Fisheries and Oceans Science | Pêches et Océans Sciences

C S A S | ***S C É S***

Canadian Stock Assessment Secretariat | **Secrétariat canadien pour l'évaluation des stocks**

Research Document 2000/085 | **Document de recherche 2000/085**

Not to be cited without permission of the authors [1] | Ne pas citer sans autorisation des auteurs [1]

Population Status of Eastern Georges Bank Cod (Unit Areas 5Zj,m) for 1978-2000

J.J. Hunt and B. Hatt

Gulf of Maine Section
Biological Station
St. Andrews
New Brunswick
E5B 2L9

[1] This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

[1] La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at: Ce document est disponible sur l'Internet à:
http://www.dfo-mpo.gc.ca/csas/

ISSN 1480-4883
Ottawa, 2000
Canada

Abstract

An analytical assessment of the Georges Bank cod stock in 5Zj,m was completed using updated catch-at-age and research survey indices. Results of the assessment provided statistically significant parameter estimates for the 2000 beginning-of-year population at ages 2 through 8**.** Bias and precision for the estimates were within acceptable limits. The adult biomass increased between 1995 and 1999 to about 18,600 t, primarily due to survival and growth of the 1992 and 1995 year-classes, but decreased slightly to 18,200 t in 2000. Exploitation decreased from more than 60% in the early 1990's to slightly above the $F_{0.1}$ = 16% reference level in 1995 to 1997. It decreased further in 1998 to 15%, or slightly below the $F_{0.1}$ reference level and was 10% in 2000. Recruitment in recent years has been poor, with the 1992 and 1995 year-classes being only moderately stronger than adjacent year-classes. Estimates for the 1996 year-class at age one were somewhat higher than previous estimates. The 1997 and 1998 year-classes appear to be very weak**.** Projections for 2000 indicate a yield of about 3,700 t at the $F_{0.1}$ reference level. However, the stock biomass in 2001 will decline at this level of yield. Only at 2000 yields of 1,500 t or less is there a 50% or better chance of stable or increasing biomass. The stock biomass remains below a threshold of 25,000 t, above which chances of good recruitment are improved.

Résumé

Une évaluation analytique du stock de morue du banc Georges en 5Zj,m a été effectuée à partir d'indices sur les captures selon l'âge et des résultats des relevés de recherche mis à jour. L'évaluation a permis d'obtenir des estimations significatives de paramètres pour les populations d'âges 2 à 8 au début de l'an 2000. Le biais et la précision des estimations se situaient dans les limites acceptables. La biomasse des adultes a augmenté de 1995 à 1999 pour atteindre 18 600 t environ, surtout à cause de la survie et de la croissance des classes de 1992 et 1995, mais a ensuite diminué légèrement à 18 200 t en 2000. Le taux d'exploitation a chuté pour passer de plus de 60 % au début des années 1990 à un niveau légèrement supérieur au niveau de référence $F_{0.1}$ = 16% de 1995 à 1997. Elle a ensuite décliné d'avantage pour atteindre 15 %, valeur légèrement en deçà de la valeur de référence $F_{0.1}$, et était de 10 % en 2000. Le recrutement des dernières années a été faible, les classes de 1992 et 1995 n'étant que modérément supérieures aux classes voisines. Les estimations de la classe annuelle de 1996 à l'âge 1 étaient quelque peu supérieures aux valeurs antérieures. Les classes de 1997 et 1998 semblent très faibles. Les prévisions pour l'an 2000 indiquent un rendement de 3 700 t environ au niveau de référence $F_{0.1}$. Cependant, la biomasse du stock en 2001 diminuera à ce niveau de rendement. Seul un rendement de 1 500 t ou moins en l'an 2000 correspond à une probabilité de 50 % ou plus de maintenir ou d'accroître la biomasse. La biomasse du stock demeure faible au niveau seuil de 25 000 t, après lequel on note une meilleure probabilité de bon recrutement.

Introduction

This report incorporates commercial catch data and research survey results for the 1978-2000 time period to estimate the stock status of cod in the two NAFO unit areas 5Zj and 5Zm (5Zj,m) (Fig. 1). Definition of this management unit was based on analysis of tagging results and commercial and survey catch distribution (Hunt, 1990). Hunt and Johnson (1999) reported the status of the stock in 1999 (DFO, 1999).

Cod are taken in 5Zj,m by both Canada and the USA and all data relating to USA catches and research vessel surveys were provided by the National Marine Fisheries Service (NMFS) at the Woods Hole, Mass., Laboratory.

Information presented in this report was reviewed by the Transboundary Resource Assessment Committee at a meeting held in Woods Hole, MA in April 2000. Proceedings of that meeting (CSAS, 2000) and the resulting Stock Status Report (DFO, 2000) are available for reference.

The Fishery

Canadian landings of Georges Bank cod 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, Fig. 2). The 1999 Canadian Georges Bank cod fishery was limited to a Canadian allocation of 1,800t, a decrease from the 1,900t allocation in 1998, and remained closed until June, 1999. The 1999 Canadian Management Plan allocations by fleet sector and reported landings (from December 19th, 1999 Quota reports) are shown below:

Fleet Sector	Allocation	Landings	Percent
Fixed <65'	1175	1169	99
Mobile <65' (ITQ)	513	521	102
Fixed 66 - 100'	16	16	100
Mobile 65 - 100'	21	16	76
Vessels >100'	76	79	104
Total all sectors	**1801**	**1801**	**100**

Between 1978-2000, USA landings reached 11,000 t in 1984, then were stable at about 6,000 t until 1993 when a closed area was implemented. Landings ranged from 560t to 1230t between 1994-1999 and were 1150t in 1999. Almost 100 percent of USA catches in 5Zj,m are taken by otter trawl gear.

Combined USA and Canada landings for 1978-1999 are shown in Table 2 and Figure 3.

Samples of landings and catches (Commercial samples and Observer program) were used to estimate catch at length and age composition for the Canadian fishery. A summary of the number of length and age samples used to estimate catch-at-age is shown in Table 3. About 25,000 length observations and 900 age determinations were available to construct the catch-at-age for 1999 (Table 4). The number of trips that included an Observer was similar in 1998 and 1999 and landings were regulated by 100% dockside monitoring.

Comparison of 1999 on-shore samples with Observer at-sea samples showed some evidence of smaller fish in the observed trips. Discarding was reported by some fishermen during pre-assessment meetings but the extent and quantity of discards are uncertain. Mobile gear catches by tonnage class group were derived to account for potential differences between large offshore trawlers and tonnage class 2,3 trawlers in areas fished and size composition.

Precision estimates of age determinations by the new Canadian age reader with those from the previous reader as well as with historical samples were completed and results were acceptable with a CV of 2.6 and overall agreement of about 86 percent. Canadian inter-reader age comparisons were made with otoliths from the 1998 commercial fishery and the 1999 RV survey. Results are summarized in Table 5 and in Figure 4. Further comparisons and discussion with USA age readers will be addressed at a Canada-USA Aging Workshop in 2000.

Catch-at-age for the reported USA landings in 1994-99 were estimated from USA length samples. Ages for USA landings in 5Zj,m were limited and were therefore supplemented with Canadian age samples (Table 3).

Total removals-at-age and percent-at-age are given in Table 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). A length/weight relationship derived from 1986-99 surveys was used to calculate mean weight from mean length in each survey year. 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 1999 assessment are shown in Figure 5, and indicate considerable divergence in the contribution of the 1996 year-class at age 3. In 1999, this year-class accounted for over 40% of the catch in numbers and the 1995 year-class for about 30% (Figure 5). Catch-at-length and age contributions for 1999 are shown in Figure 6. Comparison of the 1999 percent catch at age with the short term and long term average is shown in Figure 7. The decline in survey weight-at-age between 1997 and 1998 was reversed in 1999 for some ages and was stable in 2000 but the overall trend of lower weight at age remains (Figure 8).

Indices of Abundance

Research Surveys

Hunt *et al.* (1991) describe 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 USA spring survey has used two different bottom trawls over the 1978-99 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 2000 Canadian survey showed a substantial increase following the decline observed in 1996 and 1997. The highest catch rates occurred in the Canadian zone with relatively small catches west of the International Boundary. The 2000 catch distribution pattern (shown as box symbols in Figure 9) was similar to the average (shown as density contours in Figure 9). Over 50% of the increase was attributed to one large set of over 1800 cod (3000kg). However, even with discounting this one set there was still an increase in the average catch per tow between 1999 and 2000 (Figure 10).

The Canadian survey was initiated in 1986, while the USA surveys started prior to 1978. Results of STRAP analysis for each of the surveys are given in Table 8 and Figure 11.

The USA fall survey is assumed to be a post-fishery index and spring surveys are assumed to be a pre-fishery index. Therefore, the fall survey is lagged by one year for comparison of indices (ie. fall 1977 age one vs spring 1978 age two).

The three survey indices for ages 3+ biomass, adjusted by the estimated catchability (Q's) at age from recent ADAPT formulations (Gavaris, 1988) are shown in Figure 11 (the 1982 NMFS spring survey is not shown due to scaling). In general, all three surveys appear to track year-class strength and provide a consistent index. The Canadian 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 a further increase in 2000 The 1994 USA fall survey catch per tow has a slight increase from 1993, then remained at a low, stable level in 1995 –1997, increased in 1998 and declined in 1999. The 1994 USA spring survey was the lowest observed, but increased in 1995 to the recent average level and remained stable until 1997. 1998 saw an increase with a decline in 1999.

Estimates of recruitment at age one and at age two from the surveys are shown in Figure 12 as population numbers derived from catch per tow, adjusted by catchability factors. Both the 1995 USA fall and 1996 Canadian spring surveys indicate an increase in recruitment for the 1995 year-class over the 1993-94 year-classes. Estimates for the 1995 year-class are less than 25% of the large 1990 and 1985 year-classes and similar to the average 1987 year-class. The index of recruitment of the 1996-1999 year-classes at age one is the lowest in the series. However, the 1996 year-class at age two in the 1998 NMFS spring survey shows better prospects of recruitment.

Commercial Fishery Catch Rates

The mobile gear catch rate was used as an index of abundance in the 1995 evaluation of stock status. 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 are not available.

A summary of catch, effort and catch per day for the mobile, longline and gillnet fleets for 1990-99 is given in Table 9. No standardization to account for possible tonnage class differences was applied and only trips landing more than 500kg of cod were included. Estimated total effort (number of fishing days) is calculated from the catch per day and reported catch to account for missing effort data for some trips. For example, only 30% of longline vessels reported effort in 1990, representing 825 fishing days with an average catch of 1.91 t per day. This catch per day was divided into the total reported catch to estimate total fishing days (5202/1.91 = 2724 days). The number of active vessels and total effort in 1995 were less than 50% of the 1990-94 average for all three fleet sectors**.**

The number of Canadian vessels, by gear sector, with cod landings of greater than 500kg per trip for the 1990-99 time period are shown in Figure 13. Overall, the number of vessels 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 declined only slightly since 1996. Landings per day fished declined for all three gear sectors but remained stable between 1998 and 1999. Generally, catch rates are higher for the fixed gear sector compared to the mobile gear sector.

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). Investigation of the data set indicated that some length frequencies were a subsample of the total caught and an adjustment was made to the total catch using a ratio of calculated to recorded weight. Reported values from Johnston and Hunt (1999) were also adjusted when evidence of subsampling was apparent. Preliminary results for 1996-1999 standardised catch in weight and numbers and for relative abundance of year-classes is shown in Figure 14.

This index will require additional years of data and consistency in sampling protocol before trends or changes in stock abundance can be evaluated.

Partial Recruitment to the Fishery

Hunt and Johnson (1999) derived estimates of partial recruitment to the fishery by gear type for the period 1988-98. They indicate that partial recruitment at ages three and less has declined in the recent part of the time series. Full recruitment is now at age four (see Table 13).

Spawning Stock Biomass (SSB) Calculation

Results of a study reported by Hunt (1995) were updated with more recent DFO spring survey data to estimate the proportion of cod mature at age for the period 1986-2000. A three year moving average was applied to the annual estimates with the years 1978-85 set to the 1986 value. Results are shown in Table 10 and show an increase from about 30-40% mature at age 2 prior to the mid-1980's to 40-60% in the mid-1990's and over 70% in the last part of the series. Spawning stock biomass was estimated by applying

the proportion mature at age to the population abundance estimate derived from ADAPT.

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 8, y=1978 to 1999

$I_{1,a,y}$ = USA fall survey
a=0 to 5 y=1977 to 1999 (used as ages 1 to 6 for 1978-2000)

$I_{2,a,y}$ = USA spring survey (Yankee #41 trawl)
a=1 to 8, y=1978 to 1981

$I_{3,a,y}$ = USA spring survey (Yankee #36 trawl)
a=1 to 8, y=1982 to 1999

$I_{4,a,y}$= Canadian spring survey
a=1 to 8, y=1986 to 2000

$\theta_{a,t'} = \ln$ population abundance for ages *a* = 2, 3 ... 8 at time $t' =$ 2000
$\kappa_{s,a} = \ln$ 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 $N_{a,t}\left(\vec{\theta}\right)$ is abbreviated by $N_{a,t}$. At time t', the population abundance was obtained directly from the parameter estimates, $N_{a,t'}=e^{\vec{\theta}_{a,t'}}$. For all other times, the population abundance was computed using the virtual population analysis algorithm, which incorporates the common exponential decay model $N_{a+\Delta t,t+\Delta t}=N_{a,t}e^{-\left(F_{a,t}+M_a\right)\Delta t}$.

Partitioning of the USA spring survey was introduced in 1998 to account for a change in the survey trawl in1982. Experimentally derived conversion factors between the two trawls for cod are not available and further investigation of trawl and vessel effects may be required.

The spring survey results were compared to beginning of year population abundance. The fall survey for ages 0-5 was also compared to beginning of year population abundance in year t+1 (i.e. fall 1977 ages 0-5 compared to 1978 population ages 1-6). Natural mortality was assumed constant and equal to 0.2. The fishing mortality rate on age 8 was calculated as the unweighed average for ages 4 to 7 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 statistical technique.

Initial trial ADAPT formulations which included age one in 2000 did not result in statistically significant estimates at this age and therefore the model was modified from that used in 1999 and the 1999 year-class in 2000 was set to an arbitrary low value of 1 million.

A sensitivity analysis was completed to determine the effect of the one large set of cod in the DFO 2000 spring survey (see above). Results of the two trial ADAPT results for population abundance and fishing mortality are shown in Figure 15. Inclusion of the large set in calculation of the DFO sping index gives slightly higher population estimates and lower fishing mortailty but without any strong age effect. Therefore, the DFO index derived using all sets was used for subsequent analysis.

Assessment Results

Parameter estimates, bias adjustment and population estimates derived from the above ADAPT formulation are given in Table 11. Population parameter estimates have a relative error of 29% to 56% for ages 2 to 8, similar to those seen in the 1999 ADAPT-based analytical assessment. In general, catchabilities for survey indices show a flat topped selection at ages 4 and older. Catchabilities were highest for the Canadian spring survey, followed by the USA spring survey and the USA fall survey.

There appear to be year effects in the residuals for survey indices (Figure 16). The 1982 USA spring survey has relatively large positive residuals, while negative residuals predominate in the last several years. The USA fall survey and the Canadian spring survey appear to overestimate population size (positive residuals). 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 USA 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 3+ and spawning stock biomass between 1990 and 1994 was substantial, and the biomass was the lowest observed in 1995 at 8,100 t (Figure 17, Table 12). However,

biomass shows a gradual increase in 1995-99 to about 19,200 t SSB but declines to about 18,500 t SSB in 2000 remains well below the long term average of about 30,000 t.

Fishing mortality for fully recruited ages 4+ (Table 12) increased rapidly between 1989 and 1991 and was over three times the $F_{0.1}$ = 0.2 reference level in 1991-93. The decline that began in 1994 is consistent with reduced effort. Fishing mortalities since 1995 were slightly above the $F_{0.1}$ reference level. The rate of exploitation for the stock has been over 30% for most of the time series, above 60% in 1991-94, and close to the $F_{0.1}$ reference level of about 16% since 1998 (Fig. 18).

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. 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 average. The 1992, 1995 and 1996 year-classes show some improvement to above the recent average recruitment, but indications for the 1997 and subsequent year-classes show very poor recruitment prospects (Fig. 17 and Table 12).

Retrospective Analysis

Typically, if present, a retrospective pattern results in overly optimistic estimates for a year-class in the first year with a decline as additional data are added to the model. Similarily, fishing mortality increases as more data are added. Results of the analysis (Figure 19) confirm a pattern for fishing mortality in the mid-1990's to be under-estimated relative to current estimates. However, a slight reverse trend to under-estimate initial year-class size is evident for year-class abundance at age one. The impact of shortening the Canadian spring survey index time series in this type of analysis may be the main contributing factor rather than a model bias in the ADAPT formulation.

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. Results indicated an $F_{0.1}$ fishing mortality of 0.199 and confirm the value of 0.2 used in previous assessments.

Prognosis

Catch projections were completed using the bias-adjusted beginning of year population abundance for 2000 derived from ADAPT. Partial recruitment was derived from the 1995-98 fishing mortality matrix (Table 12), to reflect possible changes in PR associated with both gear and season. Mean (1996-99 fishery) and beginning of year (1997-00) weights-at-age were used to reflect the recent trend in weight at age. Recruitment for 2000 and 2001 age one was set to 1.0 million. Details of the input for the catch projection is shown in Table 13.

Yield projection at $F_{0.1}$ for 2000 indicates a **combined** Canada/USA yield of about 3,750t. Details of the projection are given in Table 14. There is about a 20% relative error associated with the projected catch. At the $F_{0.1}$ yield, **adult biomass will decrease** by about 10% at the beginning of 2001. A stable biomass will occur with a 2000 yield of about 1,500t but even with no catch in 2000 the 2001 biomass only increases by about 5%. The 1995 year-class-at-age 5 and the 1996 year-class at age 4 are expected to account for about 33% and 25%, respectively, of the catch biomass in 2000.

Yield projection at $F_{0.1}$ for 2000 indicates a **combined** Canada/USA yield of about 3,750t. At the $F_{0.1}$ yield, **adult biomass will decrease** by about 10% at the beginning of 2001. A stable biomass will occur with a 2000 yield of about 1,500t but even with no catch in 2000 the 2001 biomass only increases by about 5%.

At a combined 2000 Canada/USA yield of about 3,000t, the same as the 1999 yield, there is a low **probability** of exceeding $F_{0.1}$ but more than 90% probability of a decrease in adult biomass (Figures 20 and 21). At a 2000 yield of 1,500t the probability of a decrease in adult biomass is about 50%. It is also important to note that even small differences in the 2000 yield near the $F_{0.1}$ level substantially increased the chances of exceeding the reference level.

Adult biomass levels and subsequent **recruitment** abundance-at-age 1 is compared in Figure 22 for the 1978-00 time period. Recruits appear to have a positive correlation with biomass and the probability of good recruitment increases at higher biomass levels. The projected 2000 adult biomass of 19,000 t is below the stock size (>25,000t) at which improved recruitment would be expected to occur. Rebuilding to increase the adult biomass above the projected 2000 level would enhance the prospects for the future.

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, about 60-90% of the total **stock production** (Figure 23) 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.

References

DFO, 2000. Eastern Georges Bank cod. DFO Sci. Stock Status Report A3-04(2000)

Gavaris, S. 1988. An adaptive framework for the estimation of population size. Can. Atl. Sci. Adv. Com. Res. Doc. 88/29: 12p

Hunt, J.J. 1990. Status of the Atlantic cod stock on Georges Bank in Unit Areas 5Zj and 5Zm, 1978-89. CAFSAC Res. Doc. 90/80, 37p

Hunt, J.J. 1995. Rates of sexual maturity for atlantic cod in NAFO Division 5Ze and catches of juveniles. J. Northw. Atl. Fish. Sci., Vol. 18: 61-75

Hunt, J.J., M-I. Buzeta and J.D. Neilson. 1991. Status of the Atlantic cod stock on Georges Bank in Unit Areas 5Zj and 5Zm, 1978-90. CAFSAC Res. Doc. 91/41, 21p

Hunt, J.J. and M-I. Buzeta. 1996. Biological update of Georges Bank cod in Unit Areas 5Zj,m for 1978-95. DFO Atl. Fish. Res. Doc. 96/23

Hunt, J.J. and T.L. Johnson. 1999. Population status of Eastern Georges Bank cod (Unit Areas 5Zj and 5Zm) for 1978-99. DFO Atl. Fish. Res. Doc. 99/77, 38p

Johnston, T.L. and J.J. Hunt. 1999. Preliminary results of a longline survey in Georges Bank. DFO Atl. Fish. Res. Doc. 99/78

Rivard, D. 1980. Back-calculating production from cohort analysis, with discussion on surplus production for two redfish stocks. CAFSAC Res. Doc. 80/23: 26 p.

Serchuk, F.M., R.K. Mayo and L. O'Brien 1994. Assessment of the Georges Bank cod stock. Report of the 19th SAW. NEFSC Lab. Ref. Doc. 94-25

Table 1. Nominal landings(t) of cod by year, gear and month for Canada in unit areas 5Zj,m.(OT-ottertrawl; LL-longline; GN-gillnet; MISC-miscellaneous. TOT - total).

YEAR	GEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
1978	OT	166	762	187	26	304	1808	1095	75	219	1633	1487	0	7762
	LL	0	0	0	0	10	308	241	77	74	19	0	0	729
	MISC	0	0	55	1	0	17	102	0	0	14	98	0	287
	TOT	166	762	242	27	314	2133	1438	152	293	1666	1585	0	**8778**
1979	OT	72	302	178	78	74	1634	649	674	648	293	28	7	4637
	LL	0	0	0	5	20	529	334	306	134	10	0	0	1338
	MISC	0	0	1	1	1	0	0	0	0	0	0	0	3
	TOT	72	302	179	84	95	2163	983	980	782	303	28	7	**5978**
1980	OT	24	86	3	52	111	1373	1593	771	633	591	68	100	5405
	LL	0	0	0	0	208	951	596	496	337	47	0	0	2635
	MISC	0	0	1	2	1	2	1	16	0	0	0	0	23
	TOT	24	86	4	54	320	2326	2190	1283	970	638	68	100	**8063**
1981	OT	2	205	55	7	38	529	1005	744	1013	36	229	97	3960
	LL	0	0	1	2	538	1476	1044	837	284	281	57	5	4525
	MISC	0	0	0	1	0	12	0	0	1	0	0	0	14
	TOT	2	205	56	10	576	2017	2049	1581	1298	317	286	102	**8499**
1982	OT	90	73	0	0	11	845	4289	2109	1507	2360	934	119	12337
	LL	0	11	26	193	772	1035	1388	1082	635	308	33	4	5487
	MISC	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOT	90	84	26	193	783	1880	5677	3191	2142	2668	967	123	**17824**
1983	OT	179	41	9	6	35	2209	1095	2115	956	171	76	11	6903
	GN	0	0	0	0	0	4	8	3	5	0	0	0	20
	LL	0	0	171	147	440	1440	698	574	1303	311	89	0	5173
	MISC	0	0	0	0	0	5	28	0	0	1	0	0	34
	TOT	179	41	180	153	475	3658	1829	2692	2264	483	165	11	**12130**
1984	OT	5	3	13	0	37	267	92	240	60	19	0	0	736
	GN	0	0	0	0	0	34	3	0	0	0	0	0	37
	LL	0	0	167	152	112	1193	1209	1183	605	286	50	0	4957
	MISC	0	0	0	1	3	21	7	1	0	0	0	0	33
	TOT	5	3	180	153	152	1515	1311	1424	665	305	50	0	**5763**
1985	OT	0	2	0	0	0	1336	2565	2440	693	435	5	80	7556
	GN	0	0	0	0	0	14	4	9	0	0	0	0	27
	LL	0	29	54	181	151	414	230	540	647	501	29	29	2805
	MISC	0	1	2	14	15	6	9	2	3	2	0	1	55
	TOT	0	32	56	195	166	1770	2808	2991	1343	938	34	110	**10443**
1986	OT	14	9	0	15	6	2364	3138	477	49	11	4	22	6109
	GN	0	0	0	0	0	44	82	75	29	0	0	0	230
	LL	0	58	86	12	24	146	120	538	606	409	12	0	2011
	MISC	0	2	9	15	10	3	7	1	14	0	0	0	61
	TOT	14	69	95	42	40	2557	3347	1091	698	420	16	22	**8411**
1987	OT	19	1	3	0	0	2485	3941	890	145	2	78	44	7608
	GN	0	0	0	0	0	109	249	308	38	0	0	0	704
	LL	0	6	112	68	8	293	591	1032	747	310	12	33	3212
	MISC	5	11	15	17	9	33	88	82	51	2	6	2	321
	TOT	24	18	130	85	17	2920	4869	2312	981	314	96	79	**11845**
1988	OT	23	520	56	0	13	3247	3181	428	17	98	29	8	7620
	GN	0	0	0	0	0	180	224	141	50	21	0	0	616
	LL	54	86	68	205	27	1247	1685	392	426	134	10	1	4335
	MISC	2	9	12	10	16	41	95	97	53	0	20	2	357
	TOT	79	615	136	215	56	4715	5185	1058	546	253	59	11	**12928**
1989	OT	5	140	7	0	2	1553	86	70	2	87	33	2	1987
	GN	0	0	0	0	0	131	359	440	175	9	0	0	1114
	LL	41	202	250	92	268	909	1057	1210	331	65	0	0	4425
	MISC	7	7	9	22	47	126	85	151	15	3	3	0	475
	TOT	53	349	266	114	317	2719	1587	1871	523	164	36	2	**8001**

Table .1 Continued

YEAR	GEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
1990	OT	0	0	0	0	1	3187	1744	1547	929	436	9	1	7854
	GN	0	0	0	0	0	114	344	309	143	0	0	0	910
	LL	125	149	260	0	129	1156	1448	1098	581	252	4	0	5202
	MISC	6	12	19	19	10	62	77	58	63	5	11	2	344
	TOT	131	161	279	19	140	4519	3613	3012	1716	693	24	3	**14310**
1991	OT	348	33	22	1	0	3455	1536	672	316	296	14	6	6698
	GN	0	0	0	0	17	427	696	364	163	20	0	0	1688
	LL	49	335	187	230	202	597	1028	860	699	363	113	43	4706
	MISC	8	8	7	25	15	59	71	104	51	6	9	0	363
	TOT	405	376	216	256	234	4538	3331	2000	1229	685	136	49	**13455**
1992	OT	261	375	0	1	12	2835	972	287	214	541	132	9	5638
	GN	0	0	0	0	1	294	350	342	203	26	2	0	1217
	LL	114	340	475	275	237	799	676	612	509	337	101	0	4474
	MISC	9	13	19	21	24	141	75	47	0	4	8	1	383
	TOT	384	726	494	296	274	4068	2073	1287	945	909	243	10	**11712**
1993	OT	826	998	77	380	0	1203	590	162	123	237	178	114	4890
	GN	0	0	0	0	0	287	367	261	212	48	0	0	1175
	LL	4	30	166	76	148	422	515	462	261	122	118	63	2387
	MISC	9	4	10	14	17	4	5	1	0	1	2	0	67
	TOT	839	1032	253	470	165	1916	1477	886	596	408	298	177	**8519**
1994	OT	0	0	0	0	0	777	410	115	128	263	117	83	1893
	GN	0	0	0	0	0	133	539	243	97	19	0	0	1031
	LL	0	0	0	0	0	409	481	869	492	5	30	0	2287
	MISC	7	7	10	14	9	6	4	2	0	1	3	1	66
	TOT	7	7	10	14	9	1327	1434	1229	717	288	150	84	**5276**
1995	OT	0	0	0	0	0	100	62	57	82	25	41	27	395
	GN	0	0	0	0	0	17	39	0	70	0	0	0	126
	LL	0	0	0	0	0	116	161	122	98	20	20	7	544
	MISC	1	4	4	5	4	5	8	3	1	0	0	0	35
	TOT	1	4	4	5	4	238	271	182	251	45	61	34	**1100**
1996	OT	0	0	0	0	0	217	96	100	58	42	40	103	656
	GN	0	0	0	0	0	26	137	81	0	0	0	0	245
	LL	0	0	0	0	0	29	381	269	81	137	65	21	984
	MISC	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOT	0	0	0	0	0	272	614	450	139	179	105	124	**1885**
1997	OT	0	0	0	0	0	360	166	210	135	56	52	53	1032
	GN	0	0	0	0	0	133	133	107	50	47	0	0	470
	LL	0	0	0	0	0	176	432	383	236	132	15	21	1395
	MISC	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOT	0	0	0	0	0	670	731	700	421	235	67	74	**2898**
1998	OT	0	0	0	0	0	173	70	138	95	99	39	27	641
	GN	0	0	0	0	0	76	90	63	25	46	0	0	300
	LL	0	0	0	0	0	74	331	221	177	86	21	18	928
	MISC	0	0	0	0	0	5	0	0	0	0	0	0	5
	TOT	0	0	0	0	0	328	491	422	297	231	60	45	**1874**
1999	OT	3	0	0	0	0	226	156	47	72	59	38	19	619
	GN	0	0	0	0	0	58	100	48	15	36	7	6	270
	LL	0	0	0	0	0	95	288	244	152	107	27	17	929
	MISC	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOT	0	0	0	0	0	379	544	339	239	202	72	7	**1818**

Table 2.Summary of total catches (t) by Canada and the USA in unit areas 5Zj,m for 1978-1999.

YEAR	CANADA	USA	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	8411	5696	14107
1987	11845	4792	16637
1988	12932	7645	20577
1989	8001	6182	14183
1990	14310	6378	20688
1991	13455	6777	20232
1992	11712	5080	16792
1993	8519	4019	12538
1994	5277	1229	6505
1995	1100	665	1765
1996	1885	773	2658
1997	2898	557	3455
1998	1874	795	2669
1999	1818	1150	2968

Table 3. Canadian and USA 5Zj,m commercial landings samples for 1978-99. At-sea observer samples are included in Canadian length samples since 1994.

	USA			**Canada**		
	Samples	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	129	26663	879
97	2	210	55	118	31882	1244
98	-	-	-	139	26549	1720
99	-	-	-	84	24954	918

Table 4. Summary of 1999 Canadian commercial and IOP samples used to estimate catch-at-age. USA catch-at-age for 1994-99. was provided by the USA, and was based on commercial landings samples prorated by market category

GEAR	MONTH	Catch (t) by Month	#LEN	#AGES	Catch (t) by Quarter
OTB+Misc					
	Jan				
	Feb				
	Mar				0
	Apr				
	May				
	Jun	229	5180	318	229
	Jul	156	2176	126	
	Aug	47	280	73	
	Sep	72	1168	47	274
	Oct	58	1559	54	
	Nov	38	455	73	
	Dec	19	765	65	116
Total Canadian		619	11583	756	
Total USA		1150			
Total		1769			
Longline	Jan				
	Feb				
	Mar				0
	Apr				
	May				
	Jun	94	1214		95
	Jul	288	5541		
	Aug	244	2001	51	
	Sep	152	240		684
	Oct	107	937	91	
	Nov	27			
	Dec	17	1130		150
Total		929	11063	142	
Gillnet	Jan				
	Feb				
	Mar				0
	Apr				
	May				
	Jun	59	265		59
	Jul	100	1250		
	Aug	48	290		
	Sep	14	519		163
	Oct	36	519		
	Nov	7			
	Dec	6			48
Total		270	2843		
Age Keys	Q1		0	0	
	Q2		6659	318	383
	Q3		13465	297	1121
	Q4		5365	283	314
	Mod				
TOTAL CANADIAN		**1818**	**25489**	**898**	**1818**
TOTAL Canada + USA		**2968**	**25489**	**898**	

Table 5. Results of intra-reader aging comparisons (BH = new reader, MIB = previous reader).

	2nd Age - BH													
1st Age MIB	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Total**
1	**3**													**3**
2		**31**	**3**											**34**
3		**1**	**49**	**4**	**2**									**56**
4			**3**	**42**	**5**									**50**
5			**1**	**5**	**59**	**5**	**1**							**71**
6					**4**	**27**								**31**
7							**9**	**1**						**10**
8							**1**	**2**						**3**
9									**1**					**1**
10														**0**
11										**1**				**1**
12														**0**
13													**1**	**1**
Total	**3**	**32**	**56**	**51**	**70**	**32**	**11**	**3**	**1**	**1**			**1**	**261**

Percent Agreement 86%

Coefficient of Variation 2.61

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

Numbers				**AGE**				
Year	1	2	3	4	5	6	7	8	total
78	2	121	3588	1076	307	110	83	21	5308
79	10	814	399	1774	545	149	22	45	3758
80	1	987	1495	265	916	345	109	20	4138
81	19	603	1443	1249	155	595	169	65	4298
82	6	2682	1686	1429	1066	189	345	157	7560
83	40	1319	3416	1474	466	283	31	71	7100
84	10	269	911	1346	511	290	230	31	3598
85	12	2792	1221	631	941	224	96	100	6017
86	28	326	2188	513	304	400	58	39	3856
87	14	3666	865	1099	144	121	167	37	6113
88	10	320	3653	646	861	144	102	143	5879
89	1	740	652	1837	193	314	56	25	3818
90	7	678	3196	962	1195	116	122	10	6286
91	11	626	783	1939	953	790	93	56	5251
92	86	2358	1251	432	908	250	233	25	5543
93	4	414	1967	809	215	332	110	93	3944
94	2	182	486	751	246	41	59	26	1799
95	0	56	235	120	89	14	4	3	522
96	1	39	231	386	75	47	11	3	792
97	3	107	155	287	291	70	32	10	955
98	-	81	272	136	138	115	18	11	771
99	2	46	422	271	80	44	41	9	915
Percent									
Year									
78	0.0	2.3	67.6	20.3	5.8	2.1	1.6	0.4	
79	0.3	21.7	10.6	47.2	14.5	4.0	0.6	1.2	
80	0.0	23.9	36.1	6.4	22.1	8.3	2.6	0.5	
81	0.4	14.0	33.6	29.1	3.6	13.8	3.9	1.5	
82	0.1	35.5	22.3	18.9	14.1	2.5	4.6	2.1	
83	0.6	18.6	48.1	20.8	6.6	4.0	0.4	1.0	
84	0.3	7.5	25.3	37.4	14.2	8.1	6.4	0.9	
85	0.2	46.4	20.3	10.5	15.6	3.7	1.6	1.7	
86	0.7	8.5	56.7	13.3	7.9	10.4	1.5	1.0	
87	0.2	60.0	14.2	18.0	2.4	2.0	2.7	0.6	
88	0.2	5.4	62.1	11.0	14.6	2.4	1.7	2.4	
89	0.0	19.4	17.1	48.1	5.1	8.2	1.5	0.7	
90	0.1	10.8	50.8	15.3	19.0	1.8	1.9	0.2	
91	0.2	11.9	14.9	36.9	18.1	15.0	1.8	1.1	
92	1.6	42.5	22.6	7.8	16.4	4.5	4.2	0.5	
93	0.1	10.5	49.9	20.5	5.5	8.4	2.8	2.4	
94	0.1	10.1	27.1	41.9	13.7	2.3	3.3	1.4	
95	0.0	10.7	45.1	23.0	17.1	2.8	0.8	0.6	
96	0.1	4.9	29.2	48.7	9.5	5.9	1.4	0.3	
97	0.3	11.2	16.3	30.0	30.5	7.4	3.4	1.0	
98	0.0	10.7	36.7	17.6	16.5	13.7	2.6	1.5	
99	0.6	6.6	42.8	30.8	8.8	5.1	4.2	1.2	

Table 7. Weight-at-age (kg) derived from fishery (mid-year) and from 1987-99 Canadian surveys (beginning of year) for 5Zj,m cod

Average Midyear Weights

	1	2	3	4	5	6	7	8
1978	0.71	1.31	2.46	3.47	4.34	5.79	7.37	8.49
1979	0.89	1.49	2.15	4.21	4.89	7.18	9.18	10.31
1980	0.84	1.46	2.47	3.67	5.65	6.68	8.39	9.09
1981	0.88	1.50	2.36	3.42	5.21	7.22	8.57	9.89
1982	0.77	1.40	2.66	3.83	5.35	6.51	9.36	9.90
1983	0.97	1.49	2.38	3.31	4.64	6.39	7.96	10.29
1984	1.05	1.64	2.45	3.62	5.08	6.58	8.91	10.10
1985	0.91	1.42	2.09	3.89	5.09	6.41	8.10	10.24
1986	0.93	1.48	2.45	3.66	5.60	7.19	8.92	9.96
1987	0.73	1.48	2.50	4.19	5.81	7.73	8.95	10.01
1988	0.79	1.52	2.36	3.51	5.40	6.65	8.78	9.99
1989	0.81	1.62	2.27	3.77	5.40	6.69	8.22	10.72
1990	0.83	1.56	2.46	3.52	4.89	6.33	8.46	10.65
1991	1.11	1.63	2.55	3.42	4.77	5.89	7.41	10.52
1992	1.15	1.54	2.46	3.84	4.70	6.16	7.51	9.85
1993	0.88	1.57	2.31	3.08	4.50	5.73	7.08	8.88
1994	0.91	1.46	2.41	3.83	4.80	7.09	7.86	8.93
1995	0.90	1.49	2.51	3.72	5.22	6.52	11.06	10.12
1996	1.03	1.54	2.36	3.34	5.24	6.36	6.92	8.46
1997	0.98	1.50	2.23	3.34	4.25	5.80	8.05	8.33
1998	0.63	1.48	2.37	3.19	4.27	5.83	6.99	8.30
1999	0.68	1.42	2.28	3.53	4.18	6.33	6.79	8.04
78-99	0.88	1.50	2.39	3.61	4.97	6.50	8.22	9.59
96-99	0.83	1.48	2.31	3.35	4.49	6.08	7.19	8.28

Beginning of Year

1978	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307
1979	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307
1980	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307
1981	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307
1982	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307
1983	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307
1984	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307
1985	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307
1986	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307
1987	0.151	0.843	1.690	2.838	5.800	8.426	8.154	7.464
1988	0.126	0.894	1.883	3.002	4.519	6.952	9.028	9.850
1989	0.153	0.805	1.669	2.868	4.226	6.588	7.634	8.099
1990	0.204	0.787	1.896	3.075	4.581	6.336	8.307	9.491
1991	0.086	0.870	1.923	3.181	4.266	5.099	7.308	9.616
1992	0.140	0.813	1.972	3.102	4.376	6.195	7.105	8.585
1993	0.081	0.936	1.884	3.087	4.791	6.024	6.969	7.581
1994	0.076	0.655	1.439	2.865	4.340	7.591	8.091	11.428
1995	0.146	0.798	1.567	2.225	3.535	5.132	6.204	7.275
1996	0.052	0.729	1.647	2.699	4.124	6.250	5.662	11.000
1997	0.100	0.725	1.762	2.352	3.434	6.564	7.529	10.996
1998	0.102	0.620	1.349	2.461	3.312	4.811	5.931	8.386
1999	0.151	0.999	1.414	2.425	3.317	4.848	7.116	11.222
2000		0.905	1.608	2.423	3.276	4.854	6.189	7.984
87-00	0.121	0.806	1.700	2.783	4.202	6.217	7.311	9.307
97-00	0.118	0.812	1.533	2.415	3.335	5.269	6.691	9.647

Table 8. Survey indices of abundance (catch per standard tow in numbers) adjusted for vessel and door conversions.

Spring Canada	1	2	3	4	5	6	7	8
1986	1.78	8.19	7.41	0.77	1.6	1.03	0.51	0.08
1987	0.12	4.31	1.55	1.81	0.39	0.21	0.44	0.21
1988	0.36	1.08	12.85	1.36	2.02	0.23	0.19	0.43
1989	0.84	5.22	1.84	4.11	0.62	0.8	0.1	0.2
1990	0.25	1.91	8.36	4.7	10.6	1.29	2.63	0.35
1991	2.83	2.43	3.4	3.93	2.06	2.87	0.36	0.6
1992	0.11	4.93	2.94	0.99	1.55	1.09	0.72	0.22
1993	0.07	0.85	4.15	1.5	0.89	1.82	0.66	0.64
1994	0.03	1.51	1.66	3.1	1.15	0.44	0.88	0.2
1995	0.08	0.45	2.99	1.82	1.25	0.45	0.11	0.16
1996	0.22	0.49	4.20	10.44	3.45	2.49	1.07	0.26
1997	0.07	0.90	1.37	3.19	3.04	0.52	0.12	0.08
1998	0.01	1.42	2.04	0.79	0.77	0.58	0.14	0.07
1999	0.01	0.38	3.12	2.63	1.08	0.76	0.46	0.02
2000	0.00	1.02	3.12	12.06	5.10	2.44	1.27	0.76
Fall USA								
1978	0.1	0	6.31	1.26	0.35	0.27		
1979	0.21	2.64	0.26	5.1	0.73	0.11		
1980	0.32	2.96	2.93	0.21	2.71	0.44		
1981	0.6	1.43	0.76	1.21	0.05	0.35		
1982	0.6	4.24	2.19	1.69	0.48	0.02		
1983	0	1.05	1.29	0.08	0.12	0		
1984	1.47	0.12	0.42	0.89	0.05	0.03		
1985	0.06	2.84	0.14	1.03	1.68	0.05		
1986	2.24	0.39	1.8	0.3	0.03	0		
1987	0.22	5.2	0.11	0.35	0	0		
1988	0.29	0.24	1.53	0.23	0.19	0		
1989	0.18	1.02	0.33	2.13	0.25	0.44		
1990	0.41	0.72	1.68	0.28	0.77	0.1		
1991	0.36	0.72	0.79	1.49	0.21	0.37		
1992	0	0.36	0.13	0.16	0.02	0.06		
1993	0	0.37	1.31	0.28	0	0.07		
1994	0	0.14	0.19	0.28	0.03	0		
1995	0.02	0.14	0.54	0.39	0.28	0.14		
1996	0.4	0.05	0.22	0.54	0.12	0.05		
1997	0.02	0.56	0.15	0.56	0.41	0.1		
1998	0	0.29	0.7	0.32	0.1	0.15		
1999	0	0.32	1.29	0.90	0.12	0.2		
2000	0	0.03	0.03	0.44	0.21	0.06		
Spring USA1								
1978	0.27	0	5.1	1.12	1.61	0.34	1.37	0.19
1979	0.69	2.65	0.22	2.57	1	0.34	0.17	0.22
1980	0.03	2.96	2.9	0.28	3.01	0.59	0.12	0.08
1981	1.7	1.57	2.43	1.73	0.07	0.6	0.31	0.12
Spring USA2								
1982	0.79	11.58	24.99	22.29	16.98	0	5.55	1.24
1983	0.69	3.63	6.33	1.36	1.06	0.66	0.28	0.11
1984	0.2	0.22	0.81	1.22	0.48	0.39	0.34	0
1985	0.08	3.67	1.15	1.92	2.75	0.6	0.35	0.45
1986	1.13	0.62	2.05	0.55	0.78	0.98	0.05	0.21
1987	0	2.17	0.46	0.98	0	0.34	0.28	0.06
1988	0.58	0.45	5.05	0.5	0.84	0.08	0.03	0.14
1989	0.21	1.55	0.47	2.39	0.46	0.54	0.07	0.06
1990	0.13	0.62	3.14	1.09	1.18	0.29	0.3	0.03
1991	1.31	1.12	0.92	1.63	0.83	0.69	0.08	0.03
1992	0.14	1.2	0.65	0.17	0.45	0.27	0.29	0.05
1993	0	0.83	2.32	0.47	0.08	0.33	0.08	0.08
1994	0.1	0.37	0.29	0.36	0.09	0.02	0.06	0
1995	0.09	0.52	1.64	0.88	1.63	0.35	0.47	0.06
1996	0.25	0.54	1.78	2.41	0.22	0.17	0.05	0
1997	0.1	0.37	0.11	0.73	0.93	0.10	0.23	0.1
1998	0	1.99	3.80	1.91	1.88	1.17	0.06	0.06
1999	0.1	0.24	1.24	1.14	0.66	0.31	0.17	0.06

Table 9. Summary of Canadian catch in tonnes and effort data by gear sector for Georges Bank cod (value in brackets for effort is the calculated value from total landings divided by average landings per day).

	Mobile	**Gillnet**	**Longline**
1990 Total catch (t)	7854	910	5202
Total with effort (t)	7285	534	1579

Number of Boats	176	14	103
Percent with effort	92.7	58.7	30.4
Effort (fish_days)	3837(4133)	215(367)	825(2724)
Catch per day	1.90	2.48	1.91
1991 Total catch (t)	6698	1688	4706
Total with effort (t)	6395	1084	1581
Number of boats	188	26	118
Percent with effort	95.5	64.2	33.6
Effort (fish_days)	3769(3940)	308(480)	849(2530)
Landings per day	1.70	3.52	1.86
1992 Total catch (t)	5638	1217	4474
Total with effort (t)	5583	684	1893
Number of boats	138	19	130
Percent with effort	99.0	56.2	42.3
Effort (fish_days)	2051(2073)	389(691)	1076(2542)
Landings per day	2.72	1.76	1.76
1993 Total catch (t)	4890	1175	2387
Total with effort (t)	4877	943	1179
Number of boats	125	20	135
Percent with effort	99.7	80.3	49.4
Effort (fish_days)	2377(2385)	635(789)	1377(2776)
Landings per day	2.05	1.49	0.86
1994 Total catch (t)	1893	1031	2287
Total with effort (t)	1886	79	73
Number of boats	95	21	78
Percent with effort	99.6	7.7	3.2
Effort (fish_days)	1926(1932)	-	-
Landings per day	0.98	-	-
1995 Total catch (t)	313	123	505
Total with effort (t)	313	116	494
Number of boats	64	11	49
Percent with effort	99.9	94.3	97.8
Effort (fish_days)	506(506)	202(216)	522(532)
Landings per day	0.62	0.57	0.95
1996 Total catch (t)	656	245	984
Total with effort (t)	656	245	984
Number of boats	76	10	102
Percent with effort	100.0	100.0	100.0
Effort (fish_days)	1082	111	852
Landings per day	0.61	2.21	1.15
1997 Total catch (t)	1032	470	1394
Total with effort (t)	1009	409	1152
Number of boats	74	9	74
Percent with effort	97.8	87.0	82.6
Effort (fish_days)	1159(1186)	164(188)	708(860)
Landings per day	0.87	2.49	1.62
1998 Total catch (t)	640	299	928
Total with effort (t)	626	299	861
Number of boats	71	9	64
Percent with effort	97.8	100.0	92.8
Effort (fish_days)	1028(1051)	180	578(623)
Landings per day	0.61	1.66	1.49
1999 Total catch (t)	607	264	912
Total with effort (t)	607	264	912
Number of boats	69	7	60
Percent with effort	100.0	100.0	100.0
Effort (fish_days)	915	175	584
Landings per day	0.66	1.51	1.56

Table 10. Proportion mature at age for 5Zj,m cod from DFO research survey (see Hunt (1995)), using a three year moving average.

	AGE							
Year	1	2	3	4	5	6	7	8
1978	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000
1979	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000
1980	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000
1981	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000
1982	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000
1983	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000
1984	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000
1985	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000
1986	0.029	0.345	0.871	0.982	0.998	1.000	1.000	1.000
1987	0.038	0.320	0.822	0.974	0.997	1.000	1.000	1.000
1988	0.032	0.320	0.878	0.985	0.998	1.000	1.000	1.000
1989	0.017	0.320	0.950	0.998	1.000	1.000	1.000	1.000
1990	0.016	0.351	0.955	0.999	1.000	1.000	1.000	1.000
1991	0.019	0.424	0.956	0.998	1.000	1.000	1.000	1.000
1992	0.018	0.525	0.979	0.999	1.000	1.000	1.000	1.000
1993	0.018	0.564	0.988	1.000	1.000	1.000	1.000	1.000
1994	0.026	0.549	0.982	1.000	1.000	1.000	1.000	1.000
1995	0.037	0.507	0.952	0.997	1.000	1.000	1.000	1.000
1996	0.035	0.383	0.891	0.991	0.999	1.000	1.000	1.000
1997	0.032	0.352	0.881	0.991	0.999	1.000	1.000	1.000
1998	0.029	0.537	0.944	0.996	1.000	1.000	1.000	1.000
1999	0.013	0.767	0.982	0.998	1.000	1.000	1.000	1.000
2000	0.001	0.872	0.976	0.996	1.000	1.000	1.000	1.000

Table 11. Bootstrap parameters for 5Zj,m cod estimated from ADAPT, with standard errors and bias

	Estimate	Standard Error	Relative Error	Bias	Relative Bias
Population Numbers					
1999 numbers Age 2	541	305	0.56	78	0.15
1999 numbers Age 3	679	289	0.43	53	0.08
1999 numbers Age 4	1860	644	0.35	138	0.07
1999 numbers Age 5	1760	501	0.29	65	0.04
1999 numbers Age 6	401	123	0.31	17	0.04
1999 numbers Age 7	446	142	0.32	8	0.02
1999 numbers Age 8	377	138	0.37	14	0.04
Survey Catchabilities					
Can, Spr. Age 1	0.000035	0.000009	0.25	0.000002	0.04
Can, Spr. Age 2	0.000464	0.000105	0.23	0.000002	0.01
Can, Spr. Age 3	0.001150	0.000273	0.24	0.000002	0.03
Can, Spr. Age 4	0.001460	0.000337	0.23	0.000002	0.04
Can, Spr. Age 5	0.001990	0.000479	0.24	0.000002	0.03
Can, Spr. Age 6	0.002280	0.000538	0.24	0.000002	0.03
Can, Spr. Age 7	0.002500	0.000581	0.23	0.000002	0.03
Can, Spr. Age 8	0.002950	0.000712	0.24	0.000002	0.04
USA Fall Age 1	0.000033	0.000007	0.22	0.000002	0.03
USA Fall Age 2	0.000123	0.000025	0.20	0.000002	0.01
USA Fall Age 3	0.000162	0.000031	0.19	0.000002	0.01
USA Fall Age 4	0.000263	0.000048	0.18	0.000002	0.01
USA Fall Age 5	0.000173	0.000034	0.19	0.000002	0.01
USA Fall Age 6	0.000245	0.000052	0.21	0.000002	0.01
USA Spr1 Age 1	0.000028	0.000013	0.46	0.000002	0.06
USA Spr1 Age 2	0.000287	0.000159	0.55	0.000002	0.10
USA Spr1 Age 3	0.000333	0.000161	0.48	0.000002	0.08
USA Spr1 Age 4	0.000362	0.000184	0.51	0.000002	0.10
USA Spr1 Age 5	0.000562	0.000267	0.48	0.000002	0.07
USA Spr1 Age 6	0.000652	0.000345	0.53	0.000002	0.11
USA Spr1 Age 7	0.001080	0.000547	0.51	0.000002	0.08
USA Spr1 Age 8	0.001300	0.000715	0.55	0.000002	0.15
USA Spr2 Age 1	0.000048	0.000012	0.25	0.000002	0.03
USA Spr2 Age 2	0.000218	0.000047	0.21	0.000002	0.03
USA Spr2 Age 3	0.000418	0.000079	0.19	0.000002	0.00
USA Spr2 Age 4	0.000587	0.000125	0.21	0.000002	0.02
USA Spr2 Age 5	0.000796	0.000169	0.21	0.000002	0.04
USA Spr2 Age 6	0.000745	0.000169	0.23	0.000002	0.03
USA Spr2 Age 7	0.000920	0.000188	0.20	0.000002	0.02
USA Spr2 Age 8	0.001070	0.000245	0.23	0.000002	0.04

Table 12. Population estimates (abundance, beginning of year biomass and fishing mortality) for 5Zj,m cod derived from ADAPT

Abundance(000's)	1	2	3	4	5	6	7	8	**1+**	**3+**
1978	11282	2208	10354	3504	1083	248	294	63	29036	15545
1979	9298	9235	1699	5261	1904	611	104	166	28278	9745
1980	9076	7604	6827	1032	2717	1069	366	66	28758	12078
1981	17092	7430	5336	4245	607	1403	566	202	36883	12360
1982	6213	13977	5540	3073	2355	358	617	312	32444	12254
1983	4496	5082	9030	3023	1240	976	125	198	24168	14591
1984	13383	3645	2976	4335	1160	598	545	74	26714	9687
1985	4487	10948	2741	1619	2341	493	231	240	23101	7665
1986	21228	3663	6455	1153	761	1075	203	103	34642	9751
1987	7037	17355	2705	3324	486	351	522	114	31894	7502
1988	13508	5749	10912	1439	1736	269	179	278	34069	14812
1989	3757	11051	4418	5659	601	653	92	56	26286	11478
1990	5325	3075	8380	3030	2986	319	255	25	23395	14995
1991	8615	4353	1908	4000	1618	1375	157	100	22126	9157
1992	2526	7043	3000	862	1544	478	424	46	15924	6354
1993	4088	1991	3653	1338	320	458	168	139	12155	6076
1994	2957	3343	1258	1239	377	72	82	41	9369	3068
1995	1818	2420	2573	595	348	91	23	15	7881	3644
1996	4907	1488	1930	1895	379	205	62	15	10880	4485
1997	3948	4017	1183	1372	1204	243	125	41	12133	4168
1998	997	3230	3192	829	865	724	136	74	10046	5820
1999	566	816	2571	2368	556	584	489	95	8046	6664
2000	1000	462	626	1725	1694	383	438	364	6693	5231

Biomass									**1+**	**3+**	**SSB**
1978	1361	1779	17597	9753	4551	1540	2147	586	39313	36173	35286
1979	1121	7440	2887	14642	7998	3799	764	1545	40197	31635	34038
1980	1095	6126	11603	2873	11416	6648	2679	612	43051	35831	37114
1981	2061	5986	9069	11814	2550	8725	4139	1882	46227	38179	39574
1982	749	11261	9415	8552	9893	2224	4511	2902	49507	37497	40814
1983	542	4094	15347	8412	5210	6065	910	1845	42426	37790	37944
1984	1614	2936	5057	12063	4872	3717	3982	690	34932	30382	30967
1985	541	8821	4659	4505	9837	3064	1687	2237	35351	25989	28834
1986	2560	2951	10971	3210	3196	6683	1487	959	32018	26506	26111
1987	1064	14622	4570	9433	2819	2955	4256	854	40573	24887	28531
1988	1706	5140	20548	4319	7844	1868	1613	2734	45773	38926	38034
1989	574	8891	7374	16232	2540	4304	700	450	41065	31601	34049
1990	1084	2421	15888	9315	13678	2021	2115	241	46762	43258	43388
1991	742	3789	3669	12721	6901	7013	1149	958	36942	32411	33851
1992	354	5727	5917	2674	6758	2960	3010	396	27796	21715	24598
1993	330	1863	6880	4129	1535	2757	1174	1057	19726	17533	18508
1994	225	2190	1810	3550	1636	547	664	463	11085	8670	9844
1995	266	1930	4031	1323	1229	466	140	110	9495	7298	8087
1996	254	1085	3180	5114	1562	1280	349	163	12986	11648	11680
1997	394	2911	2085	3228	4134	1593	944	446	15735	12430	13186
1998	102	2004	4306	2040	2866	3483	806	620	16226	14121	14949
1999	86	815	3636	5742	1845	2832	3481	1066	19503	18603	19155
2000	118	418	1006	4179	5551	1861	2713	2905	18752	18216	18542

Fishing Mortality									**4+F**	**4+ %Exp**
1978	0.000	0.062	0.477	0.410	0.372	0.663	0.371	0.454	0.41	31
1979	0.001	0.102	0.298	0.461	0.377	0.311	0.263	0.353	0.42	32
1980	0.000	0.154	0.275	0.331	0.461	0.436	0.395	0.406	0.42	32
1981	0.001	0.094	0.352	0.389	0.329	0.622	0.396	0.434	0.43	32
1982	0.001	0.237	0.406	0.708	0.681	0.855	0.935	0.795	0.73	48
1983	0.010	0.335	0.534	0.758	0.529	0.383	0.319	0.497	0.62	42
1984	0.001	0.085	0.409	0.416	0.656	0.752	0.618	0.610	0.51	36
1985	0.003	0.328	0.666	0.555	0.578	0.685	0.606	0.606	0.58	40
1986	0.001	0.103	0.464	0.664	0.574	0.523	0.375	0.534	0.58	40
1987	0.002	0.264	0.431	0.450	0.393	0.474	0.432	0.437	0.44	33
1988	0.001	0.063	0.457	0.673	0.777	0.874	0.968	0.823	0.76	49
1989	0.000	0.077	0.177	0.439	0.433	0.742	1.084	0.675	0.48	35
1990	0.001	0.277	0.540	0.427	0.575	0.507	0.739	0.562	0.51	37
1991	0.001	0.172	0.595	0.751	1.020	0.978	1.026	0.944	0.86	53
1992	0.038	0.457	0.608	0.790	1.016	0.842	0.911	0.890	0.92	55
1993	0.001	0.259	0.881	1.066	1.291	1.519	1.225	1.276	1.20	65
1994	0.001	0.061	0.548	1.069	1.222	0.960	1.489	1.185	1.12	62
1995	0.000	0.025	0.104	0.250	0.328	0.185	0.216	0.245	0.27	21
1996	0.000	0.028	0.137	0.246	0.244	0.288	0.216	0.249	0.25	20
1997	0.001	0.028	0.150	0.250	0.292	0.376	0.324	0.311	0.28	22
1998	0.000	0.026	0.093	0.189	0.180	0.176	0.155	0.175	0.18	15
1999	0.002	0.056	0.182	0.126	0.160	0.079	0.085	0.113	0.12	10

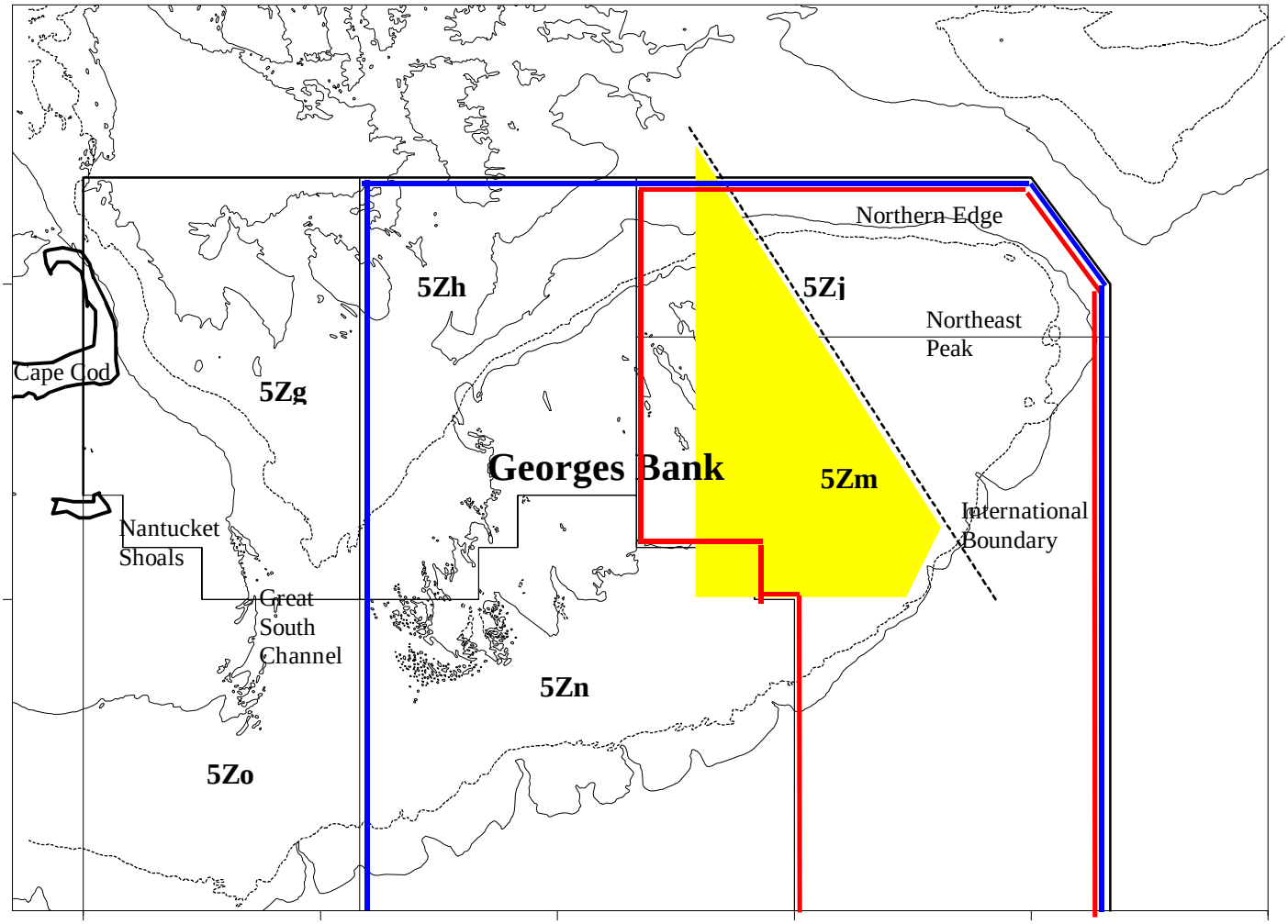
Table 13. Input for 5Zj,m cod catch projection.

Age in 2000	Population Numbers (000's) in 2000	Partial Recruitment in 2000 (1995-98 average from F)	Natural Mortality in 2000	Mean Weight kg Beg. Of Year (1997-00 average)	Mean Weight kg Fishery (1996-99 average)
1	1000	0.00	0.20	0.12	0.86
2	462	0.13	0.20	0.81	1.52
3	626	0.52	0.20	1.53	2.31
4	1725	1.00	0.20	2.42	3.35
5	1694	1.00	0.20	3.33	4.48
6	383	1.00	0.20	5.27	6.07
7	438	1.00	0.20	6.69	7.18
8	364	1.00	0.20	9.65	8.28

Table 14. Catch projection results using bootstrap bias adjusted point estimates for a target of $F_{0.1}$ =0.2

	Year	Age											
Population Numbers (000's)		1	2	3	4	5	6	7	8				
	2000	1000	462	626	1725	1694	383	438	364				
	2001	1000	819	369	462	1156	1136	257	294				
Fishing Mortality													
	2000	0	0.026	0.104	0.2	0.2	0.2	0.2	0.2				
Natural. Mortality		.											
	2000	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2				
Partial Recruitment													
	2000	0	0.13	0.52	1	1	1	1	1				
January Weight kg													
	2000	0.12	0.90	1.61	2.42	3.28	4.85	6.19	7.98				
	2001	0.12	0.81	1.53	2.42	3.33	5.27	6.69	9.65				
Projected Biomass (t)										1+	2+	3+	4+
	2000	118	418	1006	4179	5551	1861	2713	2905	18752	18634	18216	17209
	2001	118	665	565	1116	3856	5985	1720	2835	16859	16741	16076	15511
Projected Catch Numbers (000's)													
	2000	0	11	56	284	279	63	72	60				
Fishery Weight kg													
	2000	0.86	1.52	2.31	3.35	4.48	6.07	7.18	8.28				
Projected Catch Biomass (t)													
	2000	0	16	130	952	1252	384	519	497	**3749**	3749	3733	3603

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



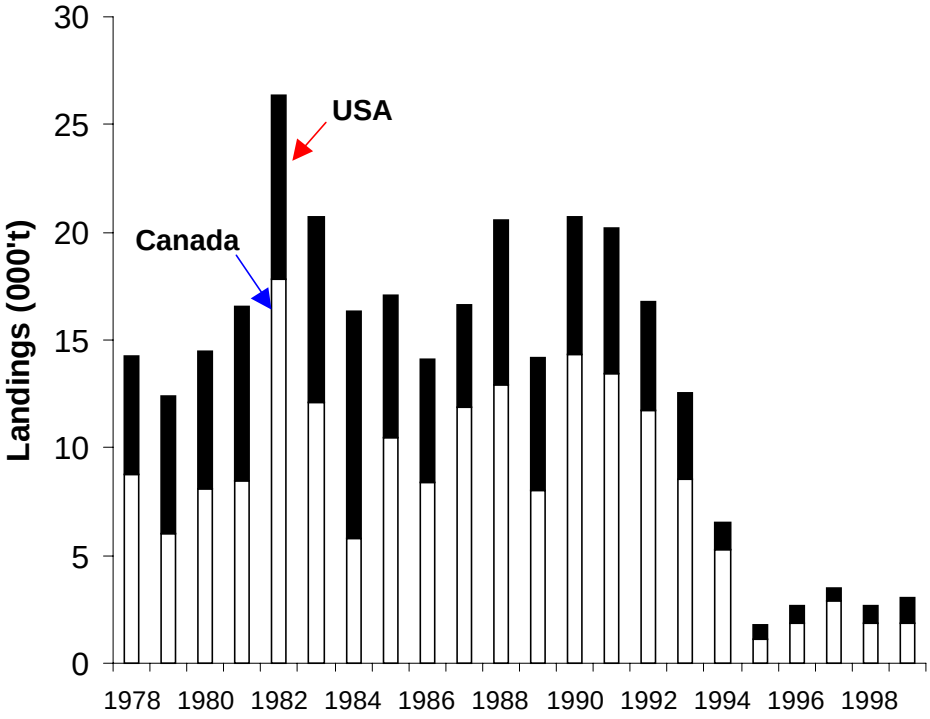


Figure 2. Landings of 5Zj,m cod by Canada and the USA

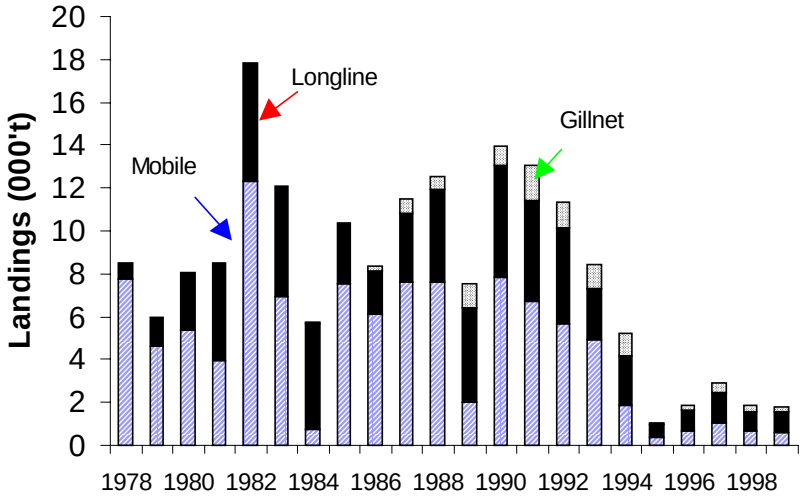


Figure 3. Landings of 5Zj,m cod by gear type for Canadian fisheries.

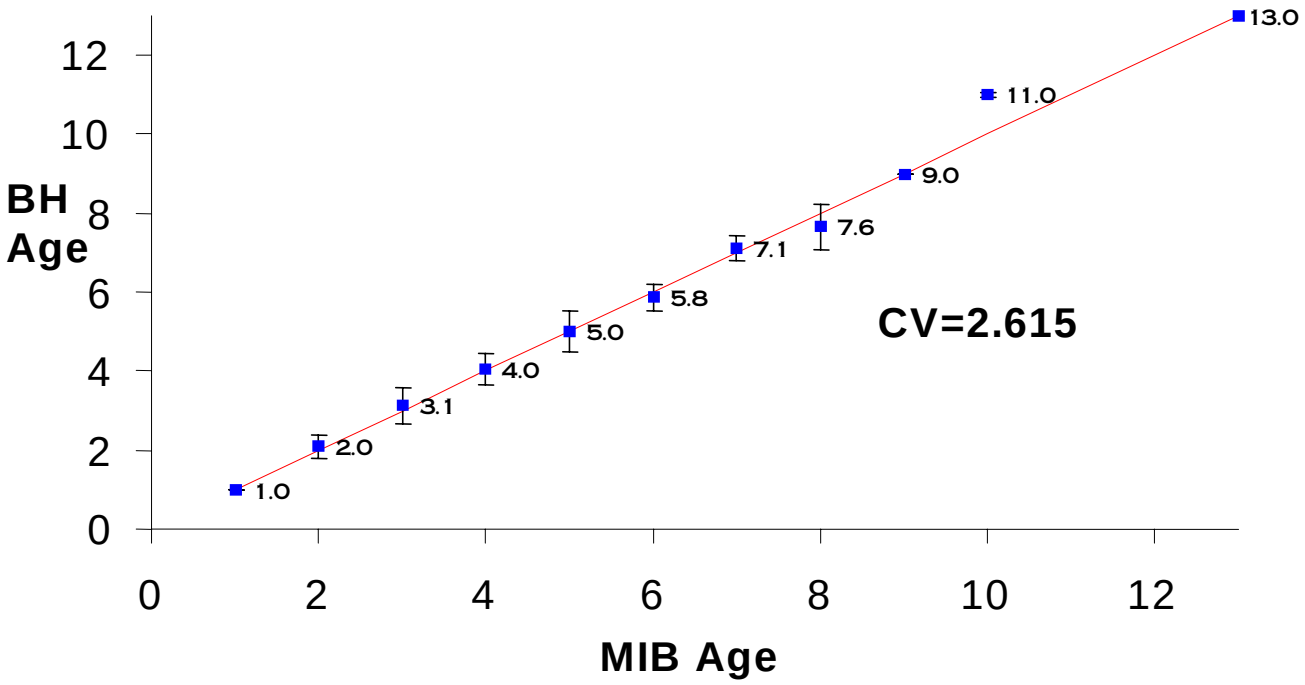
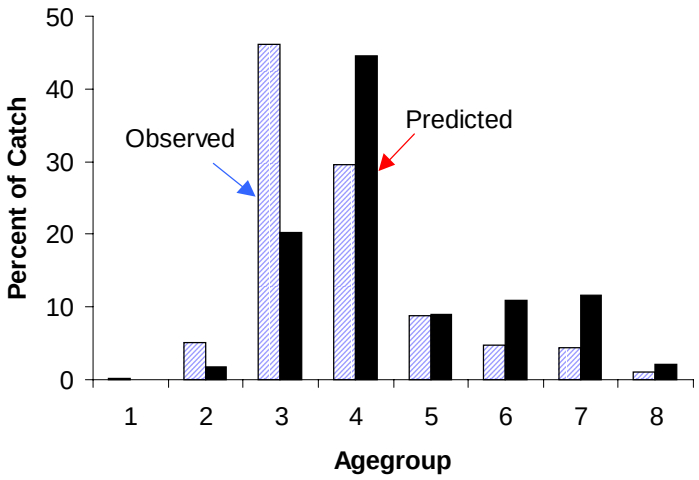


Figure 4. Canadian inter-reader age comparisons showing the average age and variance for the new reader (BH) relative to the average age of the previous reader (MIB). For example, the average BH age for cod aged as 4 years old by MIB was 4.04 years.

A



B

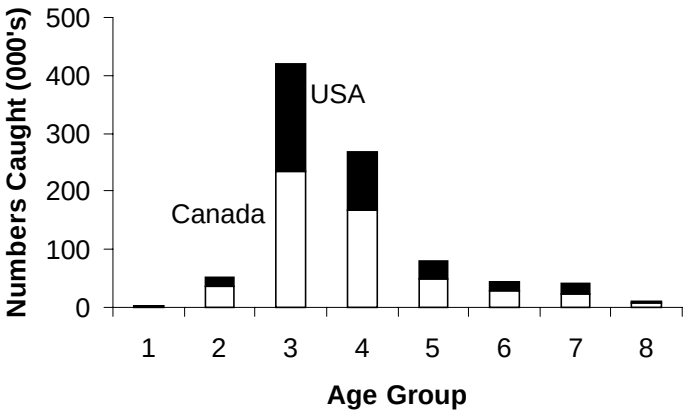


Figure 5. Observed and predicted catch at age for the 1999 (A) and for the Canadian and USA 5Zj,m cod fishery (B)

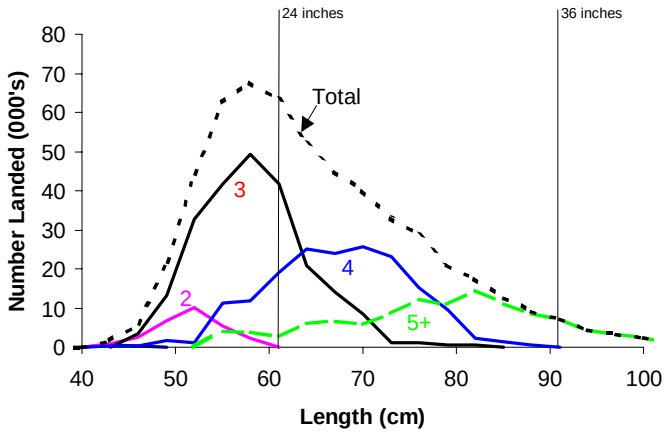


Figure 6. Length composition by agegroup for the 1999 Canadian 5Zj,m cod fishery

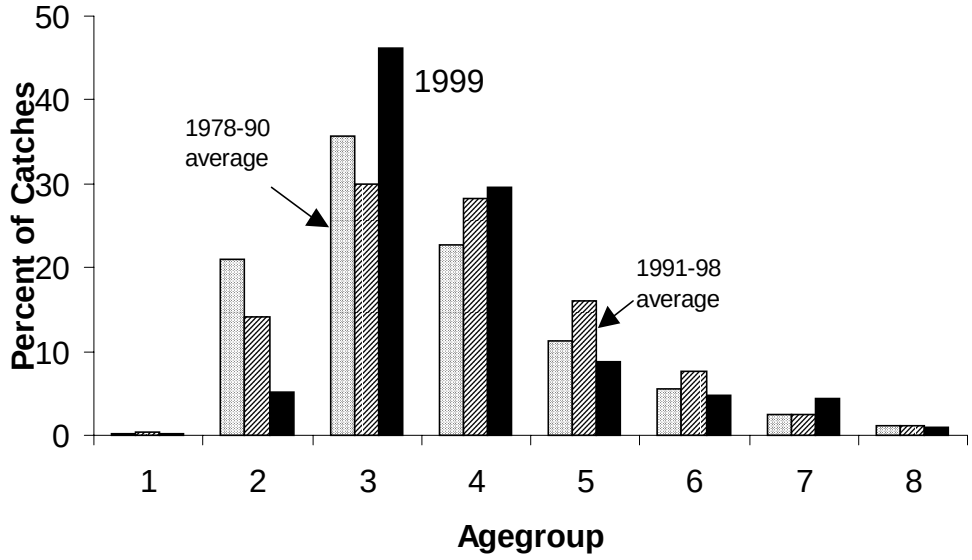


Figure 7. Comparison of the observed percent catch at age in 1999 with the percent catch at age from earlier time periods.

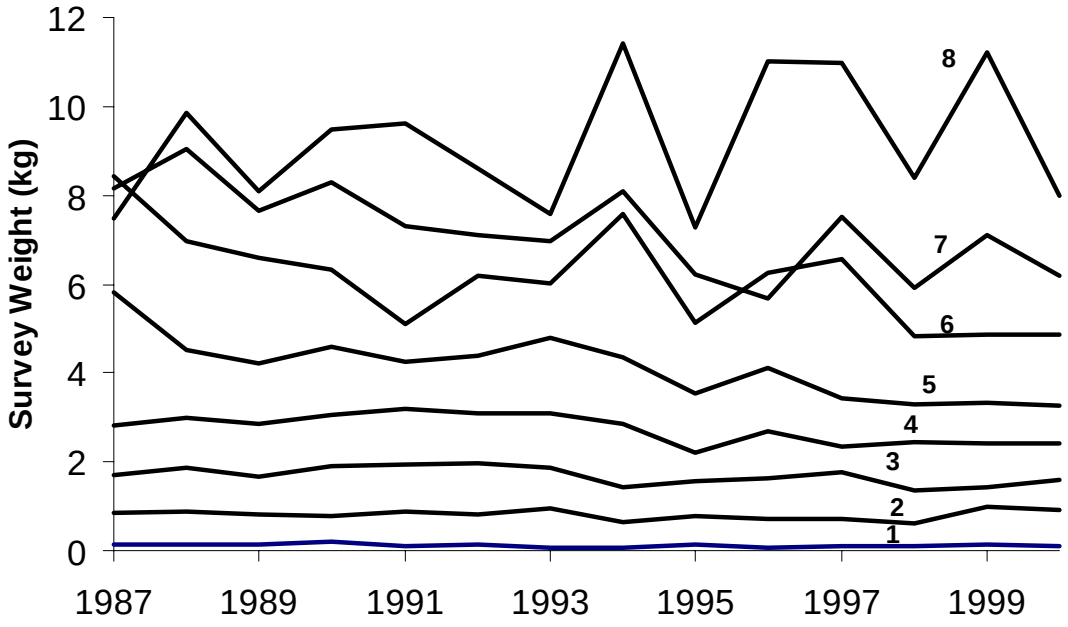


Figure 8. Beginning of year mean weight (kg) at age for cod derived from Canadian research surveys.

Cod Density Distribution (kg/tow), 1994-99 (shaded)
and for 2000 (red squares), from Canadian Research Survey

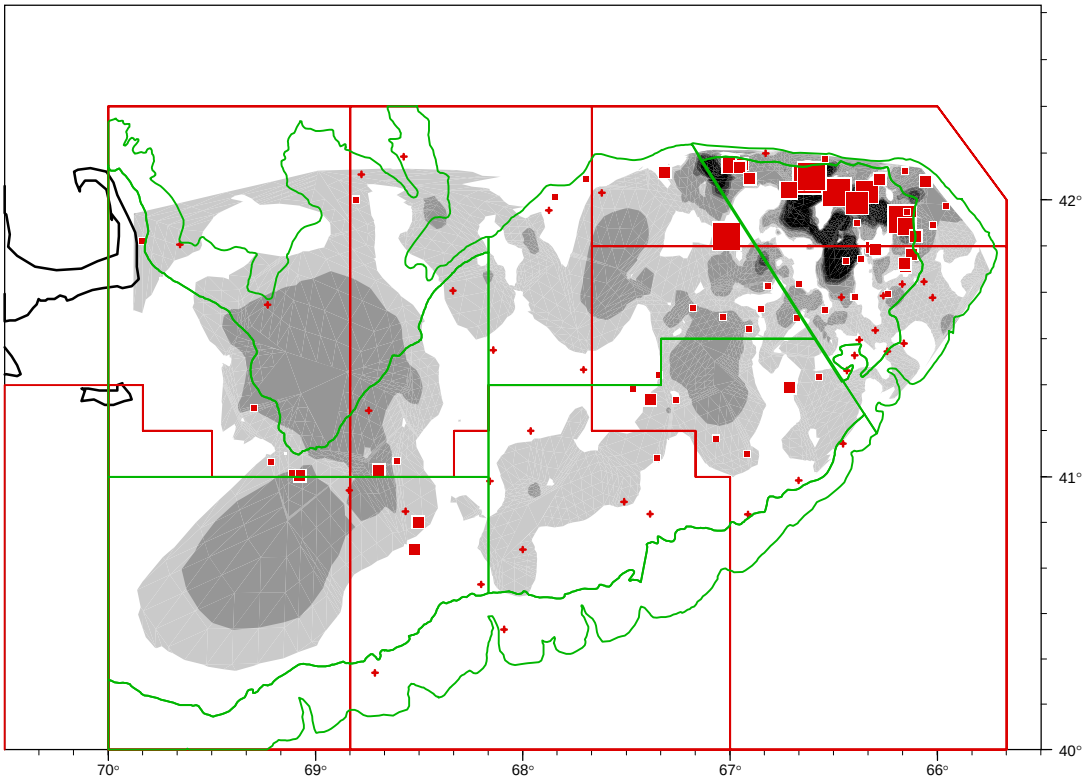


Figure 9. Comparison of cod per standard tow (kg/tow) from the 2000 Canadian research survey (box symbol) with average density gradient distribution for 1994-99.

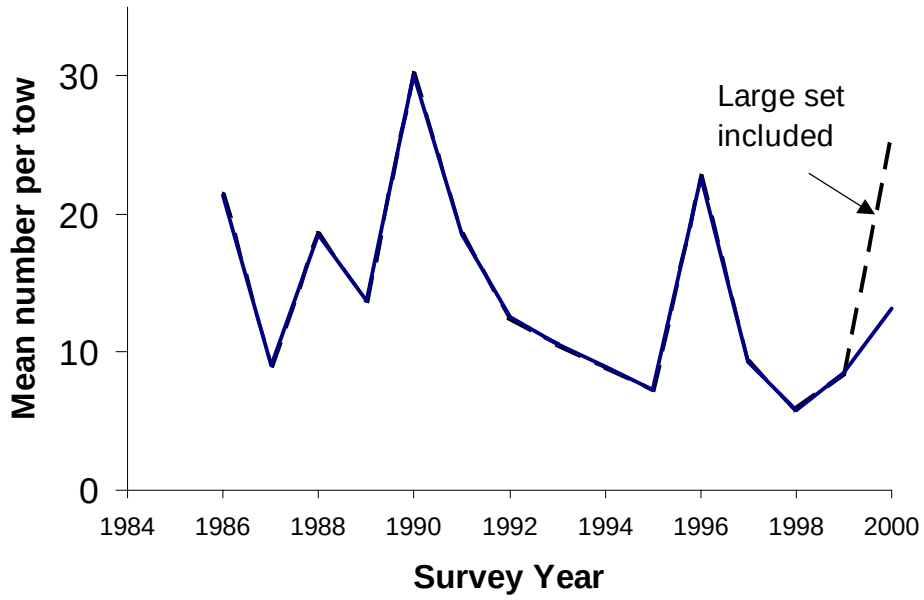


Figure 10. DFO spring survey index for 1986-2000 with a comparison of the 2000 index derived with and without a single large set.

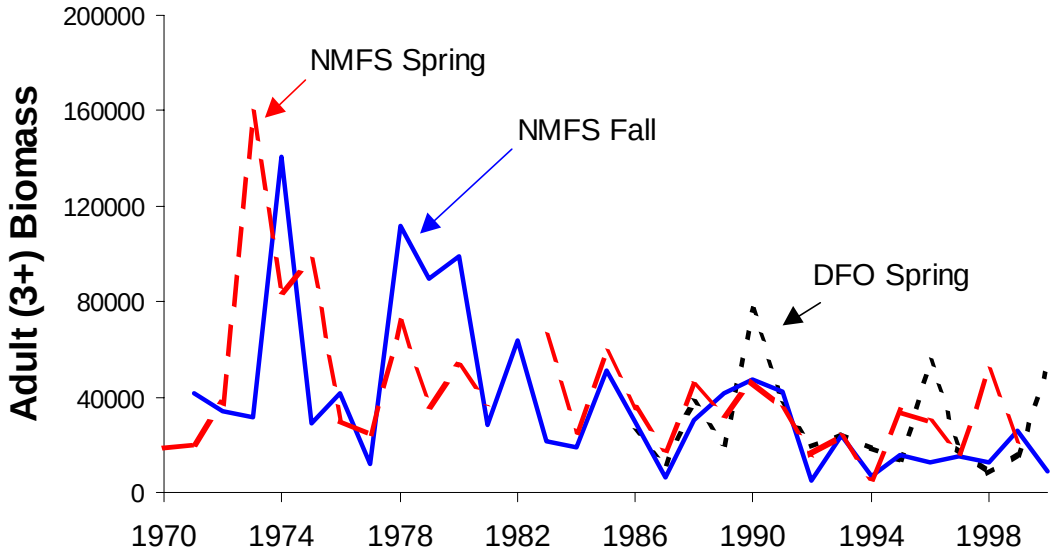


Figure 11. Estimates of adult biomass (t) indices for 5Zj,m cod from the DFO spring and NMFS spring and fall surveys in 5Zj,m

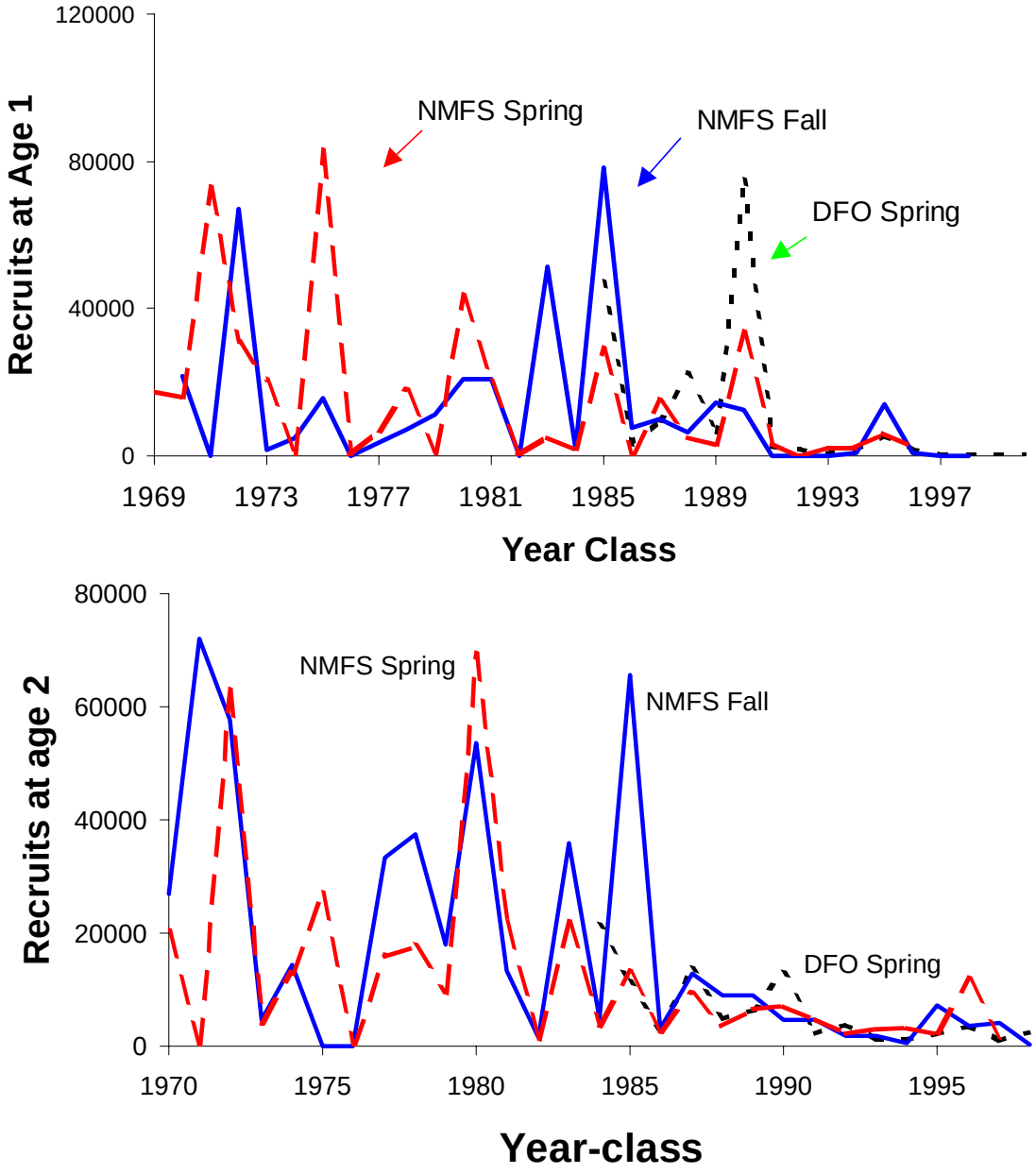


Figure 12. Estimates of recruitment at age 1 and at age 2 for 5Zj,m cod from the DFO spring and NMFS spring and fall surveys in 5Zj,m

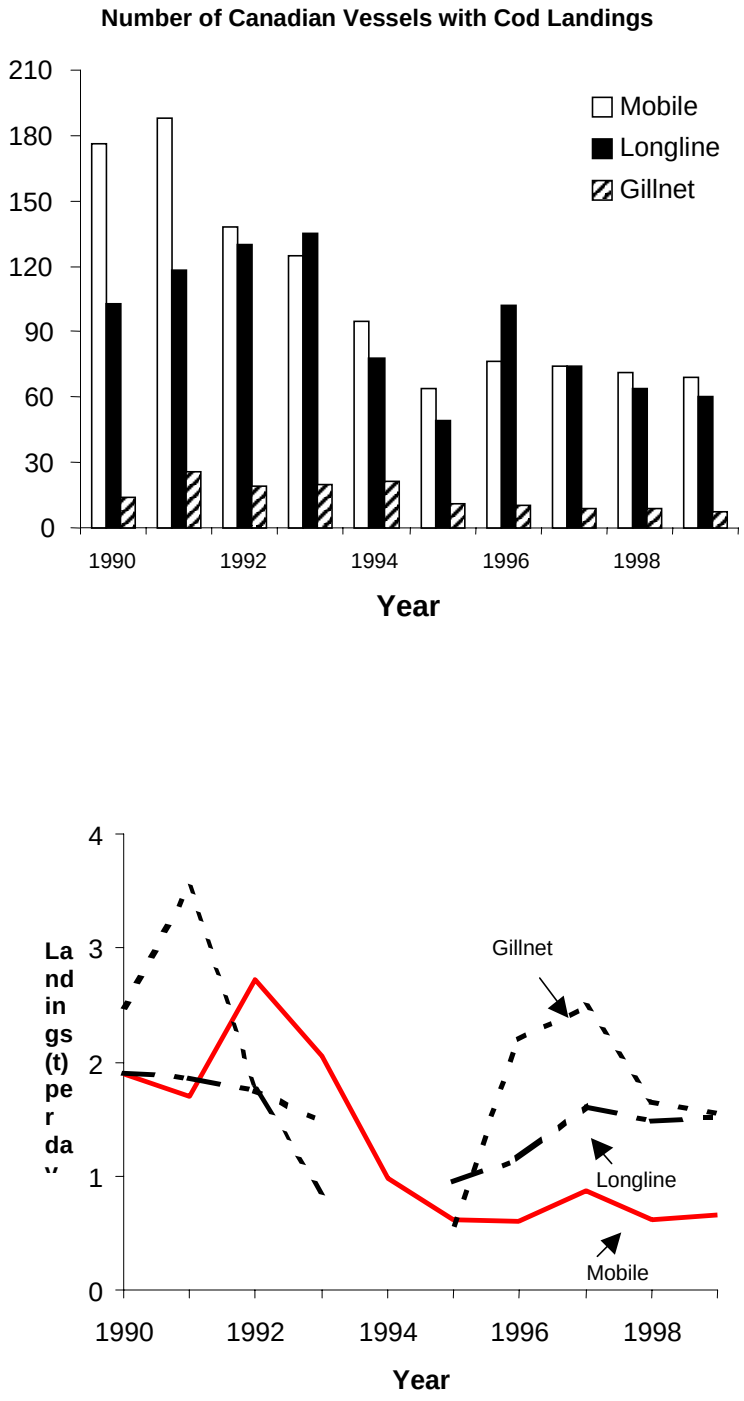


Figure 13. Number of Canadian vessels (upper panel) and landings per day fished (lower panel) by gear type for trips with >500kg cod landings. Effort data for 1994 fixed gear not available.

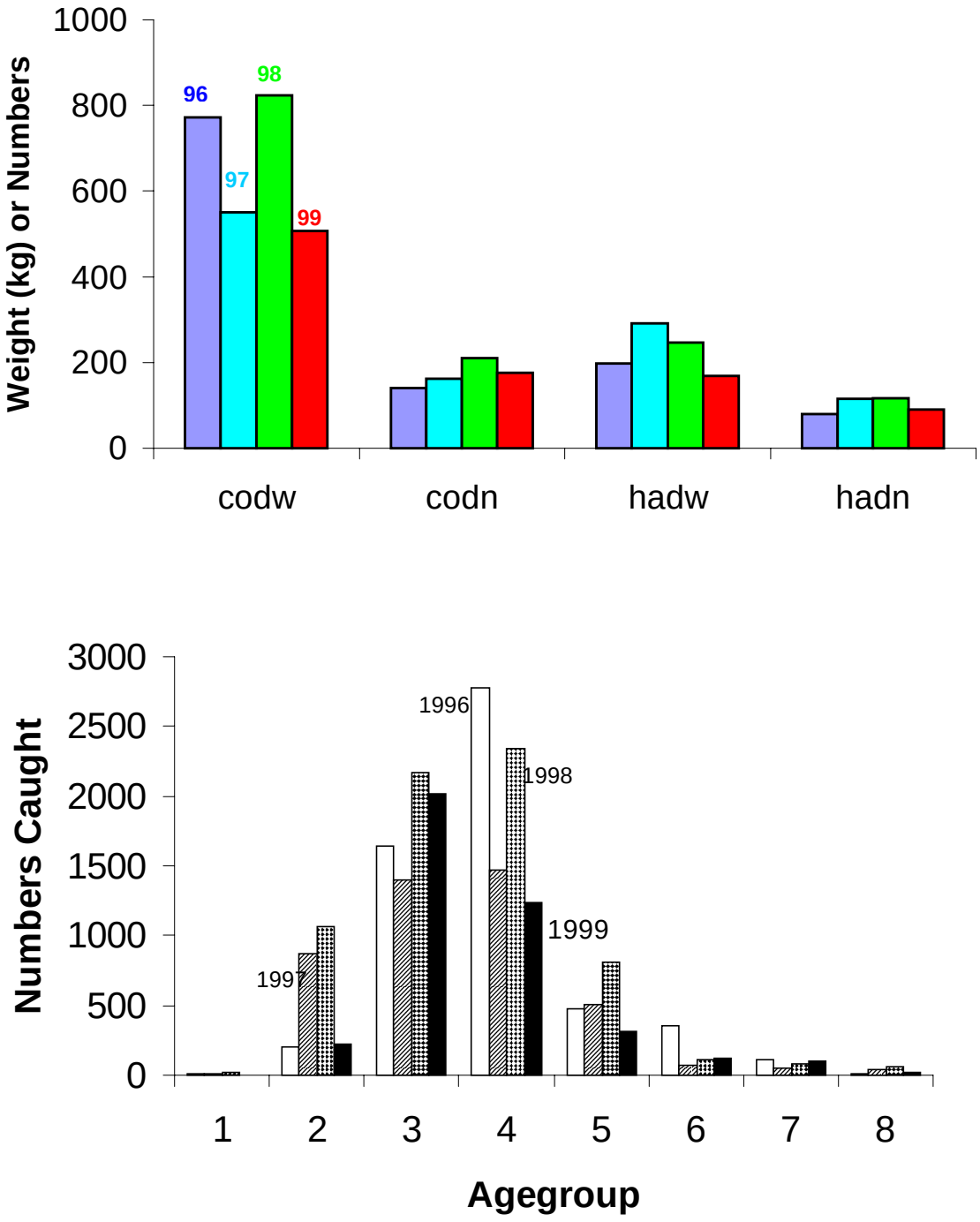


Figure 14. Results of Canadian longline industry survey. Upper panel shows the annual average weight (codw, hadw) or number (codn, hadn) for cod and haddock caught per 1500 hooks. Lower panel shows the total numbers of cod caught by year and agegroup.

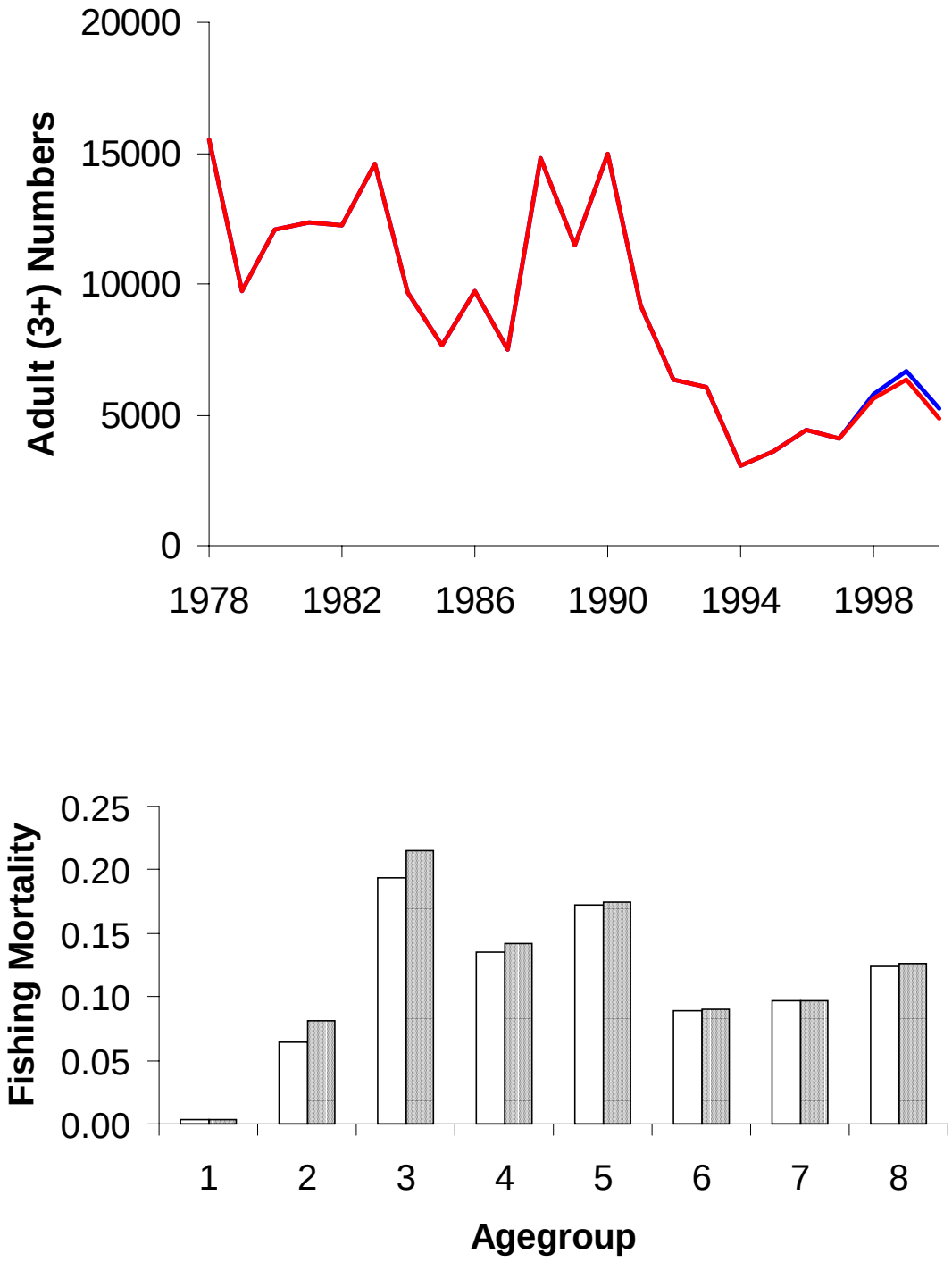


Figure 15.Comparison of ADAPT population estimates derived with (pattern bar) and without (open bar) large cod set in the DFO 2000 research survey index

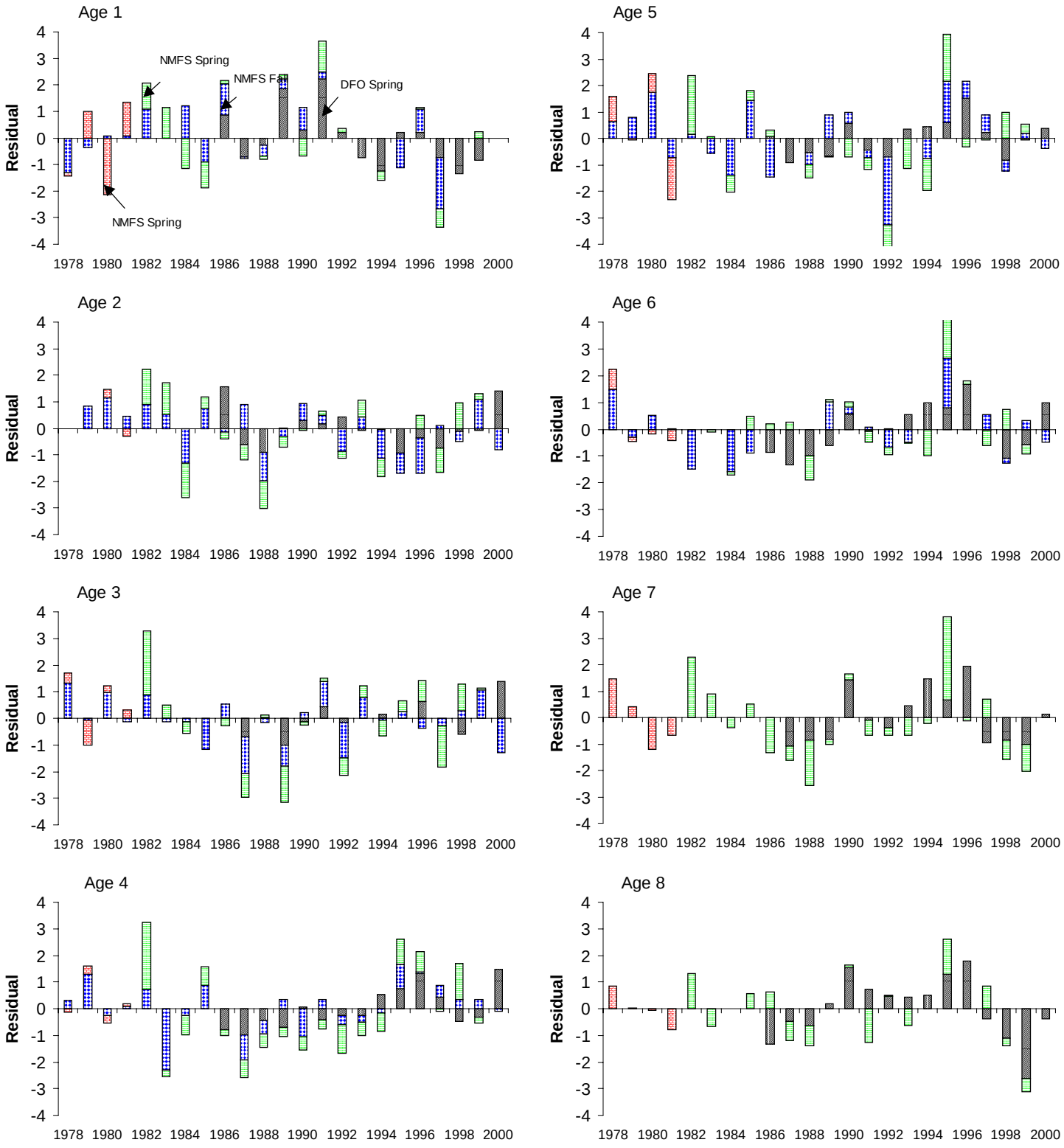


Figure 16. Standardized residuals at age from ADAPT for the DFO spring 1986-2000), NMFS fall (1977-99), NMFS spring (1978-81) and NMFS spring (1982-99) research indices.

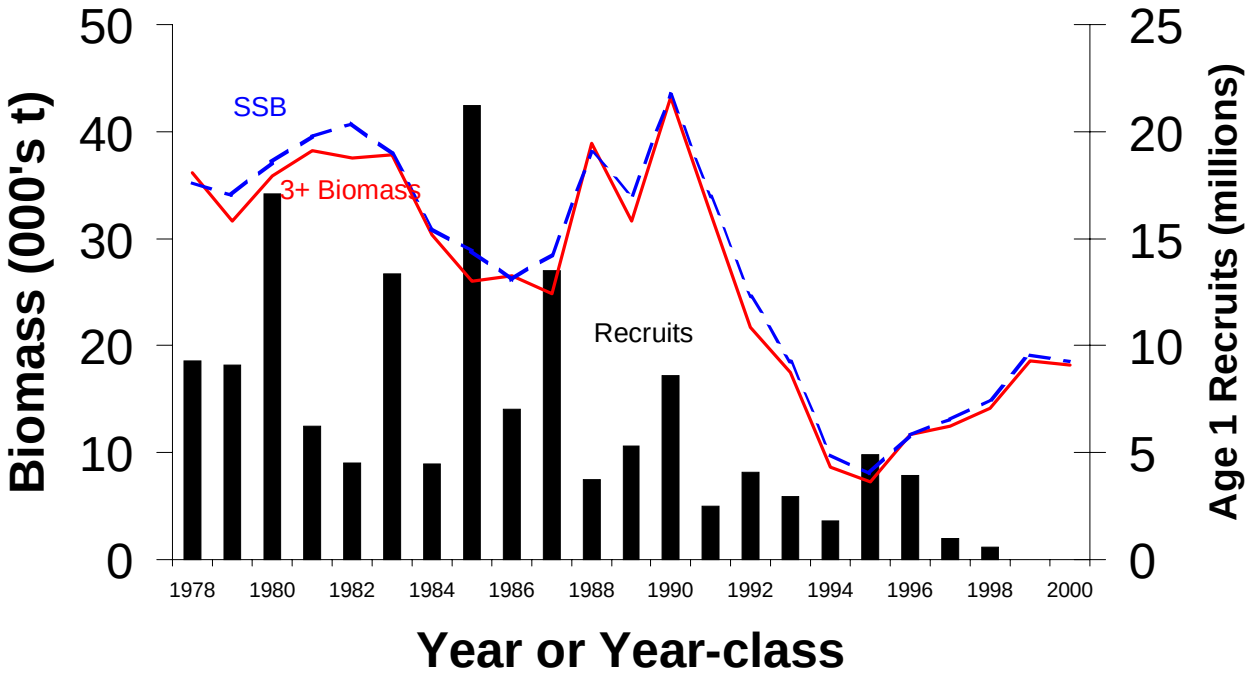


Figure17. Spawning stock (SSB), 3+ biomass and recruits at age one from ADAPT for 5Zj,m cod.

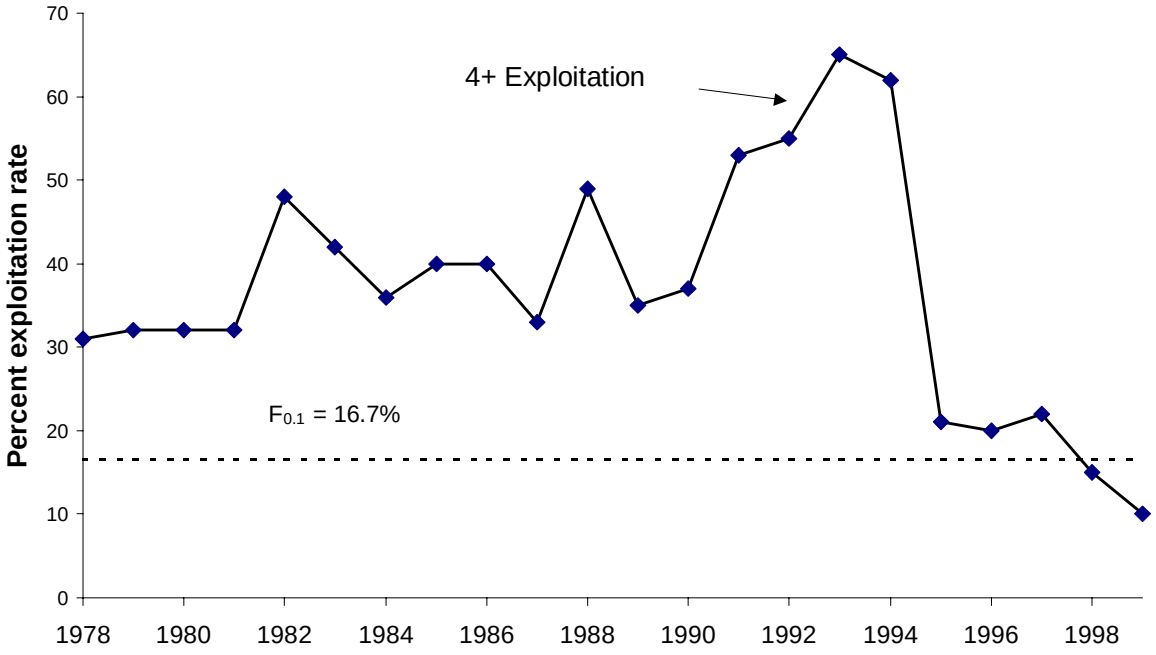


Figure 18. Percent exploitation rate at ages 4+ for 5Zj,m cod derived from ADAPT

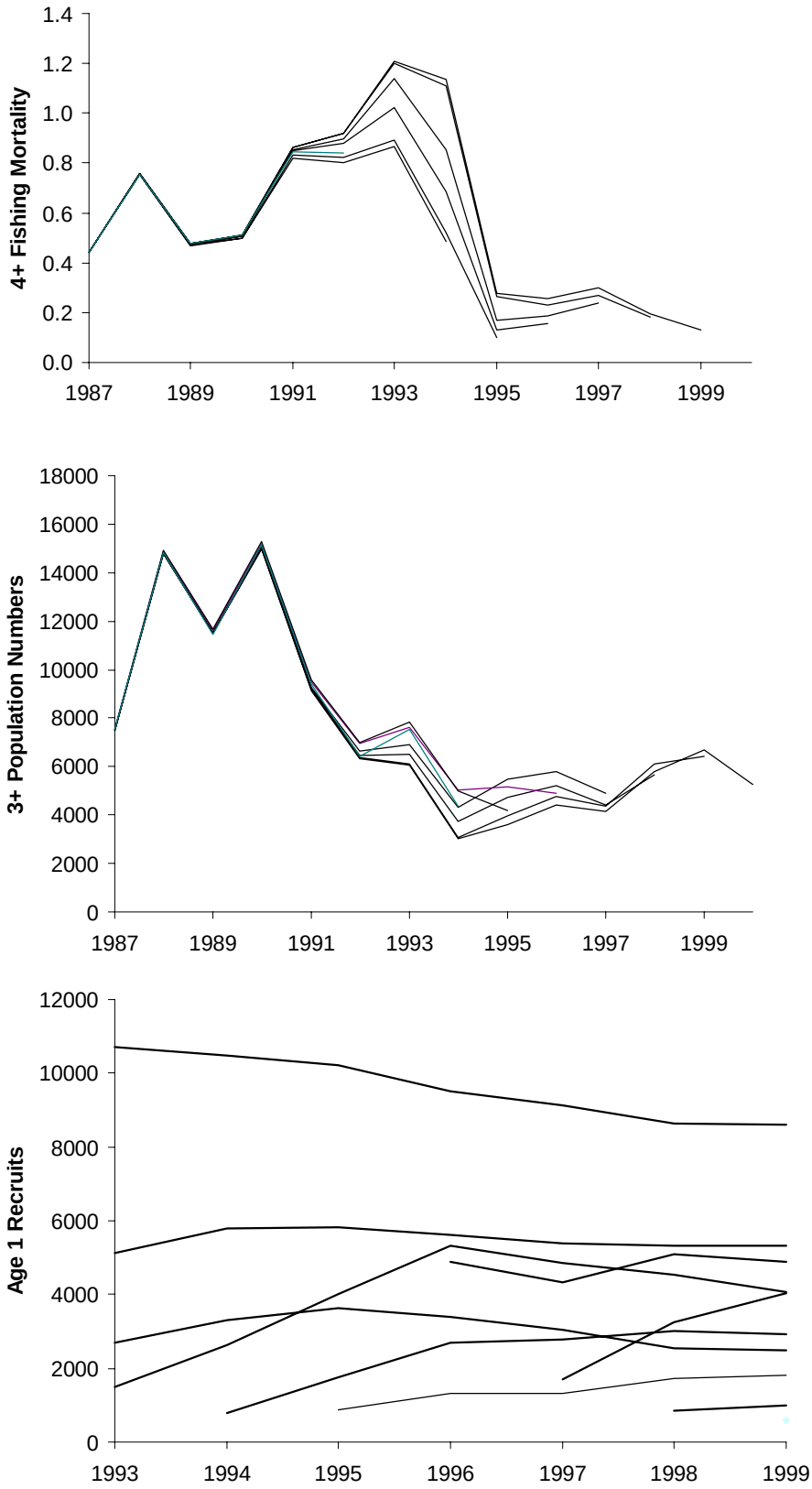


Figure 19. Retrospective pattern in fishing mortality (upper panel), population abundance (middle panel) and recruitment (lower panel) for 5Zj,m cod from ADAPT

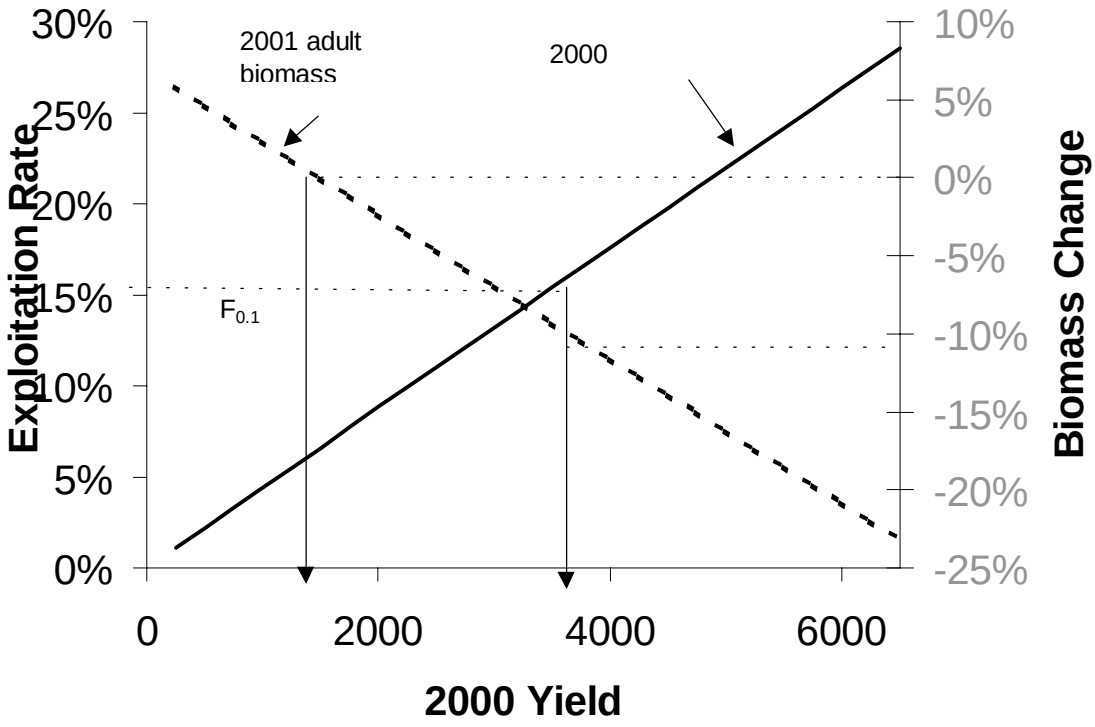


Figure 20. Probability of exceeding $F_{0.1}$ and of the 2001 beginning of year biomass being less than in 2000 at different levels of yield in 2000.

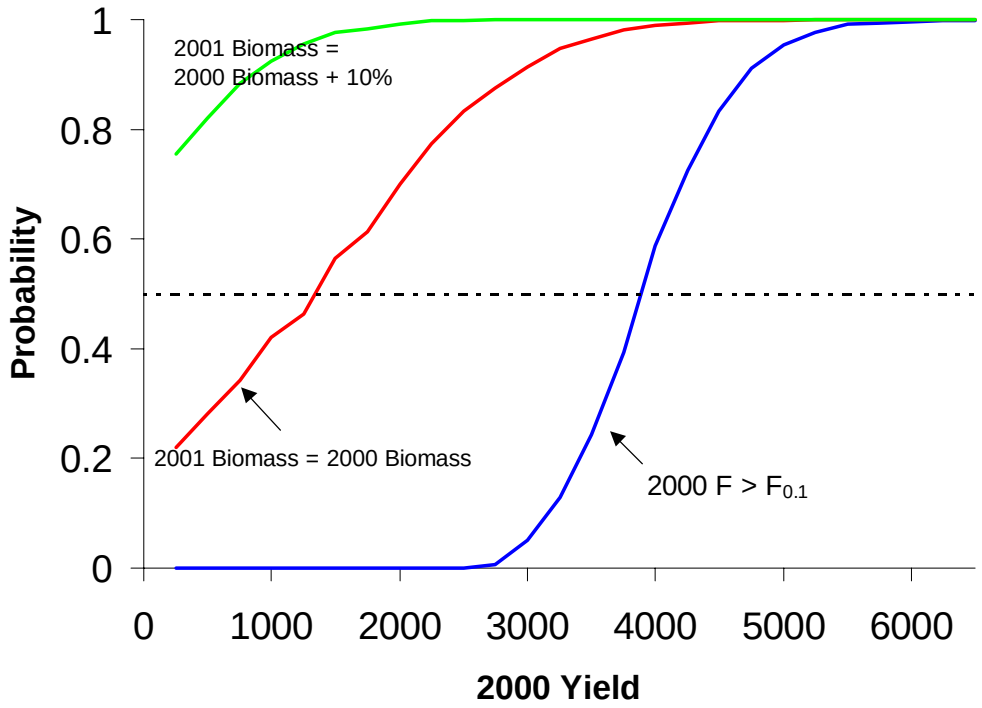


Figure 21. Probability of projected change in 5Zj,m cod spawning stock biomass from 2000 to 2001 at different yields in 2000.

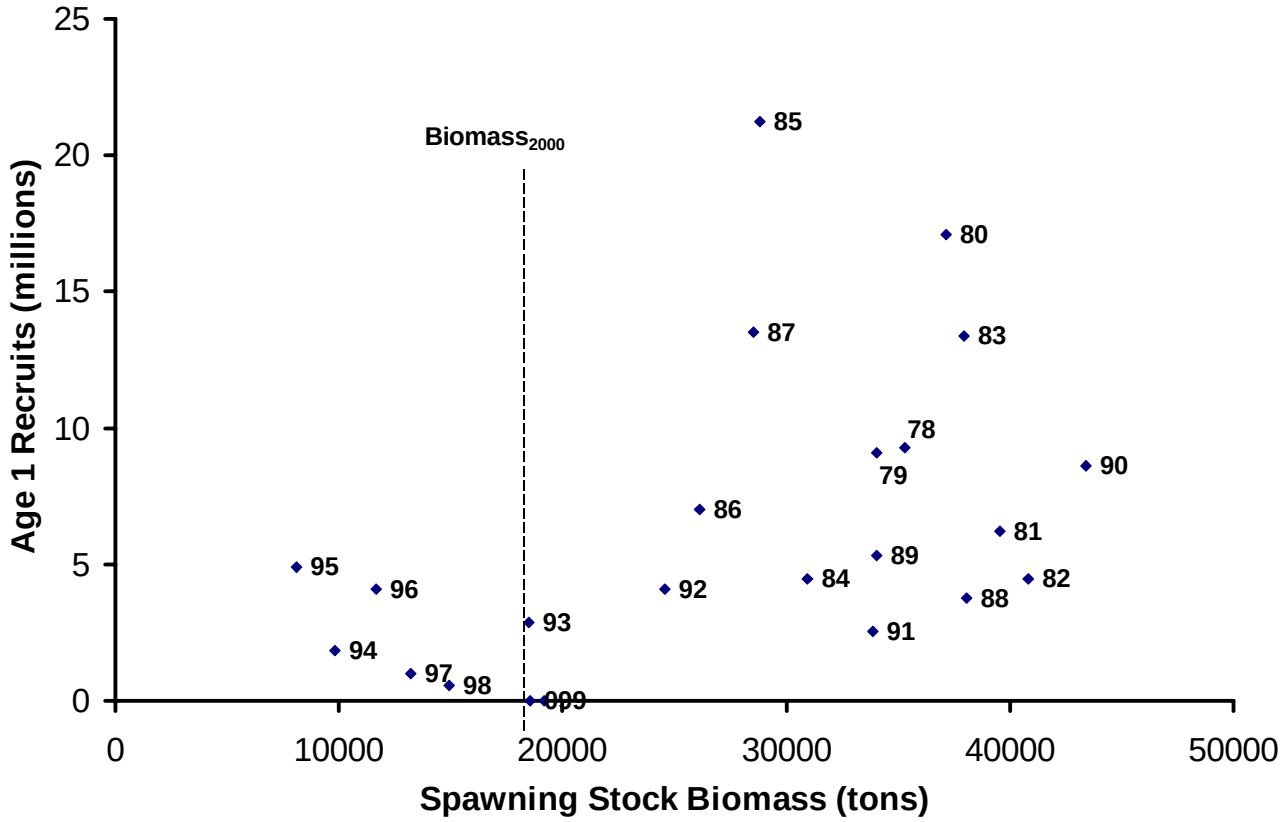


Figure 22. Comparison of recruits at age 1 and spawning stock biomass for 5Zj,m cod.

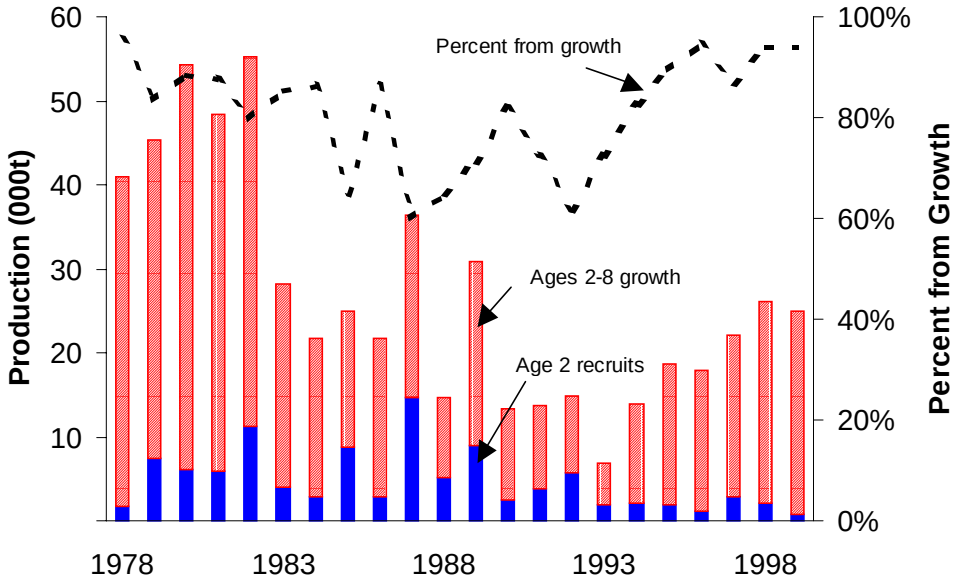


Figure 23. Comparison of stock production derived from growth and from recruitment for 5Zj,m cod.