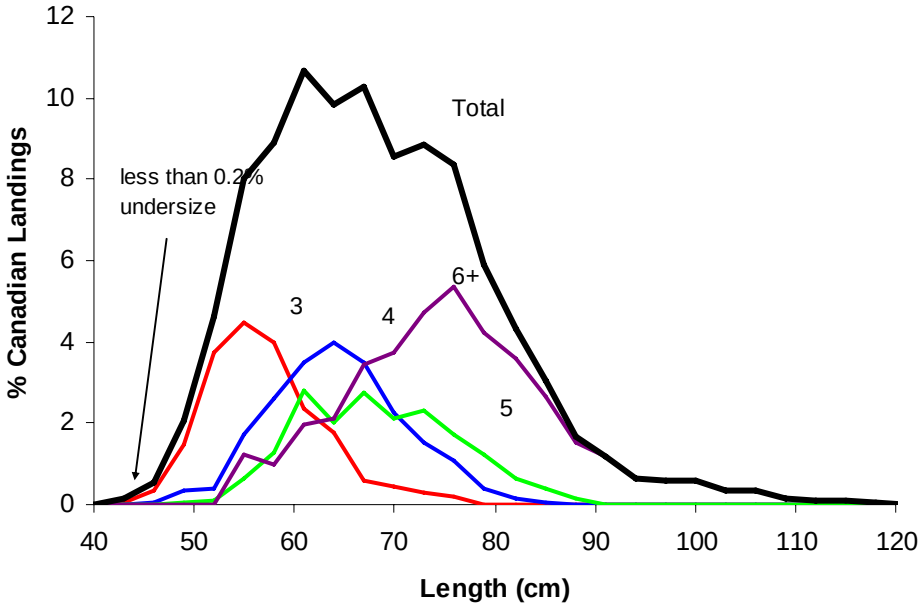


Figure 7a. Length composition by age group for the 2004 Canadian 5Zj,m cod fishery.

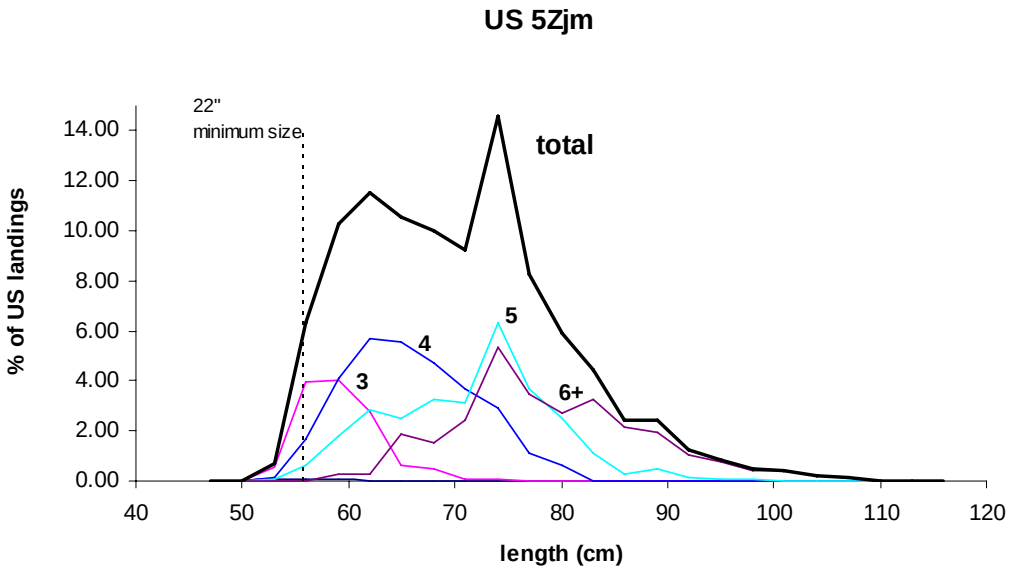


Figure 7b. Length composition by age group for the 2004 USA 5Zj,m cod fishery.

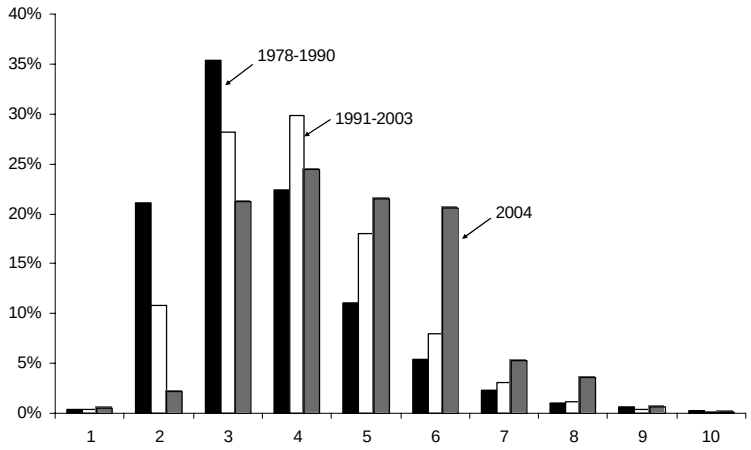


Figure 8. Comparison of the 2004 observed percent catch at age compared to short and long term averages.

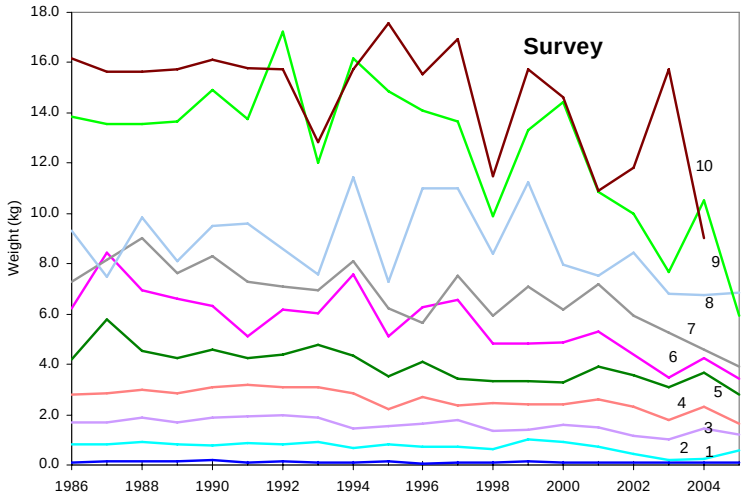


Figure 9. Beginning of year mean weight (kg) at age for cod derived from DFO research surveys.

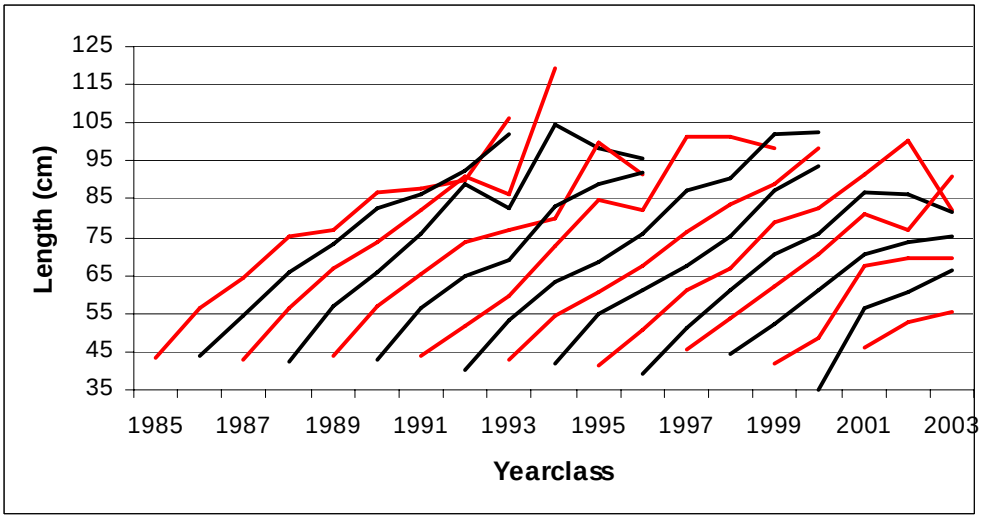


Figure 10. Mean size at age for cod derived from DFO research surveys.

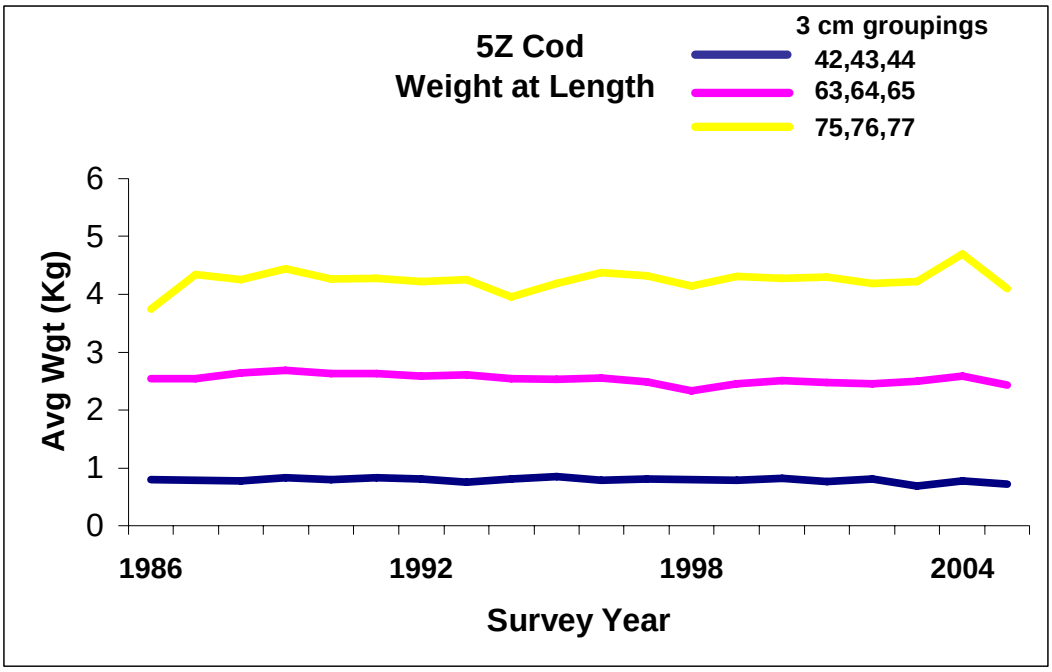


Figure 11. Condition factor for Georges Bank cod.

Cod Distribution (kg/tow), 2000-2004 density and 2005

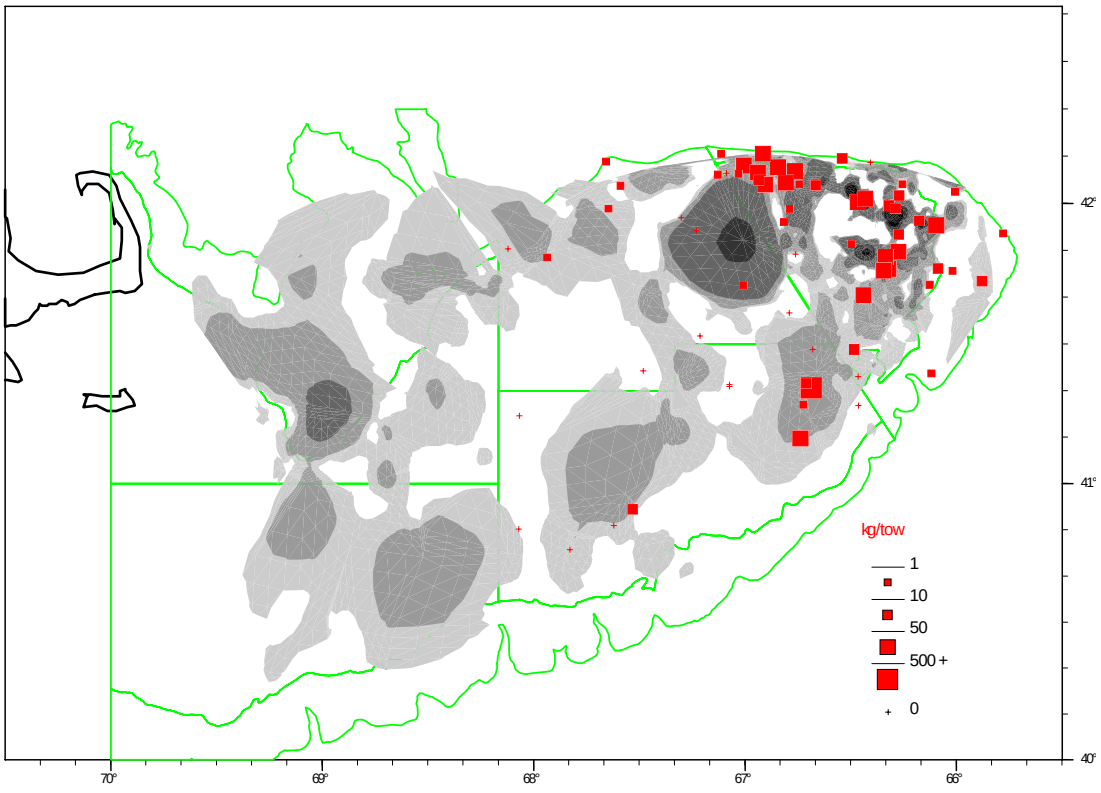


Figure 12a. Comparison of cod per standard tow (kg/tow) from the 2005 DFO research survey (box symbol) with average density gradient distribution for the 1999-2004 surveys.

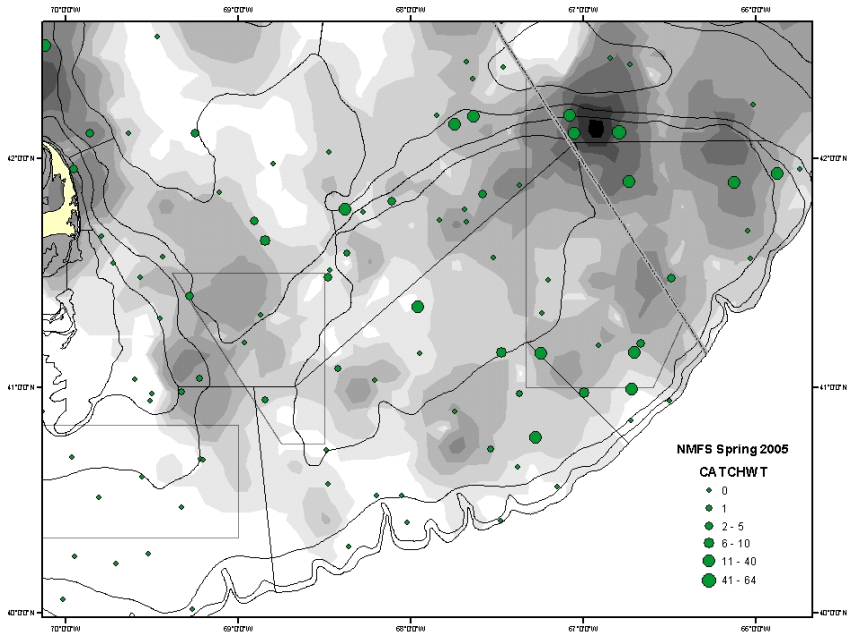


Figure 12b. Comparison of Atlantic cod per standard tow (kg/tow) from the 2005 NEFSC spring research survey (box symbol) with average density gradient distribution for the 1999-2004 NEFSC spring surveys.

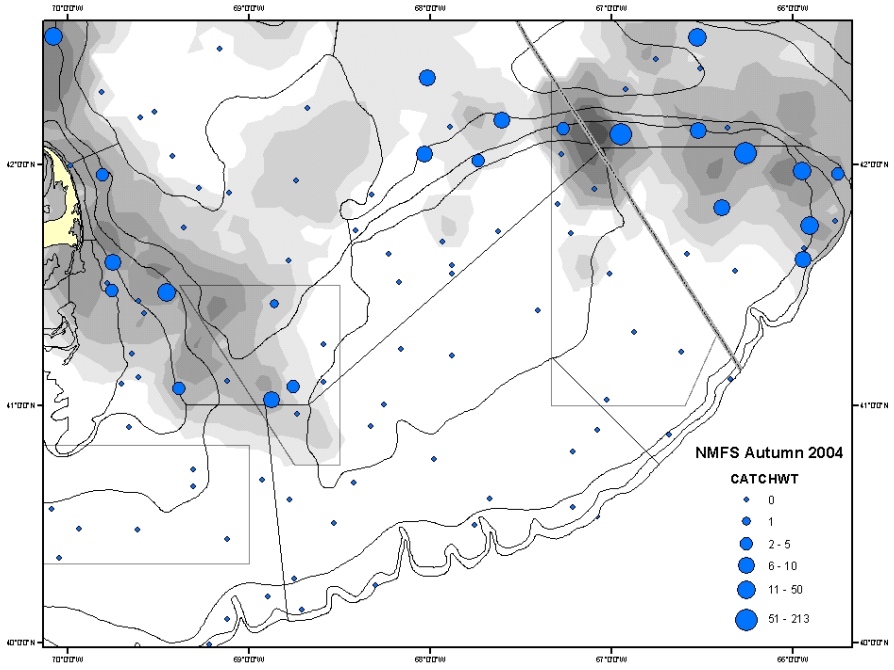


Figure 12c. Comparison of Atlantic cod per standard tow (kg/tow) from the 2004 NEFSC autumn research survey (box symbol) with average density gradient distribution for the 1998-2003 NEFSC autumn surveys.

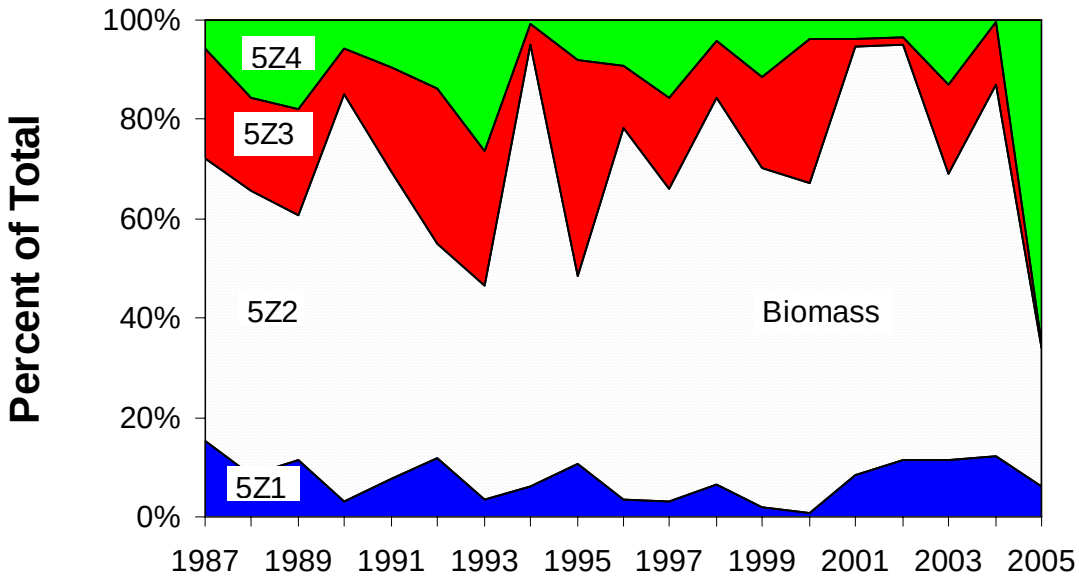


Figure 13a. DFO stratum 5Z2 generally accounts for most of the survey biomass; a large set of 1000+kg in 2005 in stratum 5Z4 increased its relative contribution.

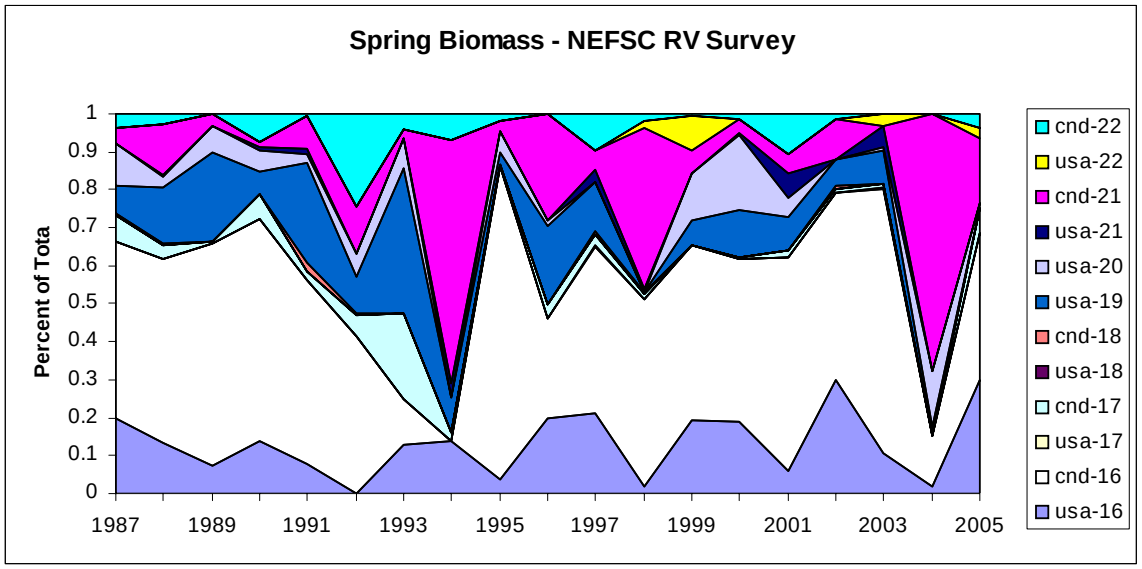


Figure 13b. NEFSC spring survey biomass index for 1987-2004 by stratum (strata 16-18, 21-22 are split by International Boundary) within area 5Zjm.

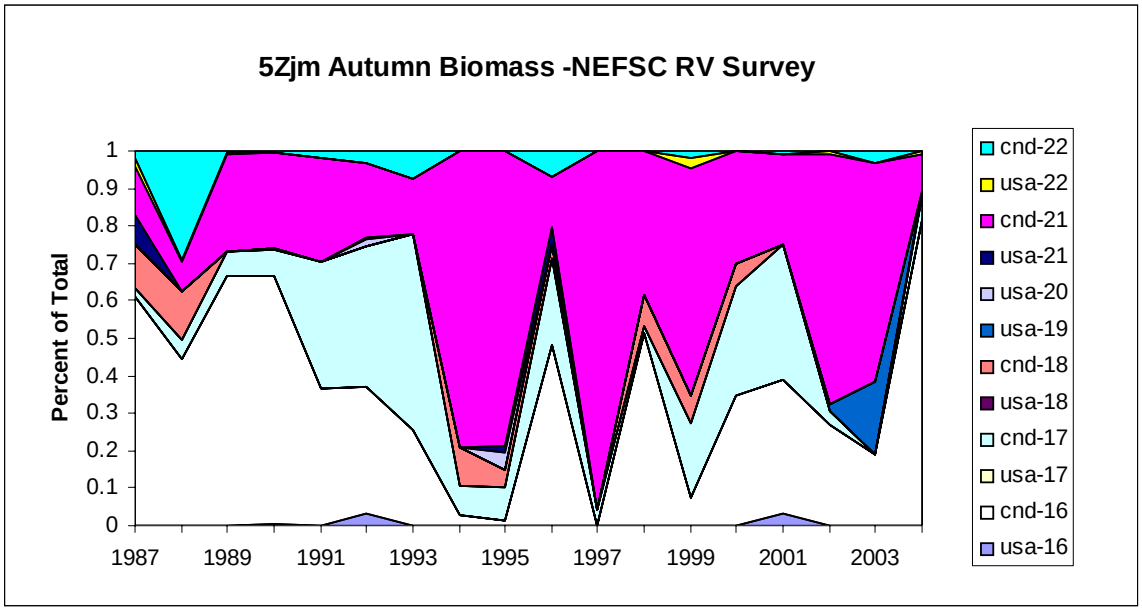


Figure 13c. NEFSC autumn survey biomass index for 1987-2003 by stratum (strata 16-18, 21-22 are split by International Boundary) within area 5Zjm.

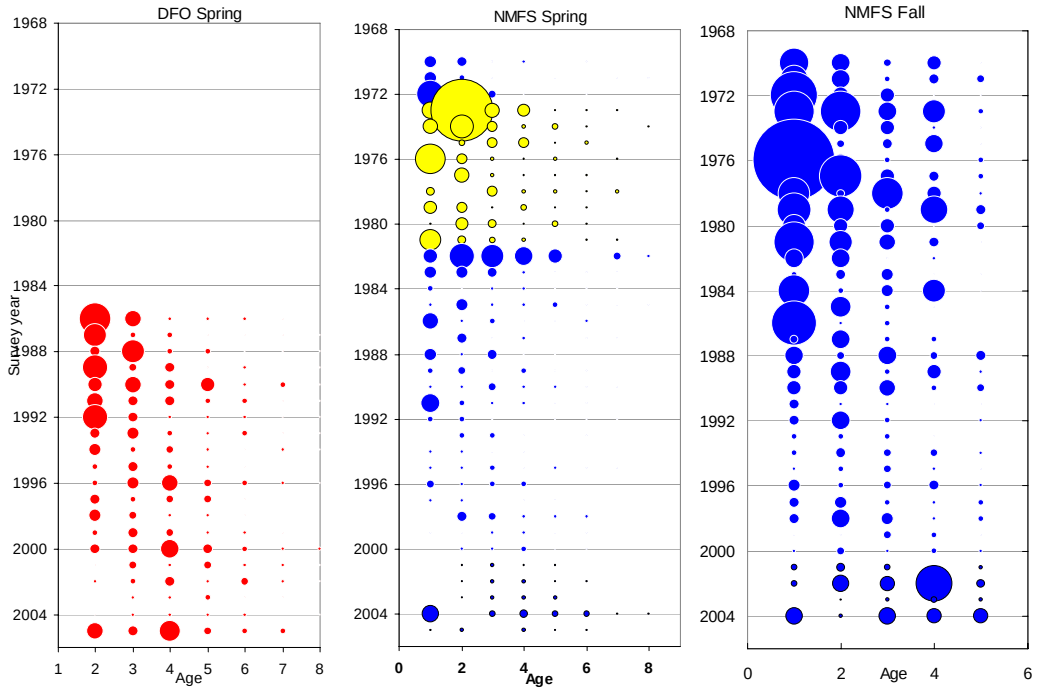


Figure 14. Catch per tow in numbers at age, adjusted by estimated average catchability at age from ADAPT, for 5Zj,m cod from the DFO spring and NMFS spring and fall surveys in 5Zj,m.

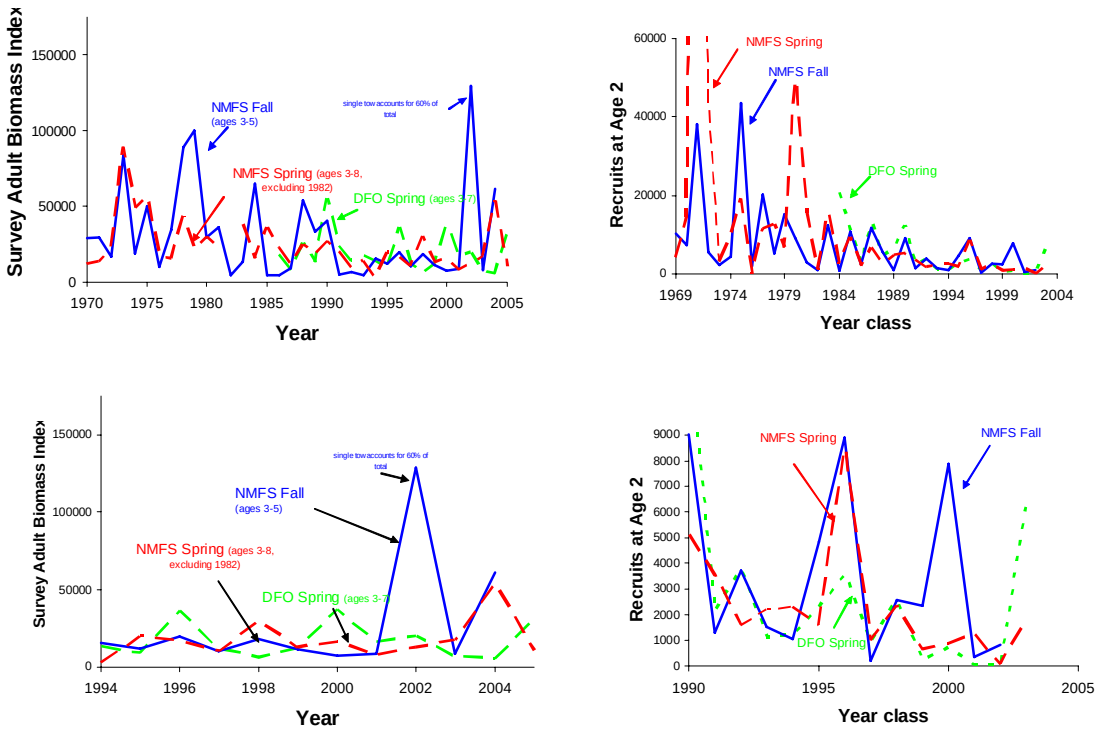


Figure 15. Estimates of adult biomass (ages 3+) (left panel) and recruitment indices at age 2 (right panel) for 5Zj,m cod from the DFO spring and NMFS spring and fall surveys in 5Zj,m.

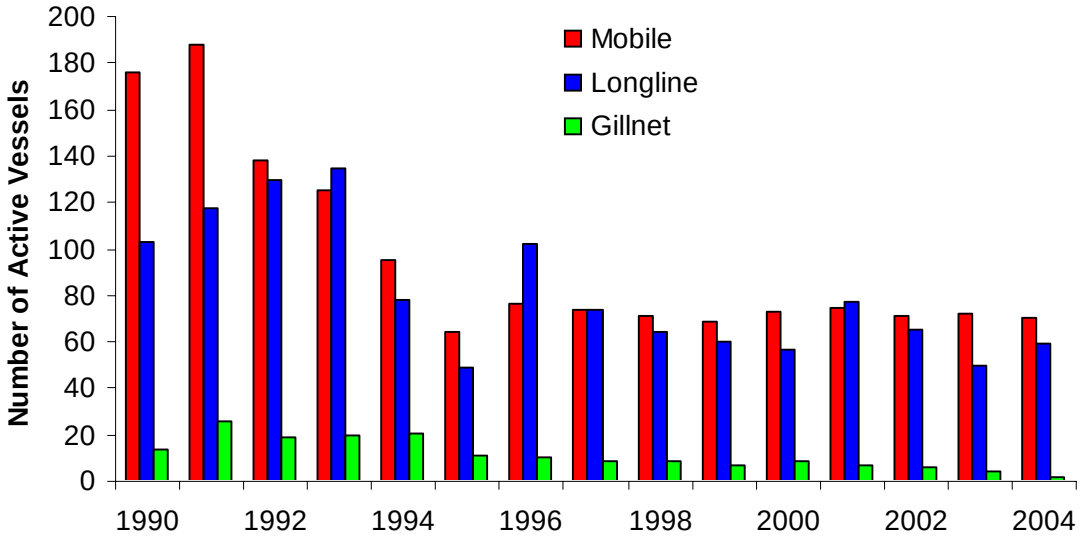


Figure 16. Number of Canadian fishing vessels by gear type.

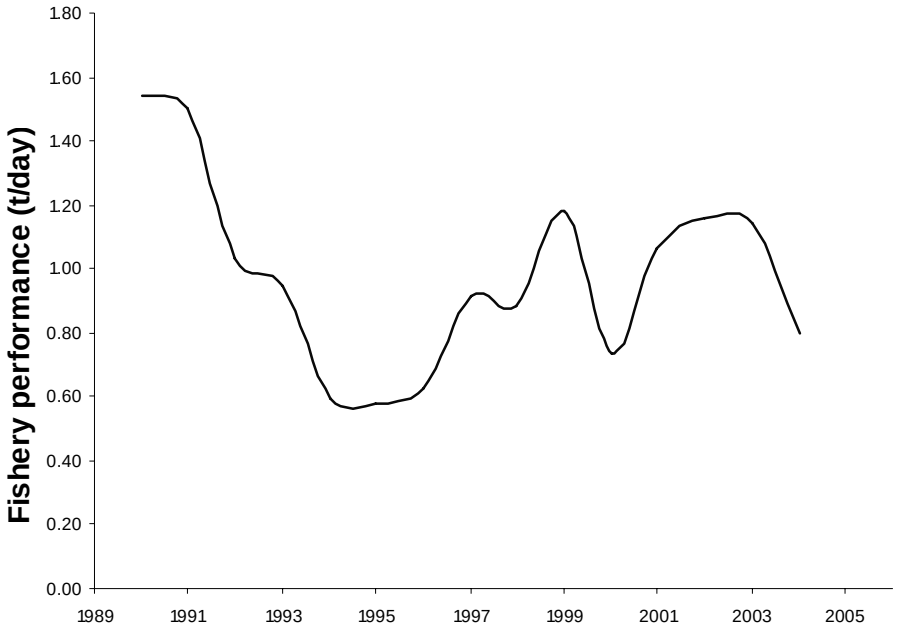
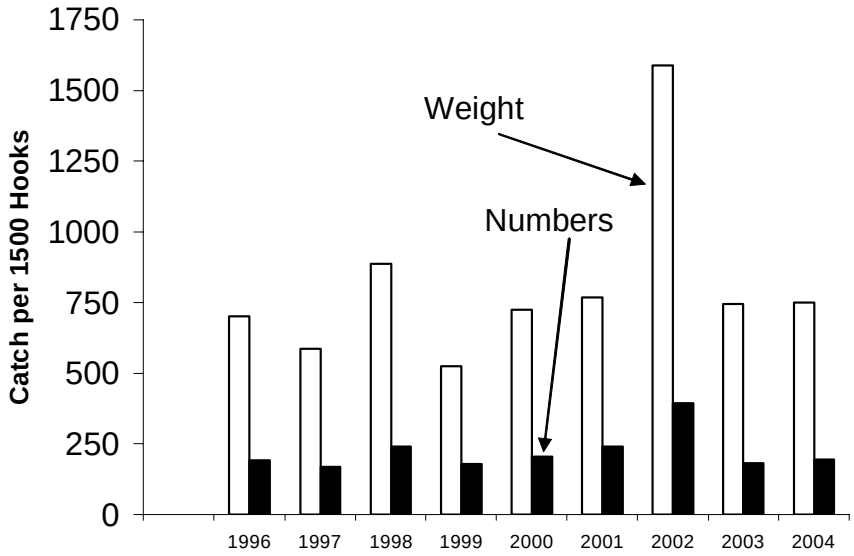
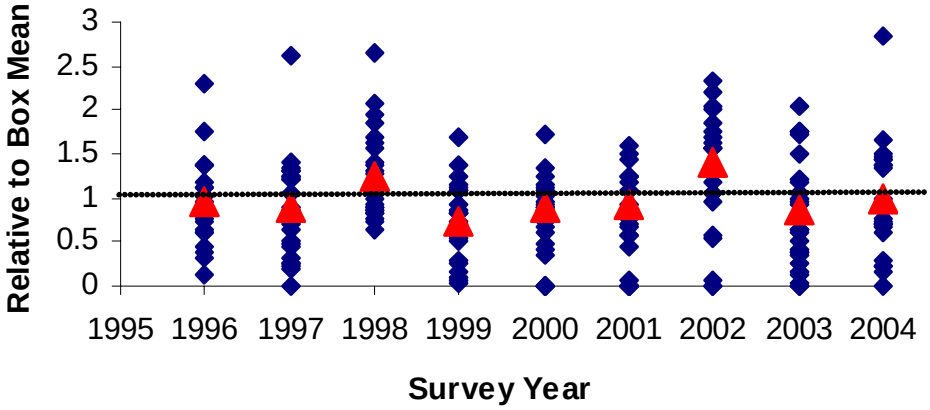


Figure 17. Fishery performance(ton/day fished) of USA otter trawl gear for trips with >500 kg of cod landings during 1990-2003.





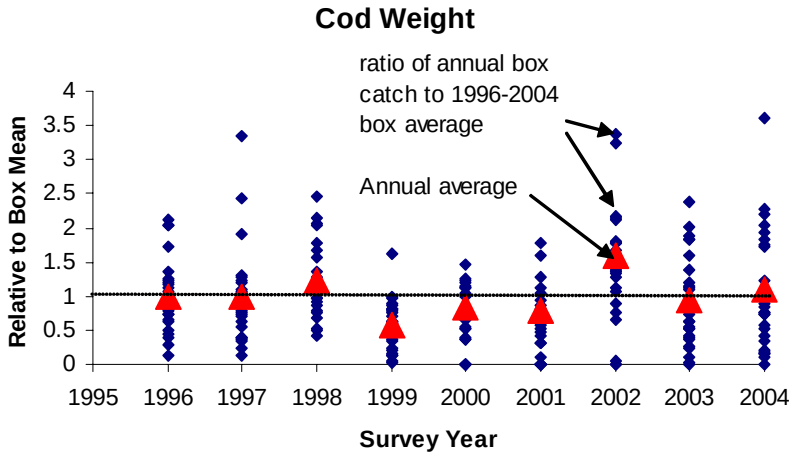
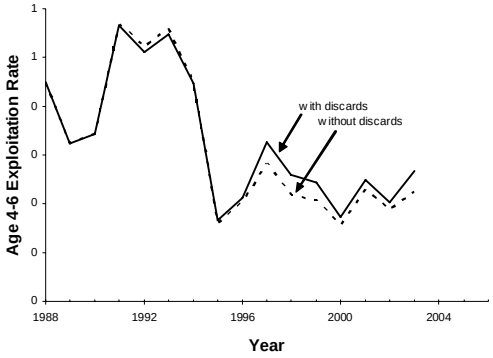


Figure 18. Results of Canadian longline industry survey showing the annual average weight and number caught per 1500 hooks and annual catch rate relative to mean of sampling units.

	3+ Biomass		4-6 Exploitation	
	Without	With	Without	With
Year	Discards	Discards	Discards	Discards
1978	34.7	34.9	31%	31%
1979	30.5	30.8	30%	30%
1980	35.2	35.4	28%	29%
1981	37.2	37.4	29%	29%
1982	37.0	37.1	48%	48%
1983	38.0	38.1	44%	44%
1984	31.8	31.9	39%	39%
1985	26.3	26.4	40%	40%
1986	28.9	28.9	42%	42%
1987	27.6	27.6	30%	30%
1988	41.6	41.6	45%	45%
1989	34.4	34.5	32%	32%
1990	45.3	45.4	34%	34%
1991	33.2	33.5	57%	57%
1992	23.4	23.5	52%	51%
1993	19.6	19.7	56%	55%
1994	10.8	10.9	45%	45%
1995	8.6	8.7	16%	17%
1996	12.3	12.7	20%	21%
1997	13.1	13.5	28%	33%
1998	11.9	12.0	22%	26%
1999	16.5	16.2	21%	24%
2000	16.0	15.6	15%	17%
2001	18.7	18.5	23%	25%
2002	16.7	16.4	19%	20%
2003	14.4	14.1	22%	27%
2004	13.9	13.5		



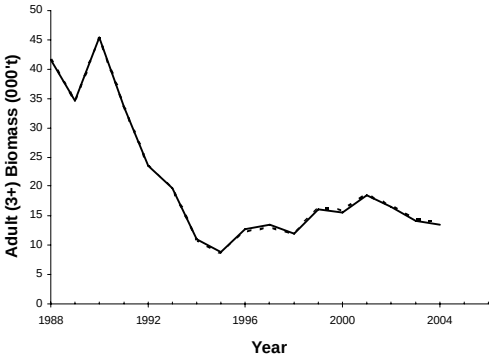


Figure 19. Comparison of adult 3+ biomass and mean age 4-6 exploitation rate derived from ADAPT using 1978-2003 catch at age with and without inclusion of discard catch at age.

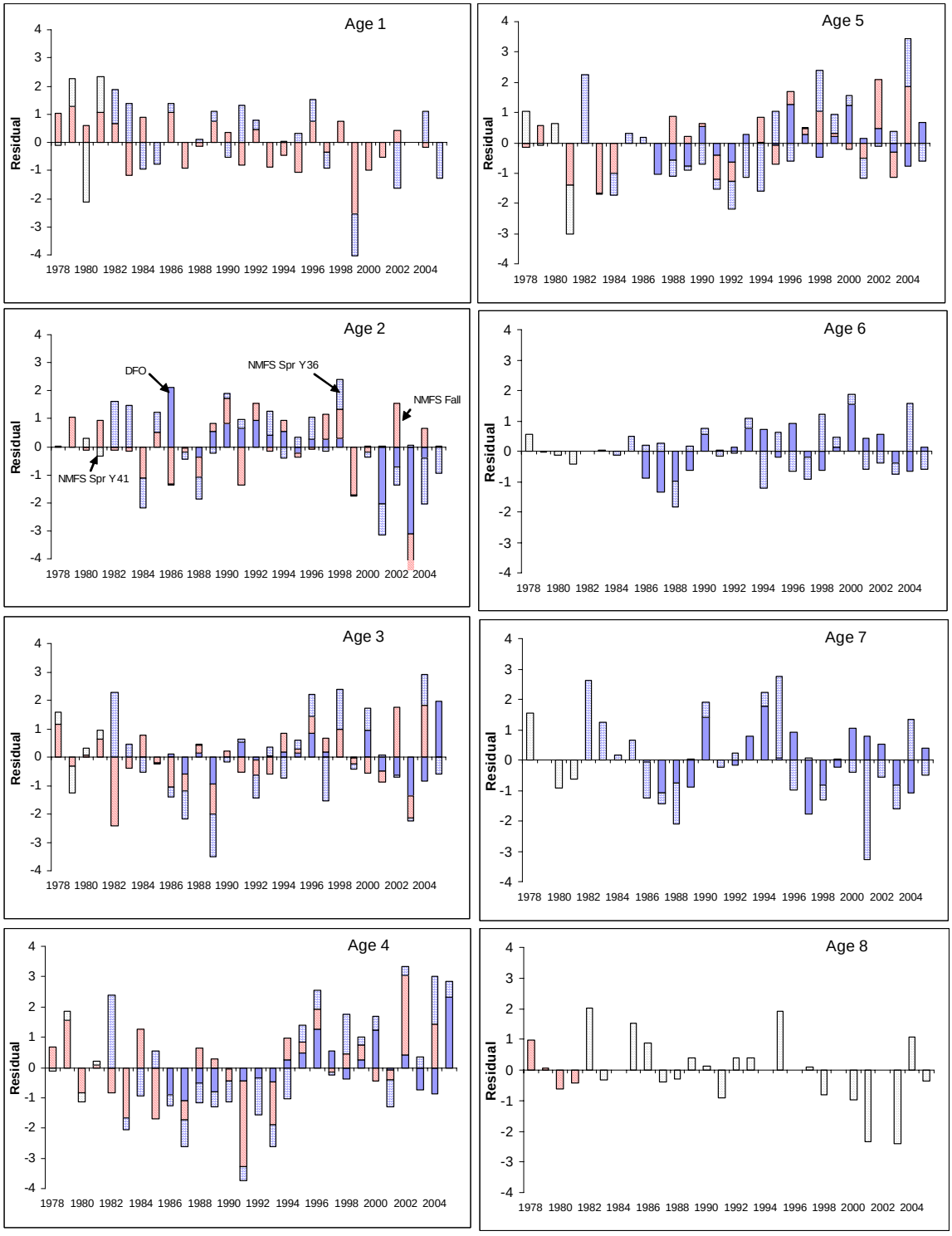


Figure 20. Standardized residuals at age from ADAPT for the DFO spring 1986-2005), NMFS fall (1977-2004), NMFS spring (1978-81,Yankee 41) and NMFS spring (1982-2005, Yankee 36) research indices.

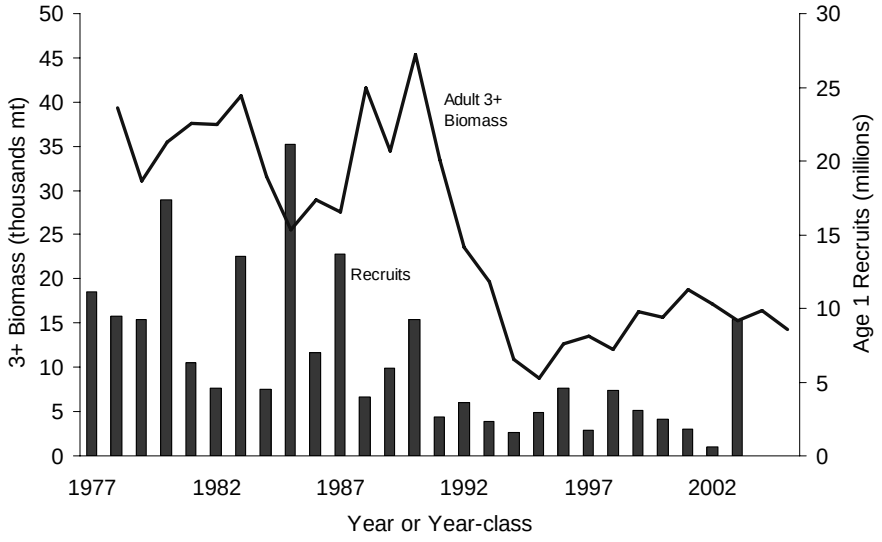


Figure 21. Spawning stock biomass and recruits at age one from ADAPT for 5Zj,m cod.

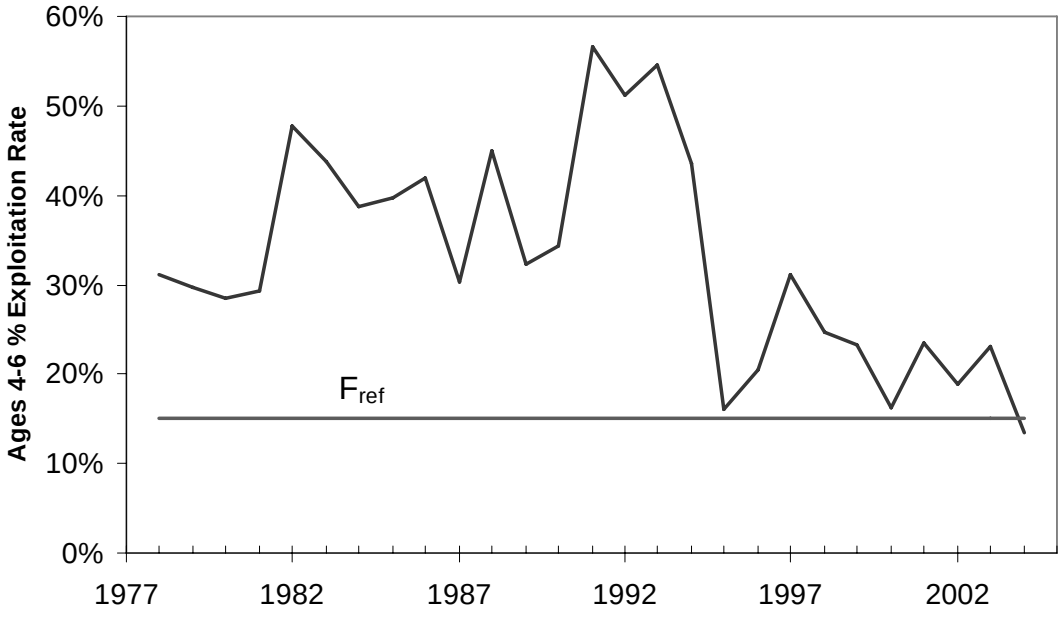


Figure 22. Exploitation rate at ages 4-6 cod derived from ADAPT.

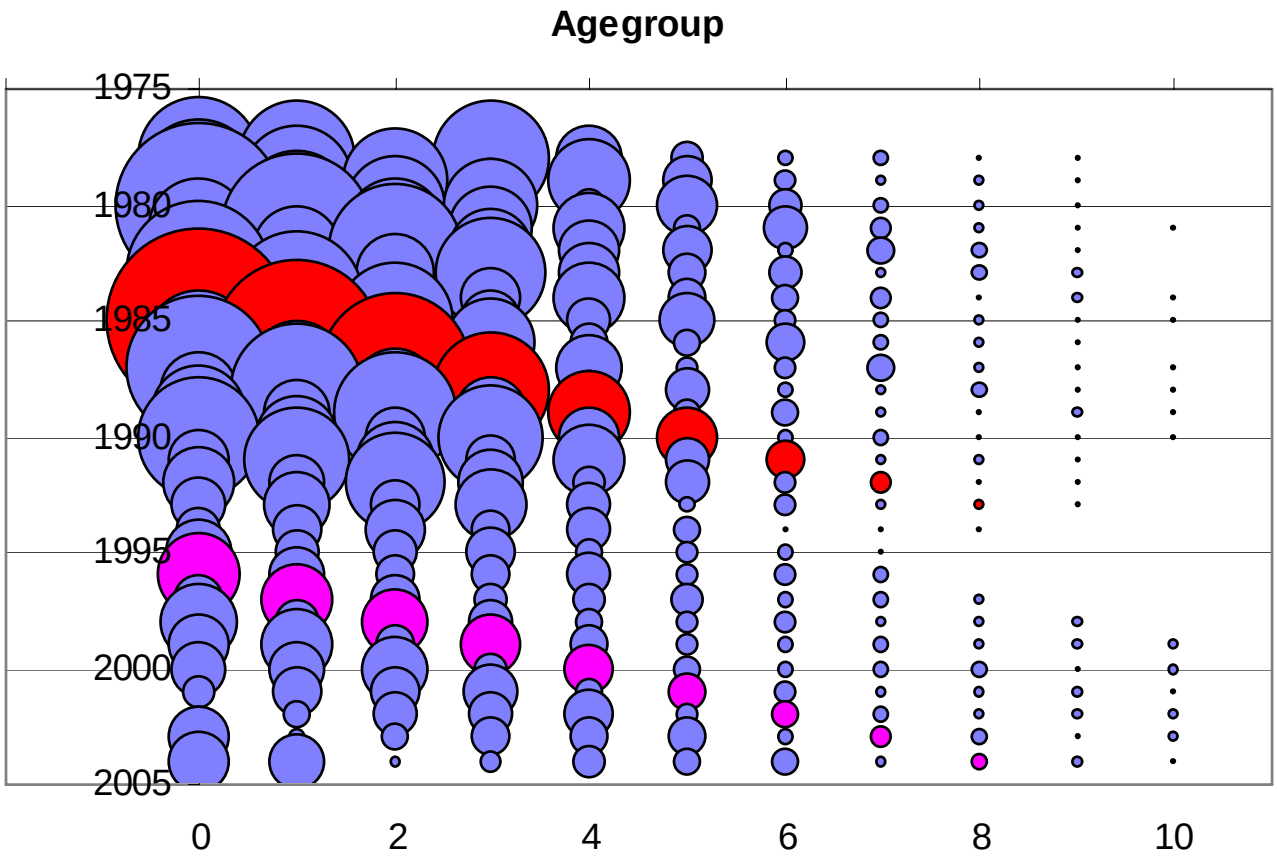


Figure 23: Relative abundance at age for 5Zj,m cod during 1978-2005.

Figure 24. Retrospective analysis of assessment results.

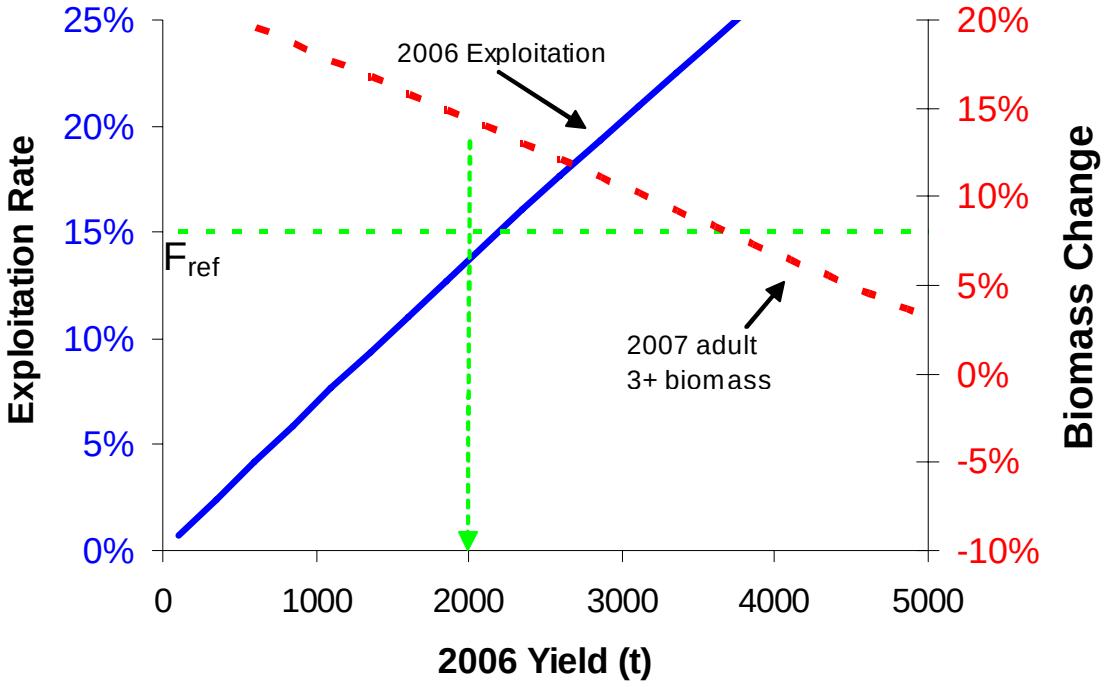


Figure 25. Projected exploitation rate and the % change in 3+ biomass in 2007 relative to 2006 at different levels of yield in 2006.

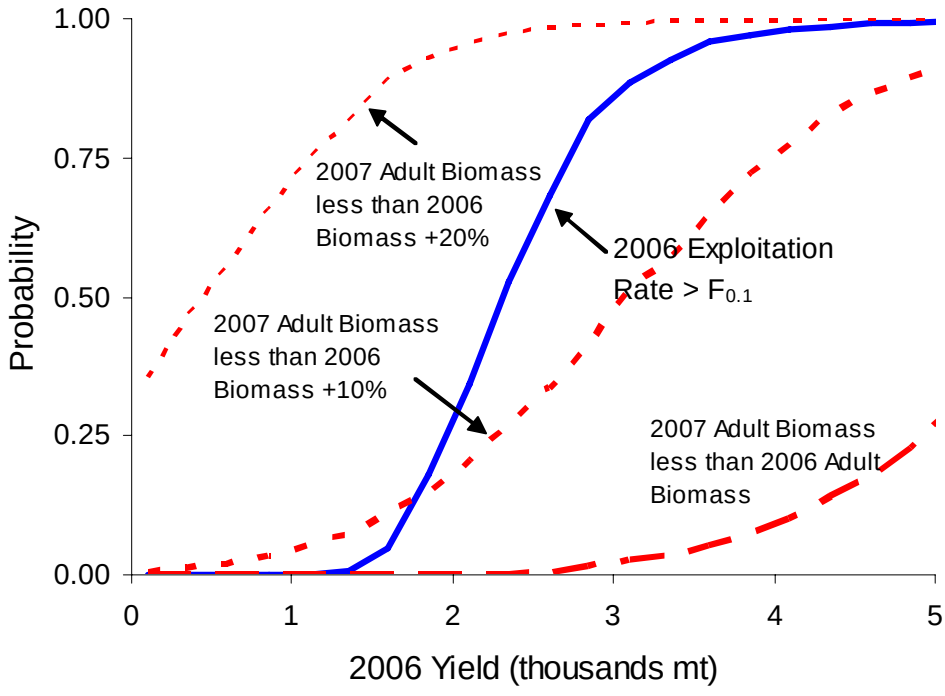


Figure 26. Probability of projected change in 5Zj,m cod adult stock biomass from 2006 to 2007 and exploitation rate in 2006 at different yields in 2006 and assuming a 2005 yield of 1,000 t.

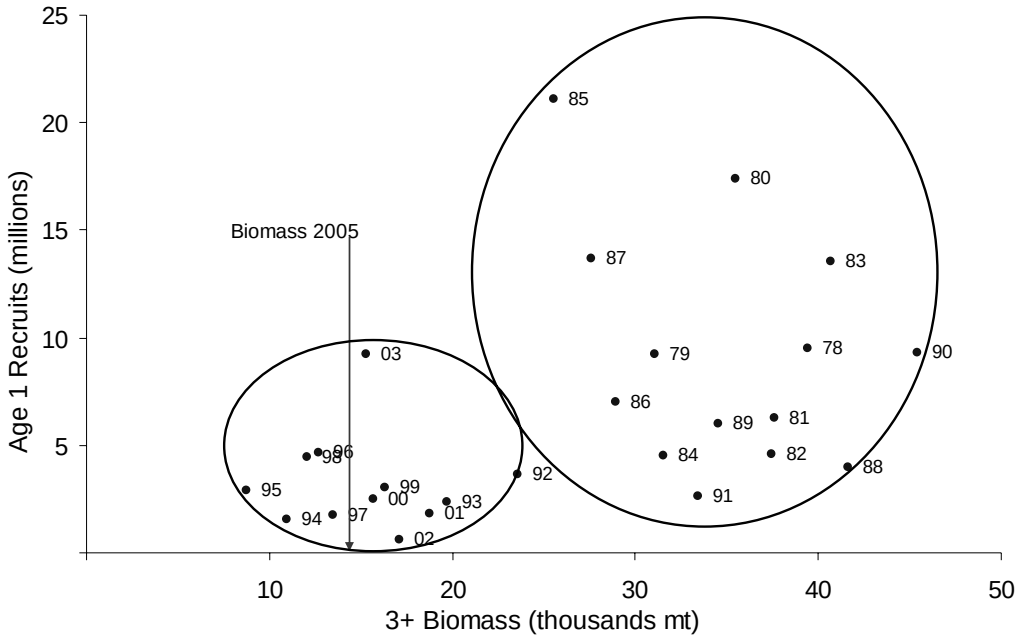


Figure 27. Comparison of recruits at age 1 and adult stock biomass for 5Zj,m cod, 1978-2005.

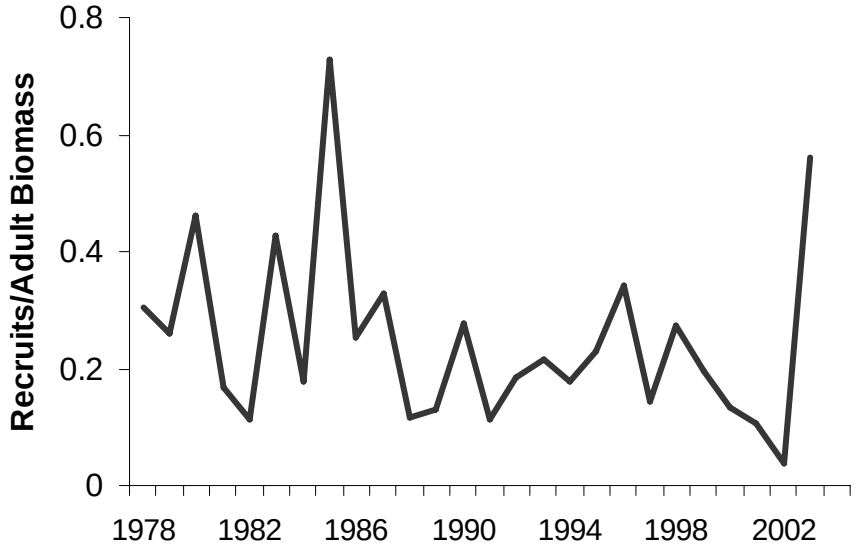


Figure 28. Relationship between recruits and spawning stock biomass (R/SSB) for 5Zj,m cod, 1978-2005.

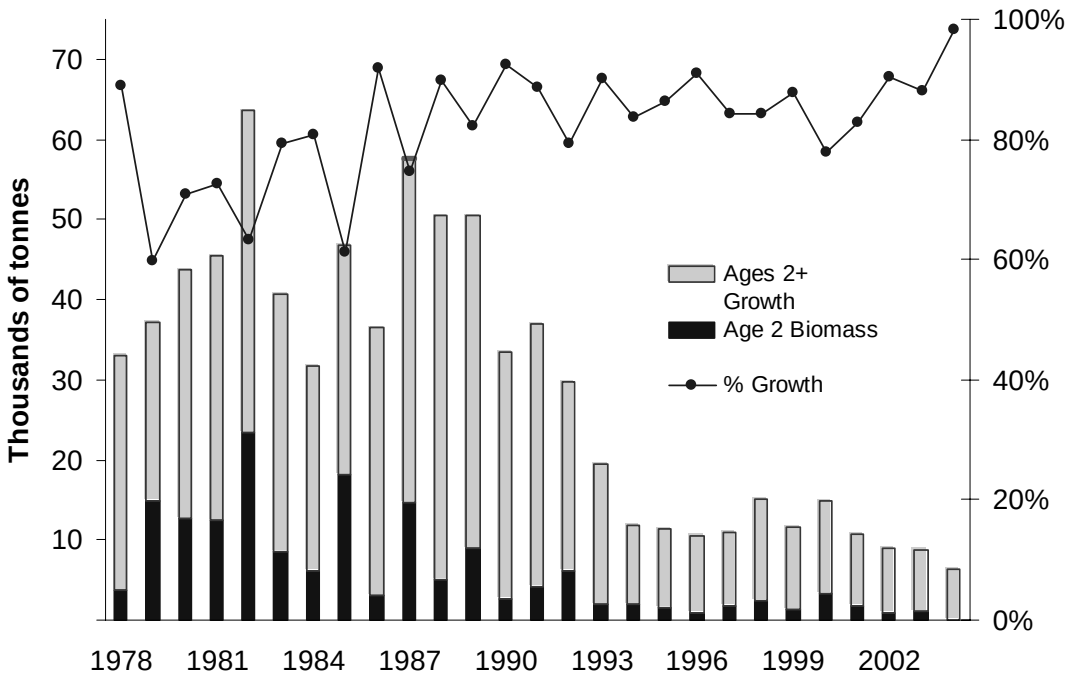


Figure 29. Comparison of stock production derived from growth and from recruitment for 5Zj,m cod, 1978-2004.

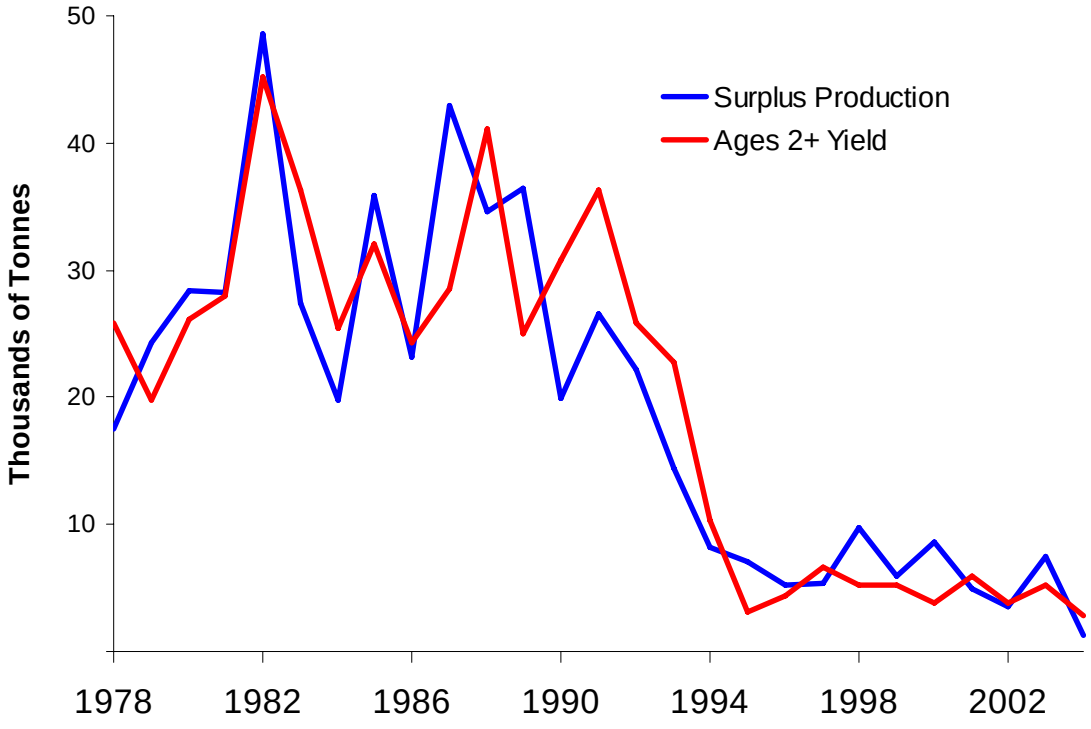


Figure 30. Comparison of surplus production and yields for 5Zj,m cod, 1978-2004.