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 2000/139 | **Document de recherche 2000/139**

Assessment of Cod in Division 4X in 2000

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ISSN 1480-4883
Ottawa, 2000

ABSTRACT

- Landings and TAC have declined throughout the 1990s, and were the lowest on record in 1999.
- Exploitation rate declined from the high of 60% in 1992 to about 23% in 1999.
- Age 4+ biomass has remained stable at a low level since 1996.
- The recruiting 1998 year-class is the strongest since 1992, initial indications are that the 1999 year-class is at least as large.
- With removals of 6,000t in 2001, there is a 50% chance of a 20% increase in the 4+ biomass between 2001 and 2002, due to improved recruitment.
- The 1999 year-class must be at least as strong as the 1998 to approach the growth implied by the three-year rebuilding plan.

RÉSUMÉ

- Les débarquements et les TAC ont diminué tout au long des années 90, atteignant les niveaux enregistrés les plus faibles en 1999.
- Le taux d'exploitation a chuté d'un pic de 60 % en 1992 à un creux d'environ 23 % en 1999.
- La biomasse de morue de 4 ans et plus s'est maintenue au faible niveau observé depuis 1996.
- La classe d'âge 1998 en recrutement est la plus abondante depuis 1992. Il y a lieu de croire que la classe d'âge 1999 est au moins aussi abondante.
- En raison de ponctions de 6 000 t en 2001, les chances se chiffrent à 50 % que la biomasse de morue de 4 ans et plus augmentera par 20 % entre 2001 et 2002 à cause d'un meilleur recrutement.
- La classe d'âge 1999 doit être aussi abondante que celle de 1998 pour s'approcher du niveau d'abondance supposé dans le plan triennal de rétablissement.

BRIEF HISTORY OF FISHERY AND ASSESSMENT

Prior to 1963, the cod fishery in Division 4X (including the Canadian portion of Division 5Y; Fig. 1) was primarily an inshore fishery. The majority of fishing was done by Canadians, handlining and longlining from small vessels. Between 1957 and 1962, 82-87% of landings were 'inshore', with the remainder split between Canadian and U.S. vessels fishing Browns and LaHave banks (Halliday, 1971). Landings showed a slow decline between 1948 and 1958 from 20,000t to 12,000t (Fig. 2). This decline was attributed primarily to decreases in effort (as fishing was directed more for haddock) but also to declining abundance (Beverton and Hodder, 1962). Foreign and Canadian otter trawlers (OT) began fishing for cod on Browns and LaHave banks in 1962. Due to the increased exploitation on the offshore banks, almost exclusively by OT, landings increased rapidly after 1962, to a maximum of about 35,500t in 1968.

In 1970, landings dropped by 10,000t. This reduction came almost entirely from Canadian OT landings, while landings by longline (LL) and handline (HL) were largely unaffected. There was no quota for cod in 4X at this time; however, due to the mixed species nature of the groundfish fishery in this area, management measures implemented to regulate fishing on one species inevitably influenced others. The large reduction in cod landings in 1970 has been linked to reductions in fishing effort due to the institution of quotas for haddock and the closure of Brown's Bank to fishing for March and April, both of which occurred in 1970.

The 4X area was recognized as including a number of separate cod spawning stocks whose distributional boundaries were unclear, thus, it was felt to be inappropriate to assess it as a unit stock. Assessments were conducted for the offshore (primarily Browns and LaHave banks) which was thought to be a discrete stock, and total allowable catch (TAC) was first established for this area in 1975. These TAC's, however, are thought to have had limited impact on landings due to misreporting to the inshore area, where no TAC was in place (Gagne et al., 1983).

Landings throughout much of the 70's remained in the region of 20-24,000t, increasing to 31,000t by 1980. As a result of this rapid increase in landings to near historically high levels, a TAC was imposed for 4X cod for the first time in 1982. The TAC was set at 30,000t (a level selected to prevent landings from exceeding the maximum landings observed in the early 1980's), and held at this level for 4 years. It had little influence on the landings as a whole, which declined from 32,000t to 21,000t between 1982 and 1985. Aside from the <65ft draggers, no quota group met its allocation from 1983 to 1985 (Campana and Simon, 1986).

The treatment of cod in 4X and 5Yb as a single stock for assessment purposes commenced in 1985. This step was taken partly in response to changes in fishing practices, and partly because mixing between inshore and offshore stocks appeared to be more extensive than had previously been thought. It was not considered possible to separate landings reliably between inshore and offshore areas. This was not a requirement for logbook records, and the increasing range of much of the fleet made the

apportioning of landings to inshore or offshore on the basis of tonnage class unreliable. Furthermore, the results from tagging of cod on Browns Bank in spring suggested there may be mixing between inshore and offshore stocks, as well as among inshore spawning groups. It was felt that an assessment which grouped all of 4X would be acceptable due to the mixing occurring among spawning groups, and the mixed nature of the fishery (Campana and Simon, 1986).

With the imposition of more stringent quotas for 4X cod in 1986, there were suggestions that unreported landings and misreporting by species had become serious problems, particularly in 1987 and 1988 (Campana and Simon, 1987; Campana and Hamel, 1990). Reported landings since 1989 are considered more accurate due to increased enforcement, and the institution of mandatory weigh-outs in 1990 (Campana and Hamel, 1992; Gavaris, 1993).

Reported landings remained around 20,000t from 1985-1989, then increased to 28,000t in 1991. Landings and TAC declined through the 1990s to a low of 6,200t in 1999. The recent reductions in landings are a reflection of the TAC, which declined from 26,000t in 1992 to 7,000t in 1999. The 2000 quota is 6,000t, 4,100t of which (66%) were landed by October 18.

More stringent management measures and quota regulations have resulted in a number of changes in fishing patterns. Late starts to fishing, and the need to save cod quota for later in the year to ensure they could continue fishing for other species, has led to a reduction in the proportion of catch coming in the first quarter after 1992. The small dragger fleet in particular now spreads its catch throughout the year.

SPAWNING AREAS FOR COD IN NAFO DIVISION 4X

Spawning is distributed broadly through the area, both geographically and seasonally. Spawning occurs in the fall (October-December) along the coast of Nova Scotia. This spawning has been described most thoroughly for Halifax Harbour and around Sambro Head to St. Margarets Bay (McKenzie, 1940). Fish aggregating in the deeper water around Sambro Head were the target of a seasonal gill net fishery, which landed roughly 1,000t of cod annually, and for a period in the 80's were also targeted by large draggers in the winter fishery. This fishery began to decline in the early 1980's, and has now all but disappeared. Fish in spawning state have been caught in this area in recent years, and juvenile cod (3-5cm) were captured with a beach seine in Halifax Harbour in spring of 1999 and 2000. Fishermen also continue to catch ripe fish in the Shelburne area in the fall.

Spawning occurs in the spring, primarily on Brown's Bank, but also in other areas. Ripe fish were caught in spring RV surveys conducted in the early 1980's in the Bay of Fundy and around Browns Bank. Fishermen have identified the waters off Digby Neck and Grand Manan as areas where they encounter spawning fish in the spring.

Egg and larval studies support these observations, showing eggs and larvae distributed along the coast of Nova Scotia and into the Bay of Fundy in fall, and on Brown's Bank and in the Bay of Fundy in spring (Neilson and Perley, 1996). The presence of both spring and fall spawners results in a bimodal length frequency for cod at age 1 in the RV and ITQ surveys.

The degree to which fish that spawn in different areas in 4X mix during the year is not clear. Fish tagged in inshore areas show little dispersal from the tagging area, and those tagged in the Bay of Fundy tend to be returned from inside the bay. Fish tagged on Browns Bank in spring, however, disperse widely through the 4X area, with the majority of tags recaptured in 4Xp and further west. Similarly, some fished tagged on Georges Bank are recaptured in 4X. The proportion of fish tagged on Georges Bank which move into 4X has generally been considered small, however recent analyses bring this into question (Hunt et al 1999). Further work on stock structure in this region is required to resolve these issue.

DESCRIPTION OF THE FISHERY

The hook and line fishery accounts for roughly half of the landings from Div. 4X, with about 10% more coming from the gill net fishery. The ITQ dragger fleet accounts for the bulk of the remainder, with the EA and TVRP vessels accounting for less than 10% of the landings (Table 1).

The fishery in 4X takes place year round. Landings generally peak in June and July, however in recent years landings have been distributed more evenly throughout the year (Table 2). The proportion of landings from the winter-spring fishery declined since 1992 (Fig. 3). Late starts in the fixed gear fishery since 1993, along with changes in seasonal fishing patterns by small draggers following the inception of ITQ's have reduced landings early in the year (Fig. 4). Catches in the first quarter generally included a higher proportion of old fish. This shift in fishing patterns has likely reduced the degree of recruitment of older fish in the fishery. Furthermore, since 1993, the proportion of older fish in first quarter catches is lower than the remainder of the year. The declining proportion of cod in the quota mix has led to changes in fishing patterns. As a result, fishermen are directing for haddock and catching small cod as bycatch.

The distribution of landings (Table 3) has also shifted to the west in recent years, with landings from 4Xmno declining to a greater degree than in other areas. In 1997, the proportion of landings coming from the Bay of Fundy was the highest ever, at 48% (Fig 5). There has been little change in the proportion of landings from the hook and line fishery in the Bay of Fundy. The gillnet fishery, however, has switched from a predominantly Scotian Shelf fishery to a fishery split almost equally between the Scotian Shelf and Bay of Fundy (Fig. 6a). Similarly, the otter trawl fishery until recently was primarily on the Shelf in the spring and winter, moving into the Bay of Fundy in the summer. This fishery was conducted primarily in the Bay of Fundy throughout the year from 1993-1997, resulting in an unusually high proportion of landings coming from the Bay (Fig. 6b). Since 1998 the winter fishery

has again focused primarily on the Shelf, and the proportion of landings coming from Fundy has declined.

Fishermen from around 4X reported mixed success in the cod fishery in 1998. Representatives from both the otter trawl and longline fleets reported that fishing was generally poor for cod east of Browns Bank. In coastal areas throughout 4X fishing was poor in 1998, particularly in the Bay of Fundy, with some quota groups landing only a small percentage of their quota. Fish distribution was unusual in 1998, with little dogfish or hake seen in inshore areas as well. Fixed gear groups fishing further offshore and in deeper water, however, reported good fishing.

In 1999, most fixed gear groups reported improved fishing. The inshore fishery was better than in the past 3 or 4 years, although it continued to be poor in coastal areas in the Bay of Fundy, and the fall gillnet fishery in eastern 4X. Despite this, 700t of the 7,900t quota for the 15 month 1999 fishery went uncaught (Table 4). Shortfalls in landings of cod by small draggers reflect their success in targeting haddock in the winter fishery. The large dragger fleet often leave some quota uncaught, and may have held some cod in reserve for bycatch for the pollock fishery. Almost half of the fixed gear shortfall was quota held by SWNB quota group. Their fishery was poor in 1999, and they were unwilling to have their uncaught quota taken from another area. The remaining 200t of cod quota left by the fixed gear fleet was split amongst a number of groups which did not land their full quota for any species. This may be a result of some quota groups leaving too much quota for the end of the year. Furthermore, many large longliners are fishing with individual quotas; some individuals will have landed all their cod, and others all their haddock, resulting in some of each species being left in the water.

Landings of cod in the first quarter of 2000 were relatively high. This increase was due to fishing directed primarily for haddock along the Shelf edge between LaHave and Bacarro Banks. Fishing has been reported to be good in most areas of 4X, except in the Digby neck hook and line fishery. 69% of the cod quota for 2000 has been landed as of Oct. 18, including 84% of the fixed gear quota. Gillnetters in the Bay of Fundy have reported that cod abundance on their usual fishing grounds is the highest they have ever seen. Fishing was improved in the Saint John spring fishery, although still poorer than usual. Fixed gear fishermen in SW Nova Scotia were able to find an appropriate mix of cod and haddock to satisfy quota mix, and generally caught their fish in fewer trips in 2000.

Effort by the otter trawl and the tonnage class (TC) 2 and 3 longline and gillnet fleets declined after the early 1990's, although effort directed for cod increased slightly in 1996 and 1997(Clark et al, 1998). The number of fishing trips made by TC1 fixed gear vessels also declined by about 50% between 1992 and 1996; however, detailed information on the effort (days fished) is only available for smaller TC1 vessels since 1996.

The number of vessels actively engaged in the fishery has dropped since 1996 for all gear types (Table 5), with a decline of over 50% for handliners. Effort for all fixed gear vessels declined in 1998, particularly for handliners (Table 6). In 1999, effort declined further, and appears likely to decline again for gillnet and handline vessels in 2000. Otter

trawl effort has declined slightly since 1997 (Fig. 7). Trips where cod is the main species caught currently account for a very low proportion of total effort. Total effort remains substantially lower than seen in the early 1990's, however fishing mortality is considered to have been unsustainable at that time.

Catch rates have increased to the highest level seen in the 5 years examined for handline and gillnet in 2000 (Fig. 8a,c). The increase is particularly marked for gillneters, whose catch per day has doubled since 1998. This is in keeping with the observations by fixed gear fishermen of improved success in the fishery in 2000. Longline catch rates show no marked pattern in the past 5 years (Fig. 8b). Fishermen maintain this is a result of fishing plans that have included trip limits in recent years, and the shift to target haddock rather than cod. Catch rates for mobile gear declined annually since 1996, increasing again in 2000 (Fig 8d). Fishermen have indicated this is not indicative of abundance, since they have been avoiding cod as the cod quota has dropped and the haddock quota increased. They maintain that cod is primarily used as bycatch when fishing for other species. The proportion of cod caught by OT in trips where cod was the main species caught dropped from 59% of landings in 1996 to 34% in 1999.

CATCH AND WEIGHT AT AGE

Fishery Samples

The 1999 catch at age was based on 37 samples that included otoliths, and 101 additional length frequency samples (Table 7a,b). Some cells were combined in the construction of length frequencies due to a lack of data. In the first half of 2000, 25 samples which include otoliths, and an additional 64 length frequency samples are available (Tables 7c,d). Only selected samples have yet been aged for 2000.

Samples were aggregated by area, quarter and gear type. Aggregation by area was done to account for growth differences between the Bay of Fundy (4Xqrs5Yb) and southwest Scotian Shelf (4Xmnop). Variability in growth rates are still found within these two areas, with cod in 4Xm in summer differing from 4Xno, and cod caught in the deep water in the south and west of 4Xp growing faster than on Browns Bank and the rest of the Shelf. As a result of shifts in the distribution of landings in 4Xp away from Browns Bank and into deeper water, separate age-length keys were derived for this area in 1999 and the first half of 2000. Similarly, with sampling available for 4Xm, separate age-length keys were derived for that area.

The recommendation that age-length keys from adjacent years be used when no samples are available for a gear-quarter combination was considered. Although length at age is quite consistent for cod in 4X, there is variability in year-class strength which would lead to misallocation of lengths to year-classes if age-length keys are not used from the appropriate year. Samples from adjacent quarters, or from other gear types in the same quarter, however show very similar age at length (Fig. 9). Thus, it was decided

to continue grouping age-length keys amongst gear in the same quarter, and substituting from adjacent quarters where necessary.

The seasonal length-weight parameters used in deriving catch numbers at age (Table 7b,d) were those from Campana and Hamel (1992). These parameters were calculated as seasonal averages over the years for which seasonal survey information were available, and have been used since 1985 when seasonal surveys in 4X were discontinued.

Inter-reader age comparison tests were conducted using commercial samples from 1996 - 1998. Agreement was satisfactory (89%; Appendix I). Additional testing is planned using otoliths from earlier years to include a greater range of ages in the comparisons.

Landings

Landings reported from 4Xu (unspecified area) were apportioned to Bay of Fundy and Scotian Shelf for each statistical district according to known area landings by gear type and tonnage class for that statistical district and quarter. Landings reported from 5Y from 1983 to 1986 for each statistical district were divided between Scotian Shelf and Bay of Fundy according to the same protocol. Misreporting to 5Y from 4X was identified as a problem in these years in past 4X cod assessments (Campana and Simon, 1987, 1988).

Fishery length frequencies from 1999 peaked at 61cm in Fundy and at 55cm on the Shelf (Fig. 10a,b). Cod caught on gillnet were larger, but all other gear-types had similar length ranges. Modal length is slightly higher in 2000, and the length frequencies have a less pronounced peak, than in 1999 (Fig 11a,b). The length frequency for longline on the Shelf is markedly different from other gears; their winter fishery, which was directed at haddock, landed primarily small cod.

A comparison of lengths at age for 1999 with a number of other years from 1948 to 1997 shows that the lengths seen in the fishery recently differ little from earlier years (Fig 12). There are fewer small fish in recent years, and fewer fish over 100cm in 1999 than in most earlier years, but the differences among years are quite subtle.

In 1999, landings by hook and line were distributed among ages 3-7 (Table 8a). Gillnet catches continued to show the 1992 year-class as a high proportion of their catch, while the 1996 year-class was dominant in otter trawl catches (Table 8a). All ages up to 7 in 1999 (Fig. 13) appear to be well represented when compared to the long-term mean. As the 1992 year-class moved through the fishery, the range of ages in the landings continued to increase (Table 9). In the first half of 2000, however, the 1992 year-class (age 8) was almost absent, and over half of otter trawl and gillnet catch came from the 1996 year-class (Table 8b), which made up a higher proportion of landings than average (Fig. 14). The 1992 year-class, along with older ages, were a much lower proportion of the landings than projected in both 1999 (Fig. 15) and the first half of 2000 (Fig. 16).

The shortfall in 1999 was spread among a number of ages, while in 2000 it is covered primarily by the 1996 cohort.

Weights at age for commercial landings from both the Bay of Fundy and the Scotian Shelf remain higher than average in 1999 (Table 10).

Commercial catch-at-age data from 1983 to 2000 were used in this assessment. While previous assessments have included landings data from before 1983 (Campana and Hamel, 1992), inconsistencies in F's among cohorts within a year, variation in the weights at age, and unusual patterns in catch curves led to the exclusion of the catch at age for the period 1948-1970 in the 1993 assessment (Gavaris, 1993). These data contain useful information and more detailed examination is warranted, however, they would have no impact on estimation of current population. Past analyses (Campana and Simon, 1987) indicate that fishable biomass from the period 1948 to 1980 generally lay in the range of 40,000-60,000t, with landings averaging 20,000t annually through most of that period.

ABUNDANCE INDICES

Annual stratified random surveys have been conducted in Division 4X during the summer since 1970. From 1970 to 1981 surveys were conducted with the RV *A. T. Cameron*, a side trawler, using a Yankee 36 bottom trawl. The gear was changed to a Western IIA bottom trawl in 1982, when the research vessel was replaced with the RV *Lady Hammond*, a stern trawler. The current research vessel, the RV *Alfred Needler*, which uses the Western IIA bottom trawl, replaced the RV *Lady Hammond* in 1983.

The ITQ survey, which has been conducted annually since 1995, employs a fixed station design. Three vessels, using balloon trawls with a 1/2in. codend liner and rockhopper ground gear are involved in the survey. In 1996, the second year in which the ITQ survey was conducted, 48 additional stations were added, mostly in deep water near the shelf edge, and at the eastern end of 4X, giving a much more inclusive geographic coverage of the 4X area (Fig. 17). A further 10 stations around St. Margarets Bay were added in 1998. Two of the three vessels switched from a 300 to 280 balloon trawl in the second year. In the last assessment, the results from the 124 stations that had been occupied in all years, were used for indices of abundance. Including different numbers of stations each year in the analysis of a fixed station survey is problematic, since assumptions must be made about the stations not occupied in any given year. Following joint Working Group discussions, it was decided to drop 1995 as an index, due to the changes in gear, and the change in number of stations after the first year.

The 10 stations added in 1998 account for roughly 1% of the survey catch each year; thus, 1% was added to the survey catch for 1996 and 1997 to account for these stations.

Comparison of proportion of ITQ survey catch in stations added in 1998					
		1998	*1999*	*2000*	*Average*
Cod catch (Kg) in:	174 sets included since 1996	3150	2399	3203	
	10 sets added in 1998	26	22	41	
% added		0.8%	0.9%	1.3%	1.0%

The length distribution of fish in these ten stations peaks around 20 cm each year from 1998-2000, similar to that from the inshore stations farther west. In augmenting the length frequencies for 1996 and 1997, the length frequency for the inshore stations sampled in those years was used as a template, and the total catch at length for the survey was increased by an amount equivalent to 1% of the surveys catch by weight.

The trends apparent in the 124 stations are still seen when the larger data set is used (Fig. 18). Aside from the influence of the single station in 2000, the pattern in catch per tow is very similar, with 1996 highest, and 1999 lowest.

Distribution of catches and Catch per tow

Compared to previous years, few cod were seen on the Scotian Shelf side of the 2000 RV survey (Figure 19), with none caught on LaHave Bank, or east of Roseway. Catches were also low on Browns Bank. Catches in the Bay of Fundy were similar to recent years. Catches in the ITQ survey showed a pattern similar to other years with most of the large catches in the Bay of Fundy (Fig.20). Catches were higher in some stations along German Bank and towards Jordan Basin. The number of null sets, and the number of stations which account for 75% of the survey catch are similar to other years (Table 11). The number of sets which were greater or less than the median in 2000 were about equal, and in both cases were distributed throughout the survey area (Fig. 21).

The catch/tow increased slightly in the RV survey for 2000, but remains among the lowest in the series (Fig. 18). The catch per tow in the ITQ survey was up considerably from 1999. Much of the increase was due to a single large set (station 310) comprised largely of two year old fish (Table 12). When this station is excluded, the weight/tow in 2000 is similar to those for 1997 and 1998 (Fig. 18).

Length Frequencies

The length frequencies from the two surveys in 2000 were similar for the Bay of Fundy; both show high numbers of fish in the 40-50 cm range, and also at about 20cm. For the RV survey, numbers are below the long-term median at most larger sizes (Fig 22). This differs from 1997 and 1998, which showed high numbers of large fish. In the ITQ survey, numbers caught were similar to the mean up to about 70cm, and generally below the mean above that (Fig 23).

The length frequencies from the two surveys were dissimilar for the Shelf area. The RV survey caught more fish in the 0-group size range than ever before, but very few fish between 20 and 75cm (Fig 24). Numbers at 75cm and above were similar to long-term averages. Numbers in the 40-80 cm range were also lower than seen in the RV survey in 1997-1999. In the ITQ survey, numbers were above average for most lengths (Fig. 25).

Length at age and Condition

Mean length at age have shown no long term trends, increased for most ages in 2000 in both Fundy and Shelf regions and are somewhat above average for both areas (Fig. 26a,b). Condition for cod, measured as predicted weight at 50cm, shows little variability among years, and is currently about average (Fig 27).

Indices at Age

As in the 4X cod assessments since 1994, only data from years since 1983, when the RV *Alfred Needler* became the standard survey vessel were for the RV survey indices (Clark and Paul, 1999). The RV index in 2000 for age 2 (the 1998 yearclass) is the highest since 1994, which reflects the 1992 yc (Table 13a,b), but is still below average. Catches at age 0 in 1999 and age 1 in 2000 suggest the 1999 year-class may be at least as strong as the 1998. The indices for ages 3-7 are below average, while age 8 is at its highest since 1988.

Age disaggregated survey indices were calculated for the ITQ survey using age-length keys from the RV survey. Separate age-length keys are used for Fundy and the Shelf. These indices track the strong 1992 year-class, with numbers for each age peaking on this year-class (Table 14a,b). The ITQ survey in 1999 had high catches of both the 1998 and 1999 year-classes. These two cohorts again appear strong in 2000. The index at age 2 in 2000 is the highest in the series, whether or not the single large set is included. This corroborates the indication of improved recruitment for this year-class seen in the RV survey. As this year-class also appeared high at age 1 in the ITQ survey, it suggests age 1 may be a reliable indicator of recruitment.

ESTIMATION OF STOCK PARAMETERS

The possibility that combining the Bay of Fundy and Scotian Shelf, which show persistent growth differences, together in a single VPA may be distorting results has been investigated in the past. This was considered again this year. Separate VPA's showed some differences in recruitment patterns for the two areas, but when summed, provided estimates of population numbers very similar to those estimated from a single combined VPA. The age specific patterns in F and survey catchability, q, from the separate analyses seemed unreasonable, and were thought to reflect the fact that the Shelf area includes some landings for cod which clearly show the faster Fundy growth pattern. Cod caught in the winter outside of Browns Bank, and in the deep basins of 4Xp would more appropriately be included in the Fundy landings. This distinction has been difficult to make, due to the

resolution in landings data. Though differences in growth suggest different survey catchabilities in the two areas, there has been little variation in the relative contribution of the two areas to the survey abundance over time, so this should not have major implications for the analysis. Given this, and the difficulties in attributing landings appropriately, the two areas continue to be grouped as 4X for analyses.

The potential impact on the analysis of a reduction in landings from 4Xm was also considered. Cod are known to spawn in fall in this area, and the summer RV survey rarely catches cod in 4Xm, thus changes in abundance here may not be detected by the survey. Growth of cod caught in 4Xm during summer is slower than elsewhere in 4X, but those caught in this area in fall and winter display the same growth pattern as the rest of the Shelf portion of 4X (Clark and Paul, 1999). 4Xm has contributed up to 15% of commercial landings, however, the majority of these came in winter, and are not clearly distinct from the rest of 4X. Thus it was determined that attributing these landings to the 4X stock remained appropriate.

Recent 4X cod assessments have indicated increasing population numbers at older ages, which have not been reflected in landings. The relative lack of old cod in the landings, compared to VPA projections of population numbers, was the focus of much debate at RAP in 1999. Also, F has been estimated as declining, while Z has remained high. A number of possible reasons for this have been explored. In the 1998 assessment, the possibility of changes in M (natural mortality) or q (the scaling factor between survey and population abundance) were explored. No compelling rationale for either of these approaches could be provided, and they have not been pursued. The 1997 assessment looked at partial recruitment (PR) patterns by gear and area (Shelf and Fundy). This indicated that prior to 1993, PR generally increased with age for the longline fleet fishing on the Shelf, and was strongly domed for mobile gear in all areas, except in the first quarter Shelf fishery. Since 1993, the partial recruitment pattern looked similarly domed for both fleets. Fishermen maintained that these changes reflected changes in fishing patterns brought about by regulations, and changes in relative quota levels among species (Clark, 1997). Past assessments have constrained the F on the oldest age, to be equal to the average over ages 5 to 7). The impact of relaxing this constraint was investigated by freely estimating the abundance for all cohorts from 1984 on. Finally, however, it was considered that while assuming F on age 14 to be the average for ages 5 to 7 was not justified, it might be reasonable to assume that F on age 14 was equal to the average for ages 10 - 12.

Results showed little variation in q for ages 4-8, thus, q on these ages was estimated as a common parameter. This constraint on q was intended to improve the stability of bootstrapped population estimates at older ages, allowing F to be estimated for more cohorts despite very low population numbers. The abundance was estimated for ages 2 - 14 in 2000 and for age 14 in 1998 and 1999.

The adaptive framework (Gavaris 1988) was used to calibrate the sequential population analysis with the survey results using the following data:

$C_{a,t}$ = catch for ages *a=1, 2,..., 14* during the time periods beginning at *t=1983, 1984..., 2000, 2000.5*

$I_{s,a,t}$ = survey abundance index for:
s= RV survey ages *a=2 to 8, years t = 1983.5 to 2000.5*
ITQ survey ages *a = 2 to 8, years t = 1996.5 to2000.5*

The summer survey results were compared to mid-year population abundance. Statistical error in the survey data was assumed to be independent and identically distributed after taking logarithms and the error in the catch at age was assumed negligible. Natural mortality, M, was assumed constant and equal to 0.2.

A model formulation using ln mid-year population abundances in 2000 (*t = 2000.5*) as parameters was employed. Define the model parameters:

$\phi_{a,2000.5}$ = ln population abundance for ages *a = 2, 3,...,14,* (age 1 abundance assumed equal to the geometric mean recruitment 1995-99), and

κ_{sa} = calibration constants for RV and ITQ surveys for ages *a = 2,3,4-8.*

ADAPT was used to solve for the parameters by minimizing the objective function

$$\Sigma \left(\ln(I_{s,a,t}) - \ln(\kappa_{sa} N_{a,t}(\phi))\right)^2$$

where the population abundance $N_{a,t}$, is taken at the corresponding time, t, to the survey. Since the sequential population analysis was conducted using quarter year catch at age data, the abundance at the mid-year time, $t = y+0.5$, is directly available.

For t = 2000.5, the population abundances are obtained directly from the parameter estimates,

$$N_{a,2000.5} = exp[\phi_{a,2000.5}].$$

For all other years, y = 1983 to 2000, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,t} = N_{a+\Delta t, y+\Delta t}\, exp[(F_{a,t}+M)\Delta t]$$

where the fishing mortality is obtained by solving the catch equation using a Newton-Raphson algorithm,

$$N_{a,t} = C_{a,t}(F_{a,t} + M)\Delta t / F_{a,t}\Delta t(1 - exp[-(F_{a,t} + M)\Delta t]).$$

Statistical properties of estimators were obtained from model conditioned non-parametric bootstrap of the residuals (Efron and Tibshirani 1993) as described in Gavaris and Van Eeckhaute (1998).

The residual plots show high positive values for the RV survey at ages 4-6 in 1996-'98, and primarily negative residuals in 1999 and 2000 (Fig. 28). The survey data suggested ages 4-6 were more abundant for a three year period than has been estimated through this VPA, while the 2000 survey in particular had very low catches relative to the estimated population.

The residuals from the ITQ survey are generally small (Fig. 28). Residuals are generally negative for the 1999 survey, but otherwise are without obvious trends. The indices for this survey show little inter-annual variability at most ages, aside from the strong 1992 yc (Fig. 29a,b). The estimates of q for this survey decline sharply with age. Given the short duration of this survey, q's are still quite volatile. The impact of this survey on the estimates remains slight. Estimates of q can easily change with additional data if there is a discrepancy between this survey and the RV survey in estimates of relative year-class strength.

The RV survey catches very few fish above age 8 (Table 15). Given these very low catches, these indices were viewed as unreliable and excluded from analyses. Age 8 was found to have higher mean squared residuals than other ages examined. Because of this, analyses were considered which omitted this age, and the possibility of weighting the ages in the VPA based on MSR was examined.

Mean squared residuals by age from 4X cod VPA

Age	2	3	4	5	6	7	8
MSR	0.23	0.19	0.12	0.21	0.18	0.17	0.34

The weighting resulted in little change in population estimates, except for ages 8 and 9 in 2000 (Fig. 30). The estimates for these cohorts increased when the influence of the age 8 indices, which were low for these cohorts, were down-weighted. Weighting of indices merits further consideration, however, given the minimal impact it has here, and the difficulties of including the much shorter ITQ series in a weighted analysis, it was not pursued further.

The impact of the large catch at station 310 in the ITQ survey on population estimates was also explored. This catch was comprised primarily of 2 year old cod. Including this station boosts the survey catch/tow of the 1998 year-class six fold. Indices for age 2 from the two surveys were compared to see if there was a consistent recruitment signal. When RV and ITQ indices are scaled to their means, they show similar estimates of recent year-classes when station 310 is excluded (Fig. 31). Including this station for the ITQ survey results in an estimate of the 1998 year-class from this survey that is 8 times larger than any other year, and is out of sync with the RV survey. When indices including this station were used in a VPA, there was little impact on population estimates, except at age 2, which roughly doubled from 10-20 million. For this assessment, it was considered appropriate that this station be excluded, and alternatives for including this station be explored for future years.

A retrospective analysis shows no consistent trend. The high surveys in 1996-98 followed by low values in 1999 and 2000 have resulted in some variability in estimates of initial cohort size, particularly for the 1992 yc, but no clear pattern (Fig. 32). Estimates of biomass and F show the impact of three successive positive surveys, followed by the negative 1999 and 2000 surveys (Fig. 33). Estimates of biomass in 1996 to 1999 dropped sharply with the 1999 and 2000 surveys. The estimate of 1999 biomass, however, increased with an additional year of data.

ASSESSMENT RESULTS

For each cohort, the terminal population abundance estimates from ADAPT were adjusted for bias (Table 16) and used to construct the history of the stock status (Table 17). Beginning of year weights at age were back-calculated from RV survey weights at age, and used to calculate beginning of year population biomass (Table 18).

Population numbers are estimated to be below average for all ages less than 8 (Table 17). Population at ages 8 and over are estimated as at or above average. With very high fishing mortality in the 1990-94 period, all cohorts prior to 1990 were depleted. With reduced F in recent years, more recent cohorts are beginning to fill out the older ages.

Population biomass declined to a low in 1995. For age 4+ biomass, the addition of the 1992 year-class led to a large increase in 1996, and biomass has remained quite constant since (Fig. 34). The estimates of age 1+ biomass in particular indicate this stock is still at a very low level, and is just beginning to improve with the 1998 yearclass. The increasing spread between 4-8 and 4+ biomass reflects the estimated increase in abundance of older fish. Given the strong dome in PR, the impact of these older ages on projected yield is minimal. Yield has generally matched or exceeded surplus production for 4X cod since the beginning of our estimating block (Fig 35).The biomass estimated from this VPA follows the trends from the RV survey, but given the extreme range between the 1996 and 1999 surveys, the trends diverged in recent years (Fig. 36).

The estimate of 12.3 million for the 1998 yc is the highest since 1992, but remains below average (Fig. 37). Recent recruitment has been uniformly poor, and has resulted in low recruitment production for this stock (Fig 38). With the advent of the 1998 yearclass, production from recruitment will increase. Indications from both RV and ITQ survey catches at ages 0 and 1 are that the 1999 yc may be at least as strong as the 1998.

Fully recruited fishing mortality (ages 4-5) is estimated at 0.28 for 1999 (Fig. 39; Table 19). This is in the range of 0.26-0.3 projected in the 1999 assessment. F peaked in the early 1990's, and with reduced quotas and fishing effort, has declined since. F from 1995-1998 is estimated as similar to those observed in the 1980's, with the estimate for 1999 the lowest in the assessment period. RV survey Z shows little trend over time, while the VPA Z peaks in the early 1990's, when effort was very high, and declines in recent years (Fig. 40). A relative exploitation rate can be derived as fishery yield/survey biomass (Fig. 41). This

summary of the survey and landings data indicate that exploitation dropped from a peak in 1993, and has been relatively low and stable since 1995.

The greatest impact on the estimates of abundance resulted from changes in the number of year-classes where F was estimated, as opposed to assuming it is equal to average F from younger ages. When F on ages 8+ was set equal to average F_{5-7}, F in recent years is estimated as high and the population estimates for these cohorts are very low (Fig. 42). Assuming that older ages are fully recruited means that the proportion of the population they are estimated at is equal to the proportion of the fishery they comprise. If partial recruitment is domed, the abundance for ages 8+ derived in this analysis, which assumes they are fully recruited, will be underestimated. The annual survey q's resulting from this population reconstruction increase markedly in recent years (Table 20), and also increase with age.

A comparison of the numbers of fish aged 4-6 with those of fish aged 8+ caught in the survey and in the fishery suggests older cod are not fully recruited to the fishery (Fig. 43). Older cod generally comprise a higher proportion of the survey catch than they do of the commercial landings, except between 1988 and 1991. These data suggest that fishing mortality has been lower since 1995, and that the reduction has been particularly strong for older fish. The reduction in numbers of old fish seen since the early 1990's has clearly been stronger in the fishery than in the survey. Estimating abundance at more ages in the VPA resulted in higher population estimates at older ages and a much higher degree of consistency in population trends between the VPA and the RV survey, as indicated by consistent q across ages, and much less pronounced annual variability in q. This also resulted in very low estimates of PR for some ages (Table 21).

Previous projections that assumed flat topped partial recruitment have resulted in overestimates of the proportion of landings that will derive from older ages in recent years. Allowing that older ages may be partially recruited increases current estimates of their abundance, and decreases the projected contribution from these ages to the fishery.

PROGNOSIS

The projected F for ages 4-5 in 2001 at a harvest of 6,000t is 0.32 (Table 22); similar to 1999 and 2000. With this yield, 4+ biomass is projected to increase by 20% (Fig 44).Since most of this increase is due to the recruitment of the 1998 year-class, a larger increase (37%) is projected for ages 4-8. The 1998 yearclass is expected to account for 31% of the landed weight of 4X cod in 2002 (Table 22).

Although point estimates of biomass and fishing mortality rate for alternative projected yields are provided, these numbers should not be treated as precise values. The risk plots are provided to give a general sense of the associated uncertainties and to assist in assessing the consequences of alternative choices. Further, these uncertainties are dependent on the set of assumptions, data, and model used in the analyses. Though these assumptions were deemed most suitable, there may be other plausible assumptions. The risk evaluation indicate that fairly significant changes in yield are required to influence the probability of not

exceeding 20% growth in 4+ biomass (Fig 45). This reflects the reliance on recruitment, which is not estimated precisely, for growth.

These calculations do not include uncertainty due to variations in weight at age, partial recruitment to the fishery, natural mortality, systematic errors in data reporting, or the possibility that the model may not reflect the stock dynamics closely enough. The uncertainty associated with making a choice among competing assumptions and models must be considered when making management decisions. Estimates from the model of relative values, such as change in biomass, rather than absolute quantities, such as biomass, should be more reliable. If the rebuilding goal is re-stated as a 60% increase in age 4-8 biomass, then the possibility of bias in estimates of population at older ages is obviated.

No projection is given for 2003, the end of the currently entrained 3 year rebuilding plan. The degree of growth in 4+ biomass to be experienced in 2002 is strongly dependent on the 1999 yearclass. The 1999 yearclass must be equivalent to the 1998 if growth of a similar magnitude to that anticipated in 2001 is to occur.

The results of the current assessment suggest greater abundance at older ages than the 1999 assessment. It appears that changes in fishing practices may account for the reduced commercial catch at these ages. The low catches in the survey in recent years, however, is grounds for concern and suggests increased mortality from other sources. There is a great deal of uncertainty regarding the abundance of fish at ages 9 and older. The survey does not consistently catch fish at these older ages in sufficient numbers to permit reliable estimation. Yield projections, however, are not influenced greatly by the abundance estimated above age 7, because the partial recruitment to the fishery for these ages is low. Further, anticipated growth for this stock in the near-term comes primarily from recruitment and is not reliant on abundance of older cod.

Biomass growth in the immediate future will be largely dependent on the incoming recruitment. Measures should be considered to ensure that the recruiting fish are not targeted by the fishery in order to maximize their yield and to enhance the future spawning potential.

ACKNOWLEDGMENTS

We would like to thank those members of the fishing industry who assisted us with sampling of commercial landings and took the time to meet with us and discuss the state of the fishery. The efforts of Emelia Williams and Gilbert Donaldson in commercial sampling is also appreciated.

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Appendix I.

Age comparison testing. Results for the new age reader compared to the previous reader were satisfactory. Additional testing using samples from the 1980's and early 1990's when a higher proportion of older cod were found are planned. Testing reported for L. Brown in 1998 using these older samples showed in excess of 90% agreement with the original age readings.

	2nd age - S. Paul											
1st age - L. Brown	1	2	3	4	5	6	7	8	9	10	Total	
	0										0	
2		22	1								23	
3			28	1	1						30	
4			5	55	1						61	
5				1	29	2					32	
6					3	35	2				40	
7						2	10				12	
8							2	5			7	
9							1				1	
10										2	2	
	0	22	34	57	34	39	15	5	0	2	208	89.42%
Total	208											
% Agreement	89.42											
Coefficient of Variation	1.733											

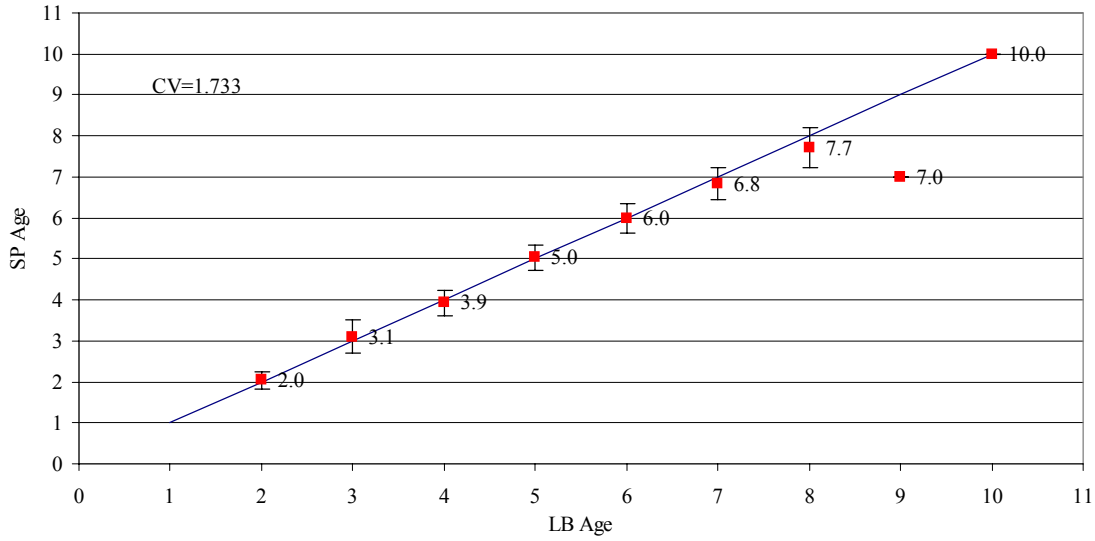

Figure A1. Inter-reader age comparisons for 4X cod.

Table 1. Nominal catch (t) of 4X cod by month.

	Otter Trawl					Gill Net		Long Line			Hand		
Year	0&1	2	3	4	5+	0&1	2&3	0&1	2	3+	Line	Misc.	Total
1980	1,322	2,769	4,284	1,042	2,037	2,683	61	8,356	2,360	898	4,198	1,267	31,277
1981	1,165	3,086	2,989	416	1,131	2,871	114	10,302	2,555	1,235	5,174	483	31,521
1982	879	3,159	4,493	563	2,217	3,154	214	9,120	3,465	1,087	4,299	484	33,134
1983	638	4,735	6,306	518	1,118	2,180	235	5,747	2,757	883	3,750	604	29,471
1984	964	4,198	5,904	302	1,513	1,248	220	3,916	2,825	980	3,005	453	25,528
1985	523	3,954	5,562	90	1,185	1,837	161	2,617	1,740	635	2,755	440	21,499
1986	573	3,663	5,123	224	974	1,453	196	2,479	1,918	576	2,490	371	20,040
1987	312	2,645	3,504	531	929	1,968	241	3,075	2,175	499	2,670	456	19,005
1988	454	3,966	3,542	160	467	903	444	3,528	3,149	672	3,081	171	20,537
1989	409	3,933	4,184	67	713	1,254	475	2,915	2,167	623	2,937	208	19,885
1990	505	3,668	3,577	268	170	1,933	692	4,201	2,967	849	4,871	203	23,904
1991	355	4,598	5,805	298	751	2,225	619	4,712	3,679	842	3,737	128	27,749
1992	238	4,494	5,711	143	726	1,811	586	4,455	3,574	719	3,517	106	26,080
1993	176	2,778	3,598	68	241	1,387	523	2,768	1,693	310	2,439	45	16,026
1994	132	2,022	2,343	138	82	993	421	2,837	1,412	231	2,367	67	13,045
1995	100	1,387	1,619	112	75	470	507	1,632	959	182	1,706	18	8,767
1996	92	1,552	2,314	157	103	611	442	1,774	1,306	201	1,914	106	10,572
1997	79	2,094	2,430	136	35	694	471	2,013	1,255	231	1,794	6	11,238
1998	96	1,407	1,892	166	22	429	376	1,663	997	244	879	0	8,169
1999	85	776	1,254	63	11	494	404	1,480	762	119	743	0	6,190
2000*	87	707	1,088	78	8	319	323	1,139	407	77	625	1	4,860

* January 1 - October 18

Table 2. Nominal catch of 4X cod by gear and tonnage class.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	TAC
1980	706	2,188	1,704	2,485	3,317	5,316	3,433	3,346	2,603	2,876	1,547	1,756				31,277	
1981	1,649	2,451	2,529	1,533	2,881	4,093	3,845	4,067	2,253	3,119	1,728	1,373				31,521	
1982	757	2,390	2,569	1,491	3,415	5,109	4,734	3,258	3,540	2,890	1,244	1,737				33,134	30,000
1983	1,713	1,654	1,648	1,888	2,743	5,713	4,554	2,832	3,183	1,787	1,037	719				29,471	30,000
1984	1,798	2,021	752	817	1,796	3,471	3,688	4,567	2,773	1,668	1,201	976				25,528	30,000
1985	779	1,699	956	1,268	1,974	2,586	3,199	2,650	2,737	1,801	787	1,063				21,499	30,000
1986	904	1,633	1,775	1,450	1,437	1,939	2,739	1,995	2,576	1,714	771	1,107				20,040	20,000
1987	1,208	1,837	1,242	1,059	1,870	2,778	2,663	1,821	1,679	1,403	910	535				19,005	18,000
1988	2,104	1,531	535	939	1,620	2,931	3,104	2,122	2,524	1,441	636	1,050				20,537	16,000
1989	2,150	2,347	1,362	1,707	1,292	3,562	1,830	1,772	1,535	1,278	637	413				19,885	13,000
1990	2,619	2,027	707	778	1,560	3,104	3,751	3,123	2,598	1,689	1,158	790				23,904	22,000
1991	2,023	2,651	993	1,666	2,322	3,167	3,963	2,881	2,967	2,208	1,650	1,258				27,749	26,000
1992	2,088	1,740	1,297	1,502	1,685	3,622	3,366	2,803	2,625	2,353	1,478	1,521				26,080	26,000
1993	657	903	994	996	1,617	2,312	2,834	2,221	1,804	1,048	562	78				16,026	16,000
1994	734	972	547	847	824	1,771	2,246	1,503	1,267	1,154	726	454				13,045	14,000
1995	610	229	317	827	574	1,236	1,771	774	1,071	521	276	561				8,767	9,000
1996	503	331	446	531	819	1,755	1,805	1,317	880	887	679	619				10,572	11,000
1997	98	362	378	806	644	1,440	1,779	1,382	1,548	1,424	710	668				11,239	13,000
1998	285	348	402	313	511	941	1,272	953	1,125	770	520	729				8,169	9,300
1999	186	105	124	330	414	1,047	1,269	856	854	445	324	235	213	255	556	7,214	7,910*
2000				113	368	884	1,080	726	527	402						4,100	6,000[x]

* Jan 1, 1999 - March 31, 2000

[x] Apr. 1, 2000 - March 31, 2001

Table 3. Nominal catch of 4X and 5Y cod by unit area.

	4Xm	4Xn	4Xo	4Xp	4Xq	4Xr	4Xs	4Xu	5Y	Total	Shelf	Fundy	Foreign
1968	3251	2059	8159	9341	1327	4785	1849	4	64	30,838	22,812	8,027	4,773
1969	2413	2923	7355	5523	974	3686	1120	59	0	24,052	18,258	5,794	8,670
1970	2851	1300	6966	2310	1077	2621	847	23	26	18,020	13,437	4,582	4,308
1971	2750	1728	9029	2157	1395	2355	755	13	119	20,301	15,674	4,626	3,197
1972	3124	1585	8908	1421	1938	2518	977	8	52	20,531	15,039	5,492	1,902
1973	2130	1478	10180	1228	1742	2186	802	179	67	19,991	15,171	4,821	2,222
1974	2243	1122	9369	955	1526	2839	768	1	120	18,944	13,690	5,254	2,166
1975	81	1374	967	1033	864	2869	133	12180	85	19,587	13,291	6,296	1,595
1976	1973	1408	8267	743	1061	2034	601	40	16	16,143	12,423	3,719	517
1977	184	1706	1229	1487	907	2686	122	13562	106	21,989	15,140	6,849	949
1978	2812	2864	8522	3591	2286	2246	676	342	384	23,723	17,996	5,727	298
1979	6565	2750	10495	1748	2325	2550	1646	229	379	28,688	21,641	7,047	75
1980	5205	3325	9899	1561	3571	4684	2278	47	166	30,736	20,023	10,712	541
1981	4767	2114	12097	1830	2413	5072	2031	419	599	31,342	21,051	10,290	179
1982	5255	2922	10451	2079	3715	4571	2009	538	1349	32,889	20,956	11,933	245
1983	3437	1690	8537	2497	3160	3787	1674	1826	2543	29,151	16,891	12,258	320
1984	2255	2251	6192	1655	2244	2959	1414	3583	2698	25,251	14,110	11,141	277
1985	3006	1199	5438	1026	1999	2301	1511	3608	1364	21,452	12,236	9,216	47
1986	2914	1762	4670	544	1754	1802	1500	4469	557	19,972	11,748	8,224	68
1987	2676	1611	4777	1131	1240	858	1207	5116	360	18,976	12,783	6,179	29
1988	1502	1086	5458	1271	1124	850	1103	7990	142	20,526	14,814	5,711	11
1989	1370	1019	5506	2820	1360	1112	915	5267	478	19,847	13,855	5,994	38
1990	1846	764	7915	1746	2238	1721	1722	5404	326	23,682	15,551	8,119	222
1991	2552	1584	8963	2440	2763	4243	2560	2246	307	27,658	17,275	10,383	91
1992	1523	1818	10347	1455	2919	3352	1503	2876	278	26,071	17,556	8,515	9
1993	1364	1646	4845	1436	1959	2428	1399	760	189	16,026	9,924	6,102	0
1994	828	561	4414	1128	1662	1883	892	1540	137	13,045	8,321	4,724	0
1995	293	696	1737	1586	1306	1032	510	1528	79	8,767	5,349	3,418	0
1996	466	813	2787	1484	1608	1659	930	654	171	10,572	6,055	4,517	0
1997	453	837	2213	1327	1793	2240	1070	1303	183	11,419	5,943	5,479	0
1998	477	907	1634	1796	983	1284	606	331	151	8,169	5,064	3,105	0
1999	397	584	1548	1288	956	778	408	111	121	6,190	3,887	2,303	0
2000*	208	323	1205	1038	999	509	372	101	105	4,860	2,833	2,027	0

*January 1 - October 18

Table 4. Summary of fishery reports for cod in Division 4X in 2000.

1998 Quota Report	cod	haddock	pollock
FIXED < 45'	84%	94%	75%
MOBILE < 65' (ITQ)	99%	100%	81%
VESSELS > 100'	89%	86%	61%

1999 Quota Report	cod	haddock	pollock
FIXED < 45'	92%	82%	65%
MOBILE < 65' (ITQ)	93%	99%	75%
VESSELS > 100'	72%	99%	59%

2000 (Oct. 18)	cod	haddock	pollock
FIXED < 45'	84%	66%	71%
MOBILE < 65' (ITQ)	53%	37%	45%
VESSELS > 100'	41%	29%	18%

Table 5. Number of fishing vessels reporting cod landings annually.

Year	Otter trawl	Gill net	Longline	Handline
1996	142	205	528	779
1997	142	197	497	657
1998	129	163	398	422
1999	129	126	357	344
2000	118	94	360	309

Table 6. Fishing days by gear type.

Year	Gill net	Longline	Handline
1996	4,912	5,210	9,880
1997	6,281	6,179	9,650
1998	4,178	5,352	5,721
1999	3,370	4,156	4,234
2000*	2,019	3,309	3,087

*2000 effort to Oct. 18, 84% of the fixed gear cod quota had been landed.

Table 7a. Construction of Age-Length keys for 4X cod in 1999.

	Fundy (4Xqrs5Y)				Shelf (4Xmnop)					
Quarter	Q1	Q2	Q3	Q4	Q1_4Xno	Q1_4Xp	Q2_4Xp	Q3_4Xp	4Xo	Q4
No. Samples	1	7	4	3	3	2	4	5	5	3
No. Aged	48	331	171	164	126	95	157	143	225	142

Table 7b. Construction of length frequencies for 4X cod for 1999, and age-length keys against which they are matched.

Gear	Quarter	Area	a	b	Number samples	Number Measured	Landings (t)	ALK used
OT	1	Fundy	0.0081	3.0503	2	604	88	Fundy Q1
GN					0	0	1	
LL					0	0	0	
HL					0	0	0	
OT	1	4Xmno			13	2,355	153	Q1_4Xno
OT		4Xp			10	1,547	103	Q1_4Xp
GN					0	0	0	
LL		Shelf			1	235	71	Q1_4Xno
HL					0	0	0	
OT	2	Fundy	0.0084	3.0410	16	2,968	562	Fundy Q2
GN		Fundy			0	OT Q2 F#	123	
LL		Fundy			3	804	77	Fundy Q2
HL		Fundy			4	657	58	Fundy Q3
OT	2	Shelf			3	740	180	Q2_4Xp
GN		Shelf			4	920	160	Q2_4Xp
LL		4Xmno			3	487	188	Q1_4Xno
LL		4Xp			1	182	101	Q3_4Xp
HL		Shelf			2	144	343	4Xo
OT	3	Fundy	0.0087	3.0233	8	1,477	587	Fundy Q3
GN		Fundy			1	289	333	Fundy Q2
LL					0	LL Q2 F#	56	Fundy Q2
HL					0	HL Q2 F#	66	Fundy Q2
OT	3	Shelf			1	195	107	Q3_4Xp
GN		Shelf			0	GN Q2 S#	196	4Xo
LLHL		4Xp			8	1,066	493	Q3_4Xp
LLHL		4Xm			0	0	151	
LLHL		4Xno			5	767	989	4Xo
OT	4		0.0063	3.1152	5	1,046	290	Fundy Q4
GN		Fundy			0	OT Q2 F#	24	Fundy Q2
LLHL					0	LL Q2 F#	10	Fundy Q2
OT	4	Shelf			6	1,236	120	Shelf Q4
GN		Shelf			0	GN Q2 S#	61	4Xo
LLHL		Shelf			5	961	499	Shelf Q4

[#] LF substituted due to absence of commercial sampling for this gear/area/quarter combination

Table 7c. Construction of Age-Length keys for 4X cod in 2000.

	Fundy (4Xqrs5Y)		Shelf (4Xmnop)				
Quarter	Q1	Q2	Q1_4Xno	Q1_4Xp	Q2_4Xm	Q2_4Xno	Q2_4Xp
No. Samples	4	6	5	5	2	1	2
No. Aged	192	266	177	206	71	90	81

Table 7d. Construction of length frequencies for 4X cod for 2000, and age-length keys against which they are matched.

Gear	Quarter	Area	a	b	Number of samples	Number Measured	Landings (t)	ALK used
OT	1	Fundy	0.0081	3.0503	7	1,603	292	Fundy Q1
GN					0	GN Q2 F#	5	Fundy Q2
LL					0	LL Q2 F#	7	Fundy Q2
HL					0	0	0	
OT	1	4Xm			0	0	0	
GN					0	0	0	
LLHL					0	HL Q2 4Xm#	16	Q2_4Xm
OT	1	4Xno			5	814	148	Q1_4Xno
GN					0	0	2	
LL					3	568	133	Q1_4Xno
HL					0	0	0	
OT	1	4Xp			9	1,837	357	Q1_4Xp
GN					2	520	45	Q1_4Xp
LL					1	280	15	Q1_4Xp
HL					0	0	0	
OT	2	Fundy	0.0084	3.0410	9	2,090	427	Fundy Q2
GN					2	333	136	Fundy Q2
LL					2	117	71	Fundy Q2
HL					5	1,197	93	Fundy Q2
OT	2	4Xm			0	0	1	
GN					1	82	1	Q2_4Xm
LL/HL					2	169	39	Q2_4Xm
OT	2	4Xno			0	OT Q1 4Xno#	33	Q1_4Xno
GN					2	240	13	Q2_4Xno
LL					1	454	136	Q2_4Xno
HL					7	1282	263	Q2_4Xp
OT	2	4Xp			6	1449	57	Q2_4Xp
GN					0	GN Q1 4Xp#	17	Q1_4Xp
LL					0	LL Q1 4Xp#	66	Q1_4Xp

LF substituted due to absence of commercial sampling for this gear/area/quarter combination

Table 8a. Landed number (000's) of 4X cod at age by gear type for 1999.

Age	1	2	3	4	5	6	7	8	9	10	11	12
LL+HL	0	24	366	279	203	177	68	13	5	0	0	1
OT	0	48	439	207	95	52	26	3	0	0	0	0
GN	0	0	29	56	50	35	26	4	2	0	0	0

Table 8b. Landed number (000's) of 4X cod at age by gear type for 2000.

Age	1	2	3	4	5	6	7	8	9	10	11	12
LL+HL	0	13	105	154	51	41	12	5	2	0	0	0
OT	0	14	109	237	70	35	11	4	1	0	0	0
GN	0	0	4	35	8	7	2	1	0	0	0	0

Table 9. Catch at age (number in thousands) for cod in Division 4X.

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	2+	3+	4+
1980	0	837	6,054	2,358	1,742	1,135	442	261	91	60	19	17	5	13,021	12,183	6,129
1981	0	818	3,870	4,265	1,844	1,045	587	297	184	75	39	19	19	13,061	12,244	8,373
1982	0	904	2,885	4,414	3,060	912	393	279	146	86	41	25	15	13,160	12,255	9,371
1983	9	1,031	3,689	2,433	2,057	1,205	459	204	120	76	36	10	10	11,330	10,299	6,610
1984	33	917	2,393	3,081	1,930	965	465	176	63	49	29	18	5	10,090	9,173	6,781
1985	0	711	1,674	1,569	2,324	1,284	514	194	71	53	18	7	6	8,425	7,715	6,041
1986	0	251	2,789	1,941	994	1,008	409	200	93	50	23	20	10	7,788	7,537	4,748
1987	0	861	902	2,053	1,087	523	511	236	140	66	33	9	7	6,428	5,567	4,665
1988	0	403	3,517	1,659	1,553	656	178	192	85	53	28	6	9	8,338	7,935	4,418
1989	17	655	2,560	3,656	632	562	163	79	60	19	10	10	2	8,408	7,753	5,193
1990	0	144	2,863	2,805	2,462	497	279	78	40	38	14	15	1	9,235	9,091	6,228
1991	2	391	1,535	5,092	1,777	1,364	215	156	32	16	28	15	6	10,626	10,235	8,700
1992	0	751	3,391	1,878	3,276	878	513	63	50	16	9	4	0	10,828	10,077	6,685
1993	0	881	3,490	2,045	660	672	186	90	14	14	5	0	0	8,056	7,176	3,686
1994	0	475	2,280	2,233	887	195	181	42	18	0	2	0	0	6,314	5,838	3,558
1995	0	135	2,146	1,081	582	130	28	40	11	5	0	0	0	4,158	4,023	1,877
1996	0	50	883	2,594	441	212	29	16	8	2	1	1	0	4,237	4,187	3,304
1997	0	59	1,126	1,556	1,193	199	82	16	2	6	1	3	0	4,243	4,184	3,058
1998	0	234	886	1,021	615	441	54	20	6	2	3	1	1	3,284	3,050	2,164
1999	0	72	834	543	347	264	120	20	7	0	0	1	0	2,210	2,138	1,303
2000*	0	27	218	426	128	83	25	10	3	0	0	0	0	921	893	675

* Landings for January - July 1.

Table 10. Mean weight at age (kg) of cod from commercial landings in two sub-areas of Division 4X.

		1	2	3	4	5	6	7	8	9	10	11	12
	1983		0.76	1.22	1.81	2.50	3.93	6.09	8.22	10.76	11.83	12.22	16.59
	1984		0.96	1.30	1.69	2.34	3.37	4.68	6.83	8.60	11.06	13.21	14.03
	1985		0.60	1.07	1.47	2.00	3.06	4.55	6.70	6.89	9.00	14.16	15.66
	1986		0.78	1.13	1.63	2.21	3.47	4.69	7.15	8.83	8.81	13.11	13.10
	1987		1.23	1.40	1.83	2.61	3.46	4.99	7.33	8.36	10.66	11.80	15.85
Scotian	1988		0.94	1.30	1.90	2.69	3.98	5.23	8.06	9.88	10.93	13.05	16.04
Shelf	1989	0.78	1.23	1.57	2.21	2.75	3.96	4.88	7.86	9.46	11.95	15.04	14.81
	1990		0.82	1.29	1.97	2.86	3.72	5.59	8.10	10.46	11.93	14.12	15.24
	1991		0.76	1.13	1.73	2.50	3.54	5.08	6.44	9.44	11.19	13.73	15.74
	1992		0.78	1.14	1.63	2.58	3.58	4.44	6.50	8.37	12.10	14.50	19.15
	1993		0.68	1.25	1.62	2.24	3.44	4.67	7.01	9.13	10.97	18.08	
	1994		0.76	1.04	1.92	2.41	3.15	4.97	5.21	9.28	15.98	13.56	
	1995		0.86	1.23	1.72	3.26	4.09	4.69	7.23	9.18	13.33	16.33	
	1996		0.75	1.21	2.06	2.96	4.77	5.53	6.39	9.80	12.02	10.12	
	1997		1.17	1.22	1.83	3.31	4.49	6.04	8.83	9.99	11.14	13.58	8.71
	1998		0.86	1.12	1.71	2.54	4.42	4.72	7.33	9.76	9.66	10.83	16.17
	1999		1.00	1.71	2.32	2.83	4.03	5.43	8.26	10.70	13.24	11.35	16.54
	Mean	0.78	0.88	1.25	1.83	2.62	3.79	5.07	7.26	9.35	11.52	13.46	15.20
	1983	0.38	0.86	1.48	2.18	3.30	4.88	6.38	8.62	9.92	12.19	14.23	20.63
	1984	0.39	0.93	1.62	2.48	3.52	4.67	6.98	7.94	12.10	13.45	4.75	
	1985	0.37	0.84	1.48	2.26	3.43	4.53	6.54	9.45	11.46	15.12	18.23	19.52
	1986	0.37	0.80	1.41	2.33	4.30	6.24	7.36	8.18	9.50	14.25	7.99	11.98
	1987		0.84	1.57	2.56	4.17	5.33	7.04	7.92	7.94	14.31	18.56	
Bay of	1988		0.86	1.46	2.24	4.09	5.36	8.99	10.14	8.89	14.69		
Fundy	1989	0.33	0.76	1.52	2.59	3.60	6.33	7.25	10.32	10.55	14.57		11.66
	1990		1.05	1.69	2.69	3.77	4.37	7.31	8.15	11.32	11.95	12.75	14.74
	1991	0.82	1.04	1.88	2.91	4.26	6.77	8.75	11.02	13.60	14.17	15.10	17.93
	1992		1.18	1.73	2.73	4.49	6.51	8.78	9.93	13.13	14.55	11.10	
	1993		0.90	1.74	2.86	4.74	6.09	7.58	9.18	14.32	16.75	13.85	
	1994		0.98	1.75	3.19	5.72	7.96	9.31	11.61	11.56		17.46	
	1995		1.29	1.91	2.78	4.38	6.01	7.76	9.84	12.49	8.57	14.32	
	1996		1.06	1.70	2.85	4.71	6.12	5.97	10.56	11.05			13.19
	1997		1.17	1.73	2.74	4.28	5.77	8.44	10.30	9.18	12.94	11.07	22.55
	1998		1.16	1.99	3.14	4.49	5.91	8.13	9.20	12.75		14.32	
	1999	0.70	1.31	1.88	2.93	4.44	6.06	7.55	4.43			8.97	14.78
	Mean	0.48	1.00	1.68	2.67	4.22	5.82	7.65	9.22	11.23	13.65	13.05	16.33

Table 11. Distribution and concentration of cod catch in the ITQ survey.

	Percent of catch accounting for 75% biomass	% zeros
1996	18%	17%
1997	13%	28%
1998	14%	20%
1999	21%	21%
2000	17%	27%

Table 12. Total weight from ITQ surveys for cod in Division 4X.

	Fundy*	Fundy	Shelf	Inshore	Total
1996	2507	2948	1141	475	4564
1997	2466	2656	723	243	3622
1998	2157	2174	612	407	3193
1999	1670	1838	521	231	2590
2000	2227	7218	671	347	8236

* excludes station 310

Table 13a. Summer groundfish survey indices for cod in Division 4X.

	2	3	4	5	6	7	8
1983	223	4,226	2,369	1,480	946	389	0
1984	1,385	3,390	2,362	1,820	688	482	63
1985	1,139	4,331	1,527	1,451	766	483	267
1986	258	2,920	1,226	314	549	448	217
1987	1,158	618	1,180	528	260	245	304
1988	564	0	0	1,548	496	210	244
1989	1,073	3,420	2,549	420	489	108	27
1990	110	5,523	2,463	2,321	240	414	80
1991	390	1,131	3,086	1,094	751	128	116
1992	874	1,569	681	1,710	471	460	124
1993	350	2,518	925	129	265	52	61
1994	711	2,739	1,605	449	36	195	88
1995	350	4,779	1,477	598	274	94	91
1996	323	2,048	5,527	880	753	148	0
1997	211	1,189	1,444	2,462	321	194	100
1998	456	1,808	1,418	1,022	1,371	225	116
1999	280	1,291	882	850	194	297	46
2000	554	830	999	409	325	157	148

* Includes stations occupied within 4X during survey N246; stations resampled during N247 were excluded.

(See Clark and Brown, 1996.)

Table 13b. Summer groundfish survey stratified total numbers for cod in Division 4X.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12+
1970	27	938	1,528	2,426	4,217	1,846	2,546	1,059	497	157	138	13	0
1971	21	363	7,079	3,934	676	1,537	707	1,054	119	0	17	0	0
1972	0	327	1,424	3,165	2,537	712	502	202	538	376	164	22	182
1973	23	114	2,197	1,174	2,141	626	253	155	33	170	63	29	26
1974	111	411	1,004	4,524	1,126	1,665	926	119	0	56	35	44	70
1975	0	1,011	2,864	1,612	2,950	2,442	985	760	158	99	0	112	35
1976	0	152	1,277	2,812	2,306	2,051	888	375	220	67	69	13	26
1977	15	251	2,281	4,211	2,541	789	1,323	325	201	38	27	59	12
1978	23	183	1,068	1,712	2,489	1,345	496	362	93	71	0	0	0
1979	0	2,728	3,521	1,814	1,890	1,764	1,019	439	307	59	62	137	0
1980	2,406	205	910	2,864	1,112	1,052	1,379	390	221	186	0	69	0
1981	62	2,269	2,366	2,387	2,496	1,345	835	470	418	98	91	27	7
1982	73	750	1,831	1,828	1,830	1,481	876	243	260	186	49	31	41
1983	208	141	1,085	4,226	2,369	1,480	946	389	0	77	37	0	6
1984	0	820	5,746	3,390	2,362	1,820	688	482	63	58	25	0	0
1985	69	495	8,760	4,331	1,527	1,451	766	483	267	165	13	0	26
1986	25	768	1,333	2,920	1,226	314	549	448	217	97	19	0	51
1987	6	392	2,348	618	1,180	528	260	245	304	75	40	63	0
1988	260	2,630	3,926	9,246	1,496	1,548	496	210	244	91	38	13	0
1989	309	794	6,089	3,420	2,549	420	489	108	27	82	37	14	0
1990	28	515	873	5,523	2,463	2,321	240	414	80	42	0	21	27
1991	34	614	1,727	1,131	3,086	1,094	751	128	116	19	21	12	0
1992	35	252	2,731	1,569	681	1,710	471	460	124	85	0	0	0
1993	14	369	955	2,518	925	129	265	52	61	0	6	41	0
1994	748	1,258	3,313	2,739	1,605	449	36	195	88	70	0	32	65
1995	1,212	122	847	4,779	1,477	598	274	94	91	34	42	7	0
1996	31	339	839	2,048	5,527	880	753	148	0	56	15	0	0
1997	95	349	569	1,189	1,444	2,462	321	194	100	0	57	0	0
1998	65	211	1,929	1,808	1,418	1,022	1,371	225	116	6	0	0	0
1999	869	382	787	1,291	882	850	194	297	46	0	0	0	0
2000	3,324	432	1,497	830	999	409	325	157	148	0	0	0	21

Table 14a. ITQ survey catch at age for cod in Division 4X; excl. station 310

	0	1	2	3	4	5	6	7	8	9	10	11
1996	1	302	662	835	737	84	31	6	0	2	0	1
1997	1	225	232	727	393	265	17	24	6	2	1	0
1998	16	179	857	619	276	112	112	15	7	0	0	0
1999	8,750	601	700	708	170	98	15	24	5	1	0	0
2000	5	1,063	1,039	351	234	62	61	15	13	0	0	0

Table 14b. ITQ survey catch at age for cod in Division 4X; all stations.

	0	1	2	3	4	5	6	7	8	9	10	11
1996	4	282	879	923	868	80	31	5	0	3	0	0
1997	1	226	238	768	416	277	17	24	6	2	1	0
1998	16	183	866	623	278	112	112	15	7	0	0	0
1999	8750	601	715	783	180	99	15	24	5	1	0	0
2000	5	1206	6092	585	306	71	61	15	13	0	0	0

Table 15. Number of cod caught annually in the RV survey over age 7.

Year	Age 8	Age 9	Age 10
1983	0	3	1
1984	3	2	1
1985	11	6	1
1986	7	4	1
1987	12	3	2
1988	10	2	
1989	1	4	3
1990	3	2	
1991	6	1	1
1992	7	2	
1993	3		
1994	3	4	
1995	4	1	1
1996		4	1
1997	4		3
1998	5	1	
1999	2		
2000	8		

Table 16. Statistical properties of estimates for population abundance and survey calibration constants for 4X cod using RV index (1983-2000, ages 2-8) and the ITQ index (1996-2000, ages 2-8).

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
		Population Abundance (000's)			
2	9786	3364	0.34	676	0.07
3	2996	745	0.25	104	0.03
4	2571	543	0.21	94	0.04
5	975	223	0.23	15	0.02
6	1026	230	0.22	47	0.05
7	390	94	0.24	12	0.03
8	818	180	0.22	22	0.03
9	210	50	0.24	0	0.00
10	249	55	0.22	7	0.03
11	117	28	0.24	3	0.02
13	61	26	0.43	3	0.05
14	27	14	0.51	4	0.14
14, 1999	51	30	0.58	6	0.12
14, 1998	44	21	0.47	3	0.06
		Survey Calibration Constants			
		DFO Survey			
2	0.053	0.005	0.10	0.0001	0.00
3	0.377	0.040	0.10	-0.0012	0.00
4 - 8	0.449	0.029	0.06	-0.0002	0.00
		ITQ Survey			
2	0.114	0.025	0.22	0.0003	0.00
3	0.171	0.034	0.20	0.0003	0.00
4	0.118	0.024	0.21	0.0018	0.02
5	0.079	0.016	0.21	0.0013	0.02
6	0.041	0.009	0.23	0.0008	0.02
7	0.032	0.008	0.24	0.0009	0.03
8	0.019	0.005	0.27	0.0009	0.05

Table 17. Estimated bias adjusted beginning of year population numbers (000's) for 4X cod.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1+	4-8
1983	13,894	11,367	16,417	9,334	5,493	2,746	1,075	518	299	181	92	30	25	10	61,481	19,167
1984	17,358	11,367	8,375	10,090	5,417	2,617	1,156	467	241	137	80	43	16	11	57,374	19,747
1985	9,864	14,182	8,479	4,709	5,497	2,706	1,279	530	224	140	68	40	19	8	47,745	14,721
1986	27,283	8,076	10,969	5,436	2,449	2,422	1,069	587	260	120	67	39	26	10	58,816	11,964
1987	18,522	22,338	6,386	6,475	2,712	1,115	1,082	509	301	130	54	35	14	12	59,686	11,893
1988	27,260	15,165	17,511	4,416	3,460	1,248	446	429	206	122	48	15	20	6	70,352	10,000
1989	9,096	22,319	12,052	11,173	2,130	1,445	437	206	180	93	52	14	7	9	59,213	15,392
1990	13,798	7,432	17,682	7,565	5,869	1,177	681	212	98	94	59	34	3	4	54,707	15,504
1991	15,236	11,297	5,955	11,899	3,681	2,605	519	308	104	45	43	36	14	1	51,743	19,012
1992	10,175	12,473	8,896	3,496	5,190	1,428	917	233	113	56	23	10	16	6	43,033	11,264
1993	17,604	8,331	9,534	4,248	1,190	1,344	390	294	134	48	32	11	5	13	43,177	7,467
1994	8,485	14,413	6,028	4,680	1,653	387	501	153	160	97	27	21	9	4	36,618	7,374
1995	7,979	6,947	11,371	2,893	1,838	563	143	248	88	115	78	20	17	7	32,309	5,686
1996	5,277	6,532	5,566	7,379	1,402	984	343	92	166	62	90	63	16	14	27,988	10,200
1997	7,486	4,321	5,303	3,762	3,717	752	616	256	61	129	49	72	51	13	26,588	9,103
1998	5,206	6,129	3,484	3,329	1,688	1,973	437	430	195	48	100	39	57	42	23,158	7,858
1999	12,333	4,262	4,807	2,057	1,809	831	1,219	309	334	154	38	79	31	45	28,309	6,225
2000	7,957	10,097	3,425	3,185	1,196	1,169	444	890	235	267	126	31	64	26	29,111	6,883

Table 18. Estimated population biomass (000 t) at the beginning of year for 4X cod.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1+	4+	4-8
1983	1,528	3,524	14,775	16,428	15,766	11,782	6,269	4,018	2,803	1,943	1,144	402	383	160	80,926	61,098	54,264
1984	1,909	3,524	7,538	17,759	15,547	11,229	6,739	3,620	2,254	1,469	1,000	572	242	181	73,582	60,611	54,894
1985	1,085	4,396	7,631	8,288	15,775	11,609	7,455	4,115	2,102	1,509	850	530	293	132	65,770	52,657	47,242
1986	3,001	2,504	9,872	9,568	7,027	10,392	6,235	4,555	2,440	1,290	843	529	404	161	58,821	43,444	37,777
1987	2,037	6,925	5,748	11,396	7,783	4,785	6,306	3,953	2,824	1,396	669	464	225	198	54,709	39,999	34,223
1988	2,999	4,701	15,760	7,773	9,930	5,352	2,602	3,333	1,933	1,308	594	195	314	90	56,884	33,424	28,990
1989	1,001	6,919	10,847	19,665	6,113	6,200	2,548	1,600	1,687	999	654	188	102	136	58,658	39,892	36,127
1990	1,518	2,304	15,914	13,314	16,845	5,048	3,971	1,644	919	1,007	737	453	41	57	63,772	44,037	40,823
1991	1,676	3,502	5,359	20,942	10,566	11,174	3,026	2,391	971	488	533	478	221	20	61,348	50,811	48,099
1992	1,119	3,867	8,007	6,154	14,894	6,128	5,347	1,805	1,060	603	285	136	245	101	49,751	36,759	34,328
1993	1,936	2,583	8,581	7,476	3,416	5,766	2,275	2,284	1,254	515	394	142	73	207	36,904	23,804	21,218
1994	933	4,468	5,425	8,236	4,743	1,661	2,922	1,191	1,501	1,042	334	286	135	62	32,938	22,112	18,754
1995	878	2,154	10,234	5,092	5,276	2,416	835	1,925	824	1,235	981	269	271	114	32,503	19,237	15,545
1996	581	2,025	5,009	12,987	4,023	4,222	2,002	714	1,557	667	1,119	849	254	229	36,237	28,622	23,947
1997	823	1,339	4,773	6,621	10,667	3,226	3,591	1,986	571	1,385	612	970	790	215	37,569	30,634	26,091
1998	573	1,900	3,136	5,859	4,845	8,464	2,547	3,340	1,828	517	1,251	525	877	667	36,329	30,721	25,055
1999	1,357	1,321	4,326	3,620	5,193	3,566	7,106	2,398	3,132	1,658	470	1,061	484	727	36,419	29,415	21,883
2000	875	3,130	3,082	5,605	3,432	5,016	2,587	6,904	2,202	2,874	1,579	412	991	409	39,099	32,011	23,544

Table 19. Estimated bias adjusted fishing mortality (F) and exploitation rate for 4X cod.

	1	2	3	4	5	6	7	8	9	10	11	12	13	Avg F (4-5)	Expl. (4-5)
1983	0.00	0.11	0.29	0.34	0.54	0.67	0.64	0.57	0.58	0.61	0.56	0.45	0.58	0.42	0.31
1984	0.00	0.09	0.38	0.41	0.49	0.52	0.58	0.53	0.34	0.50	0.51	0.62	0.43	0.44	0.32
1985	0.00	0.06	0.24	0.45	0.62	0.73	0.58	0.51	0.43	0.53	0.34	0.22	0.43	0.54	0.38
1986	0.00	0.03	0.33	0.50	0.59	0.61	0.54	0.47	0.50	0.61	0.47	0.80	0.54	0.52	0.37
1987	0.00	0.04	0.17	0.43	0.58	0.72	0.72	0.70	0.71	0.81	1.10	0.34	0.75	0.47	0.34
1988	0.00	0.03	0.25	0.53	0.67	0.85	0.57	0.67	0.60	0.64	1.02	0.60	0.66	0.59	0.41
1989	0.00	0.03	0.27	0.44	0.39	0.55	0.52	0.54	0.45	0.25	0.24	1.46	0.41	0.44	0.32
1990	0.00	0.02	0.20	0.52	0.61	0.61	0.59	0.51	0.57	0.59	0.30	0.66	0.53	0.56	0.39
1991	0.00	0.04	0.33	0.63	0.75	0.84	0.58	0.79	0.40	0.48	1.23	0.60	0.60	0.66	0.44
1992	0.00	0.07	0.54	0.88	1.15	1.09	0.90	0.31	0.64	0.35	0.54	0.54	0.00	1.04	0.60
1993	0.00	0.12	0.51	0.74	0.92	0.77	0.70	0.35	0.10	0.35	0.17	0.00	0.00	0.78	0.50
1994	0.00	0.04	0.53	0.73	0.87	0.79	0.47	0.31	0.10	0.01	0.07	0.00	0.00	0.77	0.49
1995	0.00	0.02	0.23	0.52	0.42	0.29	0.24	0.18	0.12	0.03	0.01	0.00	0.00	0.48	0.35
1996	0.00	0.01	0.19	0.48	0.42	0.26	0.09	0.21	0.05	0.03	0.01	0.01	0.00	0.47	0.34
1997	0.00	0.02	0.26	0.60	0.43	0.33	0.15	0.07	0.04	0.04	0.02	0.03	0.00	0.51	0.37
1998	0.00	0.04	0.32	0.40	0.50	0.27	0.14	0.05	0.03	0.05	0.03	0.02	0.01	0.44	0.32
1999	0.00	0.02	0.21	0.33	0.23	0.41	0.11	0.07	0.02	0.00	0.00	0.01	0.00	0.28	0.22
2000	0.00	0.01	0.13	0.29	0.23	0.15	0.12	0.02	0.03	0.00	0.00	0.00	0.00	0.27	0.22

Table 20. Estimates of q for the RV survey, derived from a formulation where F is estimated in ADAPT only to age 7 and F_{8+} was set equal to the average F_{5-7}.

q	2	3	4	5	6	7	8	9	10	avg 4-7
1983.5	0.01	0.23	0.35	0.42	0.45	0.39		0.37	0.27	0.40
1984.5	0.08	0.22	0.24	0.49	0.42	0.48	0.12	0.18	0.27	0.41
1985.5	0.06	0.37	0.18	0.32	0.48	0.67	0.56	0.69	0.08	0.41
1986.5	0.03	0.22	0.17	0.08	0.31	0.63	0.63	0.48	0.25	0.30
1987.5	0.11	0.09	0.15	0.13	0.13	0.30	0.88	0.47	0.42	0.18
1988.5	0.04			0.38	0.26	0.23	0.60	0.55	0.40	0.29
1989.5	0.16	0.39	0.62	0.24	0.29	0.15	0.06	0.42	0.37	0.32
1990.5	0.01	1.05	0.51	1.39	0.35	0.62	0.27	0.20		0.72
1991.5	0.03	0.08	0.94	0.48	1.03	0.45	0.43	0.12	0.24	0.72
1992.5	0.04	0.17	0.09	1.37	0.55	2.28	1.09	0.70		1.07
1993.5	0.05	0.17	0.17	0.03	0.37	0.12	0.52		0.10	0.17
1994.5	0.07	0.58	0.20	0.18	0.02	0.78	0.48	1.53		0.30
1995.5	0.03	0.71	0.64	0.22	0.37	0.29	1.76	0.72	3.93	0.38
1996.5	0.05	0.34	2.24	1.45	1.19	0.81		4.68	1.05	1.42
1997.5	0.02	0.31	0.62	3.18	1.82	0.94	1.85		23.52	1.64
1998.5	0.07	0.22	0.83	1.54	9.93	6.21	2.09	0.44		4.63
1999.5	0.05	0.28	0.20	1.13	0.75	6.06	3.66			2.04
2000.5	0.14	0.18	0.35	0.23	0.97	1.76	6.08			0.83
Average	0.06	0.33	0.50	0.74	1.09	1.29	1.32	0.82	2.57	0.90

Table 21. Annual and average partial recruitment values for cod in Division 4X.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1990	0.000	0.039	0.350	0.929	1.092	1.090	1.057	0.908	1.013	1.045	0.535	1.175	0.944
1991	0.000	0.059	0.506	0.958	1.135	1.274	0.877	1.210	0.608	0.731	1.867	0.915	0.915
1992	0.000	0.066	0.519	0.845	1.105	1.047	0.864	0.302	0.613	0.335	0.522	0.522	0.000
1993	0.000	0.158	0.654	0.950	1.179	0.989	0.896	0.452	0.127	0.451	0.214	0.000	0.000
1994	0.000	0.048	0.695	0.953	1.132	1.031	0.618	0.411	0.130	0.012	0.097	0.000	0.000
1995	0.000	0.045	0.480	1.082	0.870	0.595	0.494	0.368	0.246	0.068	0.022	0.000	0.000
1996	0.000	0.018	0.405	1.022	0.884	0.555	0.192	0.439	0.098	0.057	0.016	0.028	0.000
1997	0.000	0.029	0.512	1.166	0.832	0.651	0.298	0.133	0.070	0.085	0.031	0.051	0.000
1998	0.000	0.097	0.740	0.923	1.151	0.629	0.321	0.115	0.075	0.104	0.062	0.041	0.020
1999	0.000	0.063	0.726	1.170	0.807	1.457	0.388	0.247	0.078	0.000	0.000	0.039	0.000
2000	0.000	0.018	0.478	1.064	0.830	0.541	0.422	0.083	0.093	0.000	0.000	0.000	0.000
Avg. 95-9	0.000	0.047	0.534	1.048	0.934	0.607	0.326	0.264	0.122	0.078			
Avg. 95-9	0.000	0.050	0.573	1.073	0.909	0.777	0.339	0.260	0.113	0.063			
Avg. 96-9	0.000	0.052	0.596	1.070	0.919	0.823	0.300	0.233	0.080	0.061			

Table 22. Deterministic projection results for cod in Division 4X for 2000 at $F_{0.1}$ using the bootstrap bias adjusted population abundance at the beginning of 2000.

Year	Age Group																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1+	4+	4-8
Population Numbers (000s)																	
2001.25	7500	6197	7734	2111	1620	628	686	295	639	173	203	98	24	50			
2002.25	7500	6140	4993	5219	1252	961	404	502	223	499	137	166	81	20			
Partial Recruitment to the Fishery																	
	0.00	0.05	0.60	1.00	1.00	0.75	0.35	0.25	0.15	0.10	0.00	0.00	0.00	0.00			
Fishing Mortality																	
2000.5	0.000	0.018	0.220	0.366	0.366	0.275	0.128	0.092	0.055	0.037	0.000	0.000	0.000	0.000			
2001.25	0.000	0.016	0.193	0.322	0.322	0.242	0.113	0.081	0.048	0.032	0.000	0.000	0.000	0.000			
Weight at beginning of year for population (kg)																	
	0.28	0.73	1.12	1.81	2.69	3.68	4.61	6.62	8.14	12.34	14.69	15.20	15.50	16.00			
Beginning of Year Projected Population Biomass (t)																	
2001.25	2100	4499	8663	3814	4357	2310	3159	1956	5202	2138	2975	1495	371	797	43836	28574	15600
2002.25	2100	4458	5592	9430	3367	3532	1860	3321	1815	6153	2017	2521	1248	314	47731	35581	21600
Projected Catch Numbers (000s)																	
2000.5	0	115	409	554	215	170	32	49	8	6	0	0	0	0			
2001.25	0	90	1237	530	407	123	66	21	27	5	0	0	0	0			
Average weight at age for catch (kg)																	
	0.70	1.05	1.56	2.34	3.47	4.84	5.80	8.21	10.42	11.68	12.85	14.45	15.50	16.00			
Projected Yield (t)																	
2000.5	0	122	638	1295	746	822	187	403	82	71	0	0	0	0	4365	3605	
2001.25	0	93	1859	1194	1382	583	379	169	282	58	0	0	0	0	6000	4048	

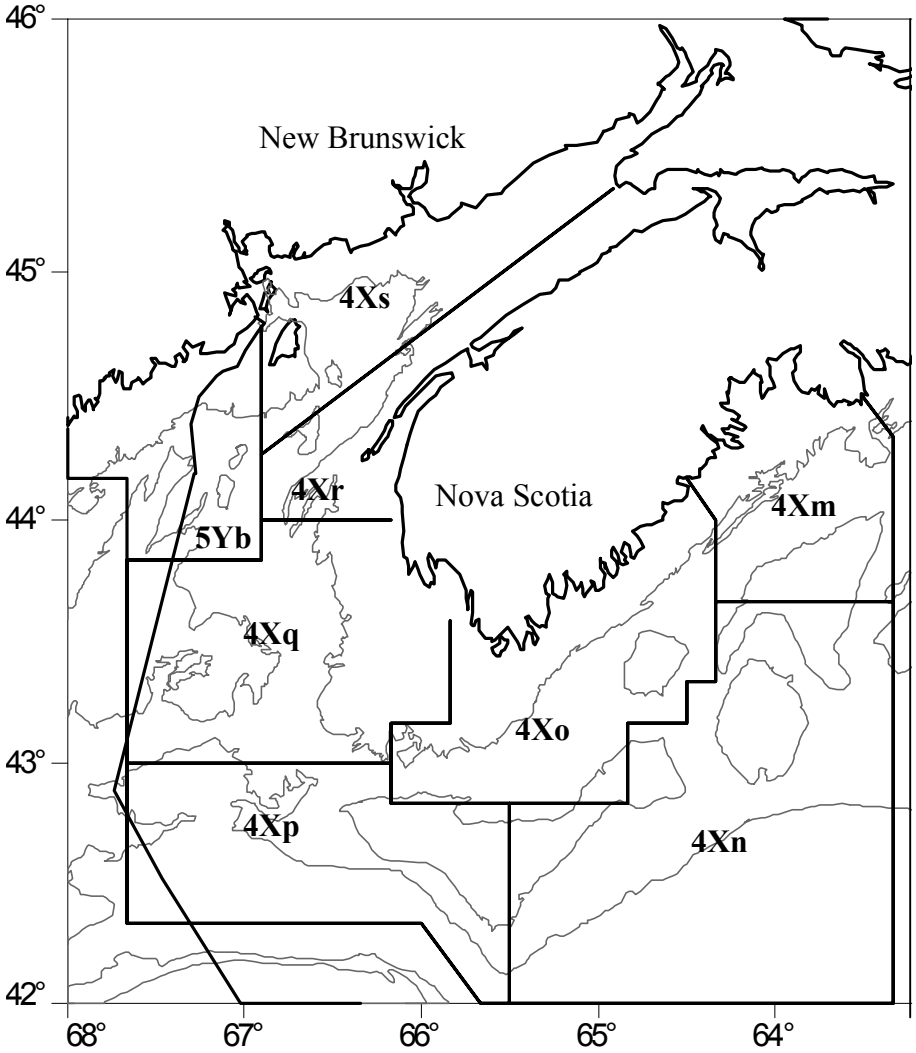

Fig. 1. Canadian statistical unit areas in NAFO divisions 4X and 5Y.

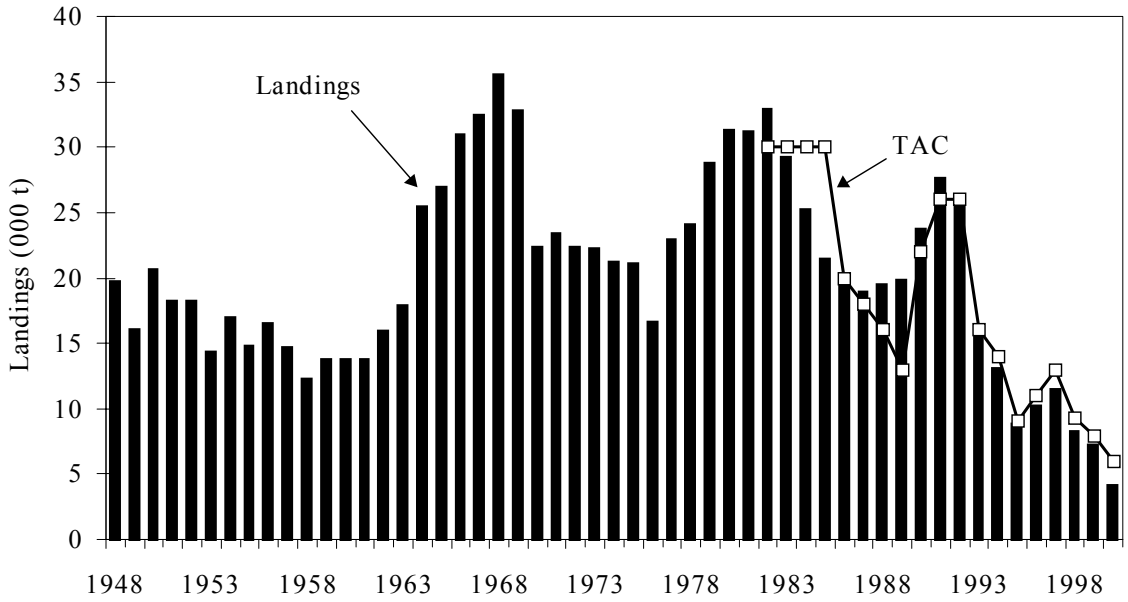

Fig. 2. Nominal landings of cod in Division 4X including catches by Canada in Division 5Y. For 2000, quota and mid-year landings are shown.

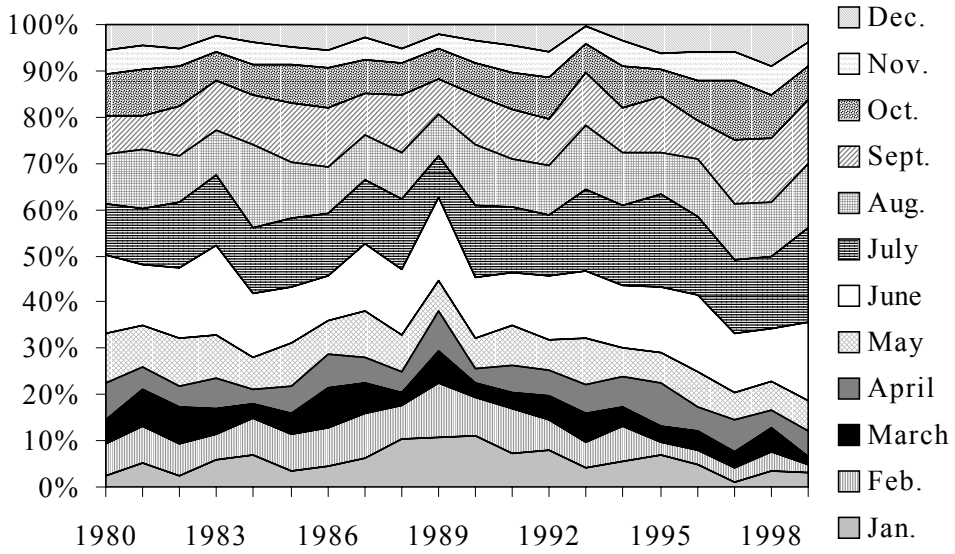

Fig. 3. Proportional catch of Division 4X cod by month.

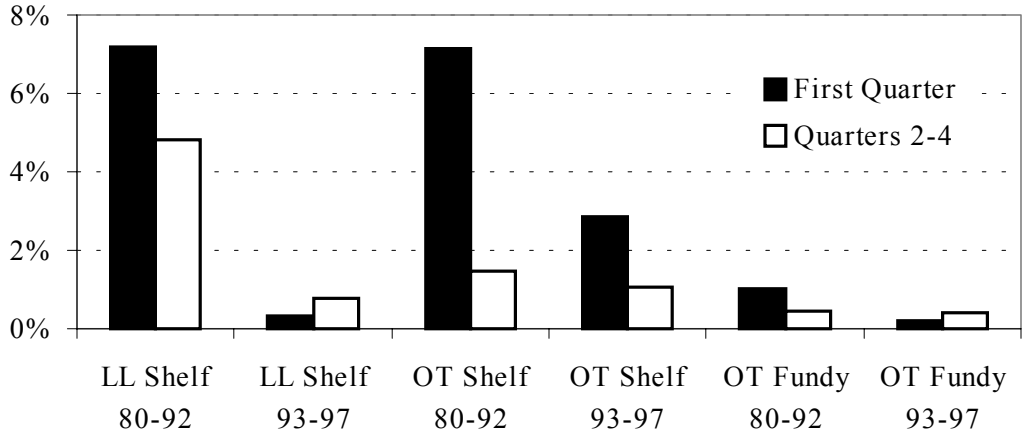

Fig. 4. Proportion of quarterly numbers of cod caught aged 8+ by longline and otter trawl vessels in the Bay of Fundy and Scotian Shelf.

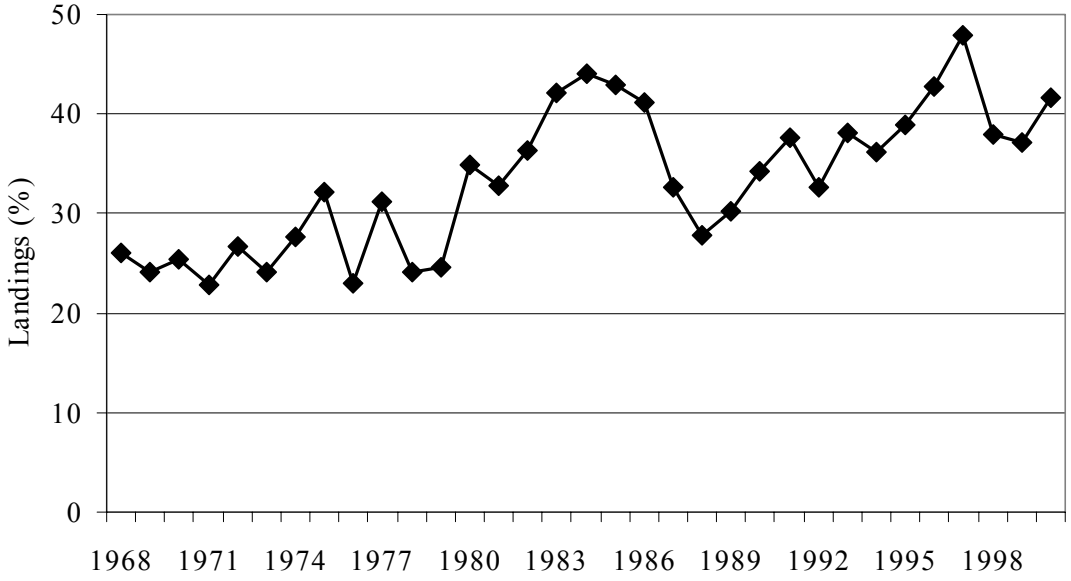

Fig. 5. Proportion of 4X cod landings taken from the Bay of Fundy.

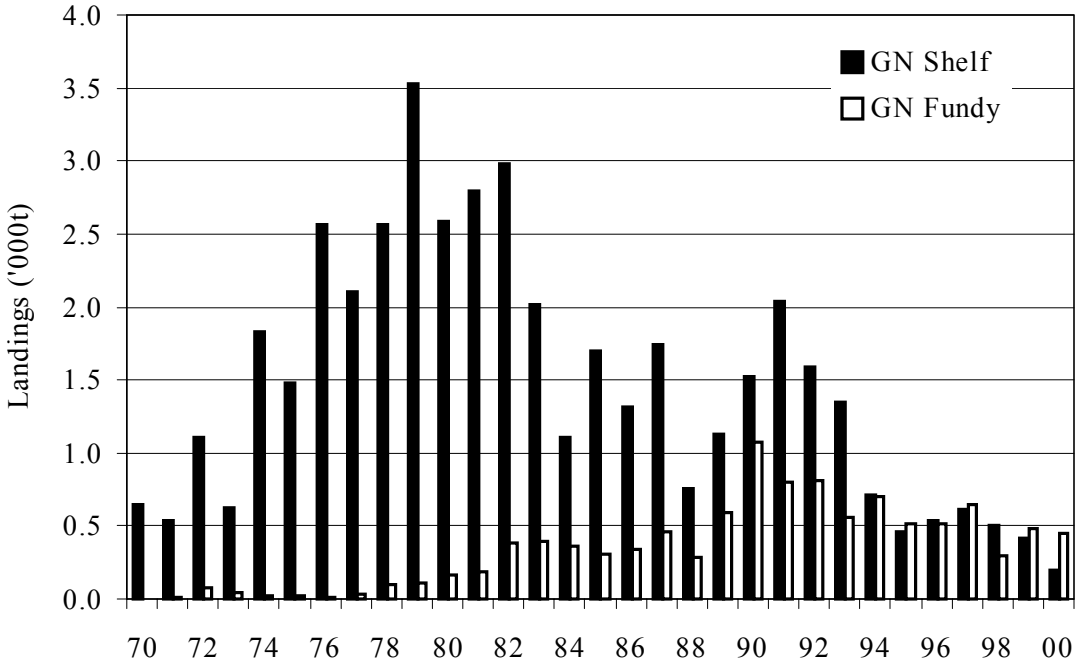

Fig. 6a. Annual landings by gill net vessels in the Bay of Fundy and Scotian Shelf.

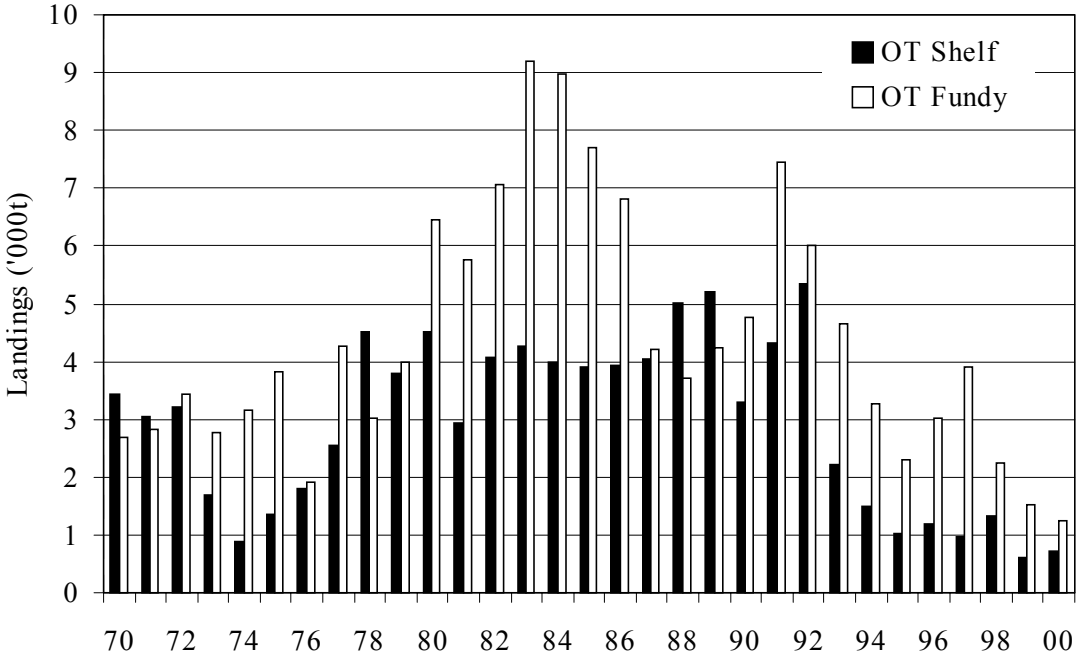

Fig. 6b. Annual landings by otter trawl vessels in the Bay of Fundy and Scotian Shelf.

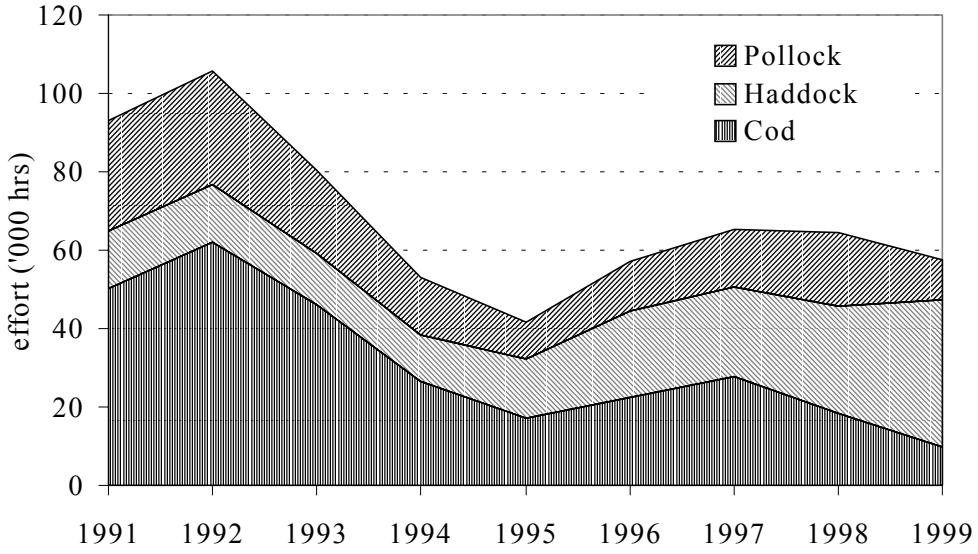

Fig. 7. Fishing effort (in hours fished) expended by otter trawl (TC 1-3) fleet.

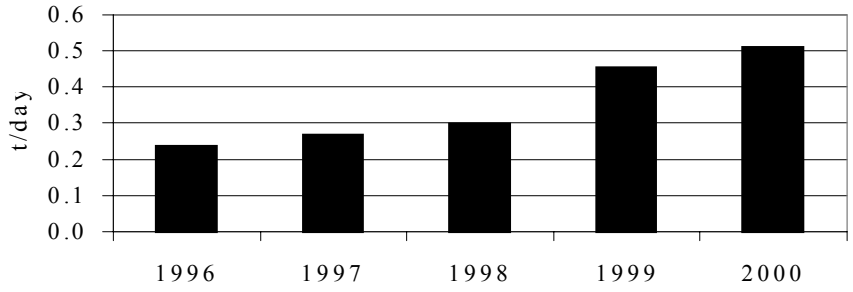

Fig. 8a. Gillnet catch rate for cod in Division 4X.

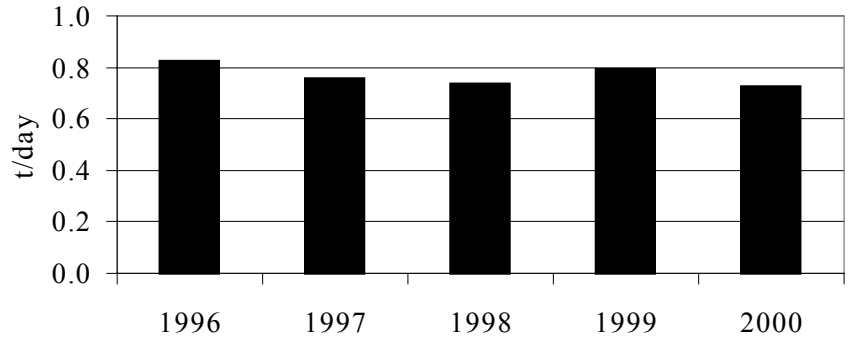

Fig.8b. Catch rates for longliners (TC 1) for cod in Division 4X (June – Sept.).

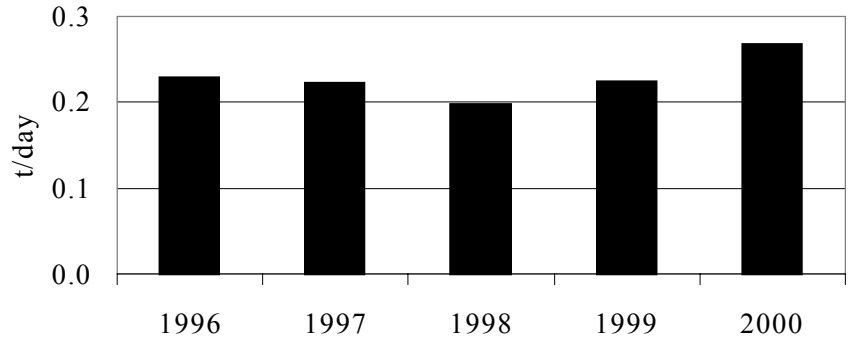

Fig. 8c. Handline catch rate for cod in Division 4X (May – August).

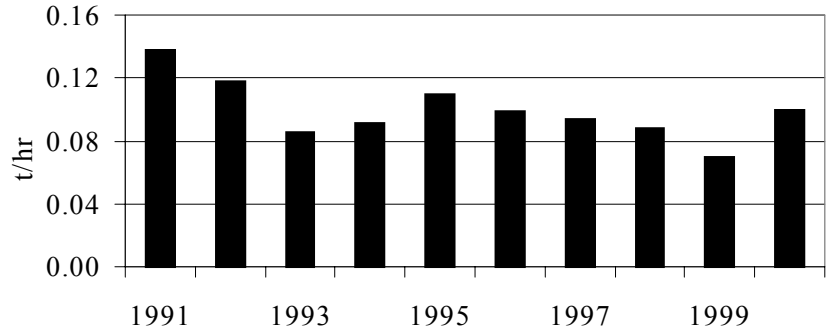

Fig. 8d. Otter trawl catch rate for cod in Division 4X.

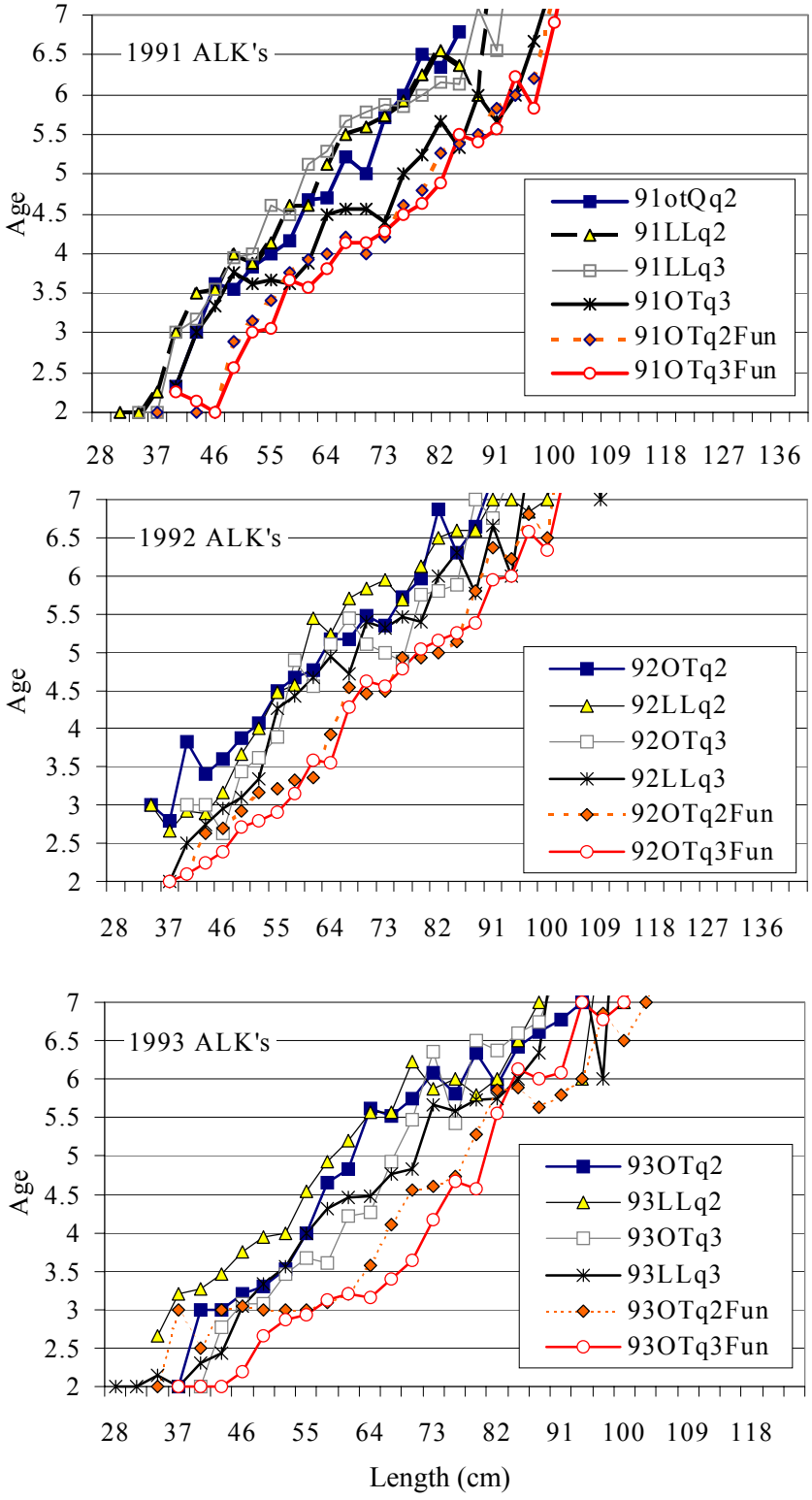

Fig. 9. 4X cod age at length comparisons from age length keys for otter trawl (OT) and longline (LL) in the second and third quarters of the year on the Shelf and in the Bay of Fundy (Fun) for 1991 – 1993.

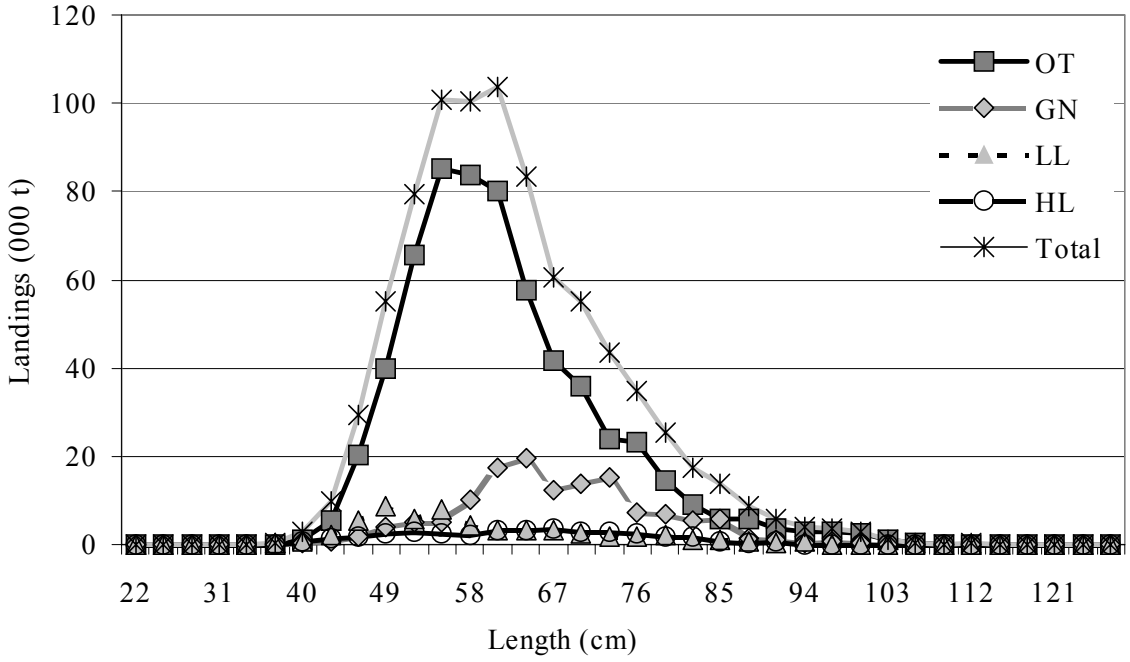

Fig. 10a. Length frequencies for 4X cod in the Bay of Fundy commercial fisheries 1999.

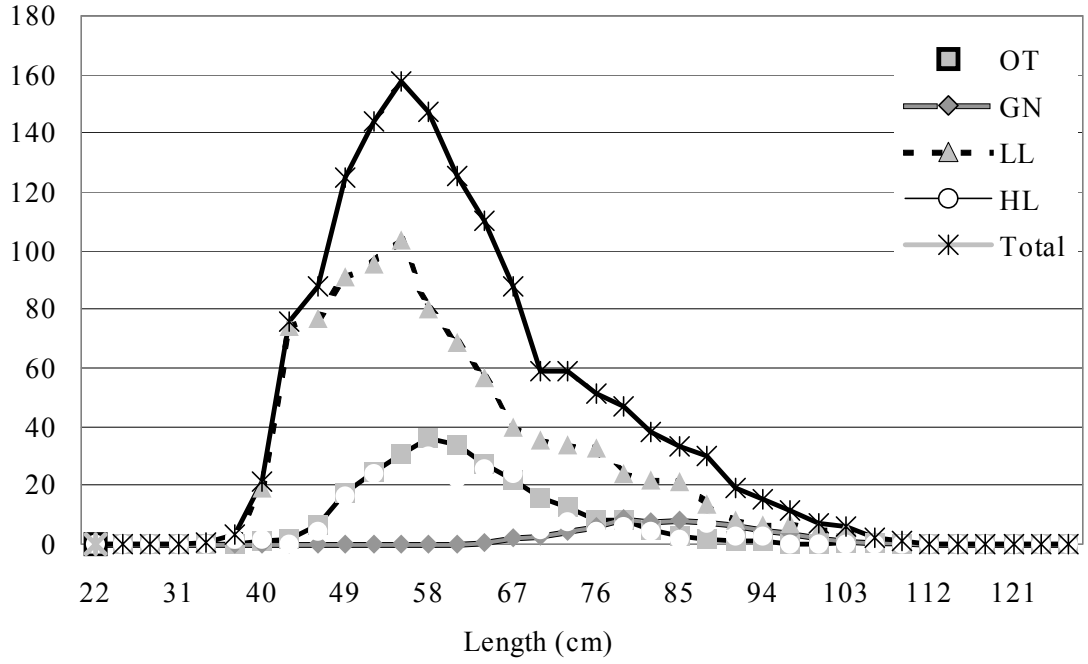

Fig. 10b. Length frequencies for 4X cod in the Scotian Shelf commercial fisheries 1999.

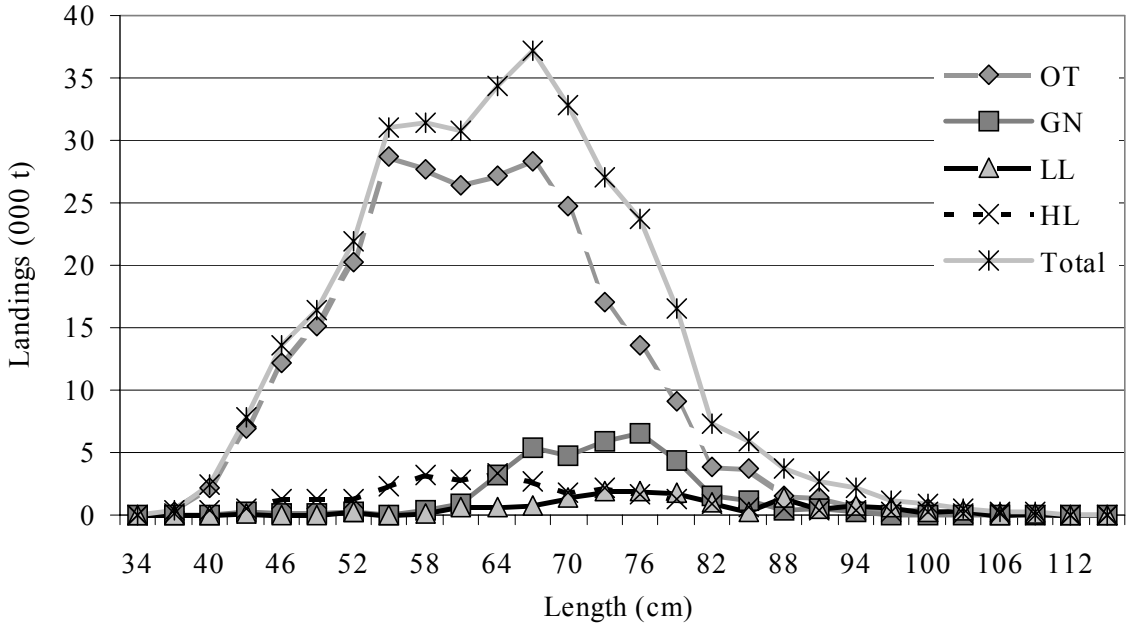

Fig. 11a. Length frequencies for 4X cod in the Bay of Fundy commercial fisheries Jan–Jul, 2000.

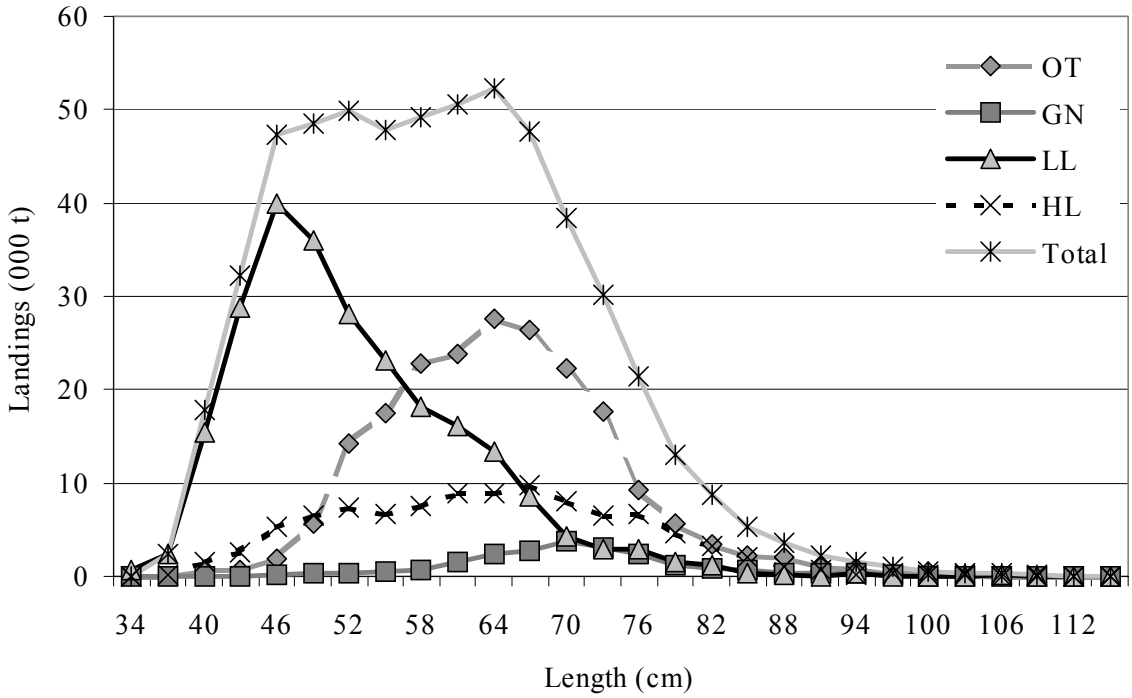

Fig. 11b. Length frequencies for 4X cod in the Scotian Shelf commercial fisheries Jan-Jul, 2000.

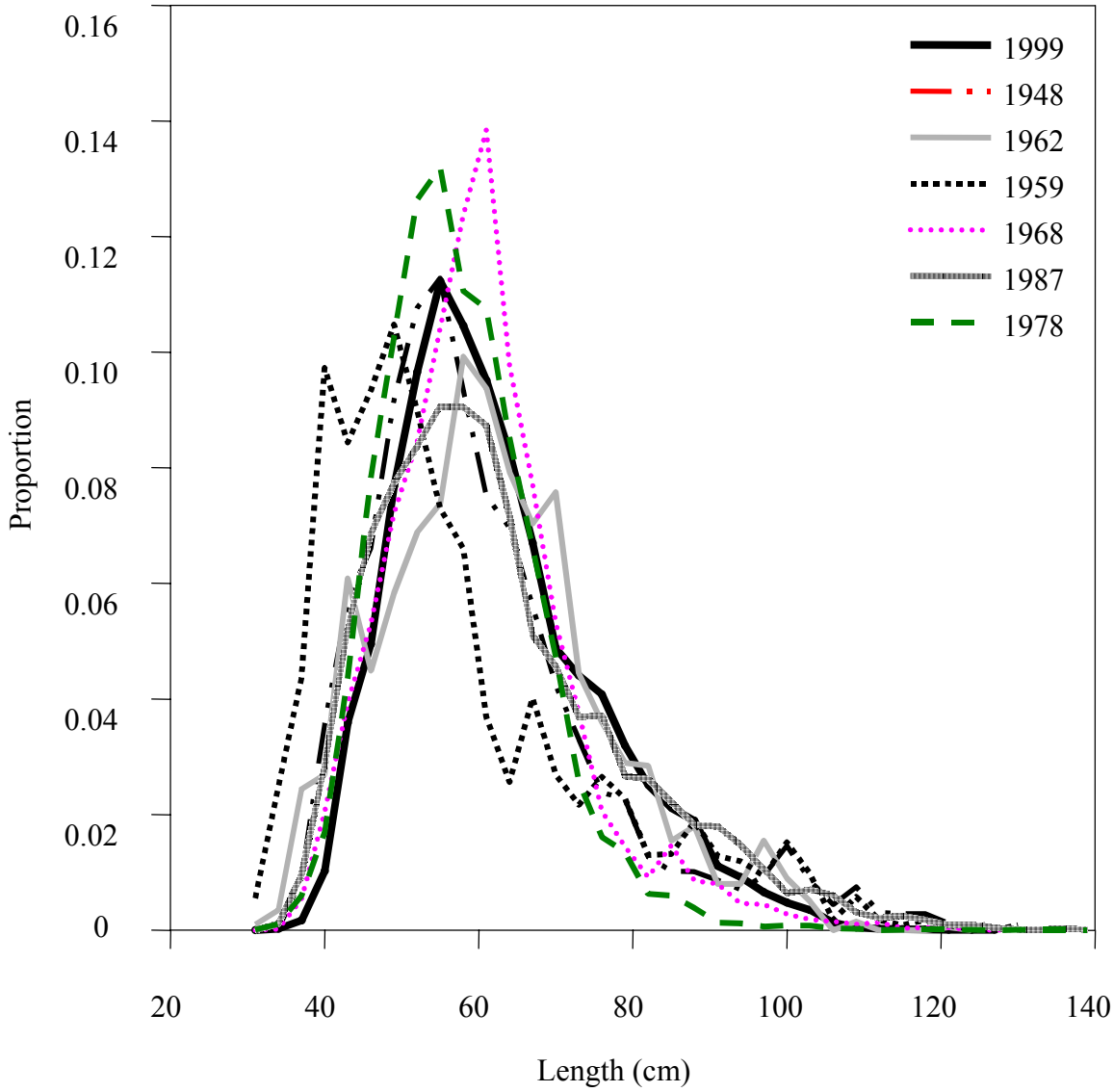

Fig. 12. Comparison of commercial length frequencies for 4X cod from 1999 with a series of years spanning the period from 1948 to 1987.

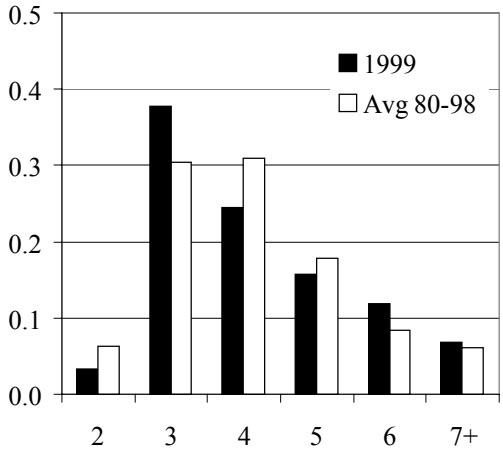

Fig. 13. Division 4X cod catch at age (numbers) for 1999 compared to the mean for 1980-1998.

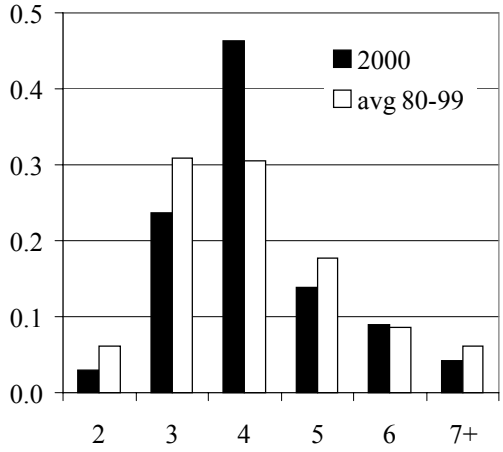

Fig. 14. Division 4X cod catch at age (numbers) for 2000 compared to the mean for 1980-1999.

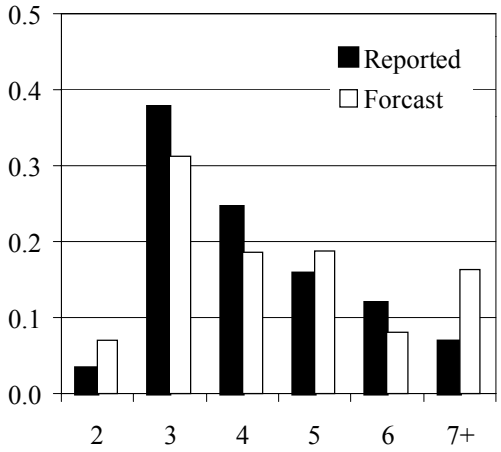

Fig. 15. Reported and forecast age composition for landings (numbers) of cod in Division 4X for 1999.

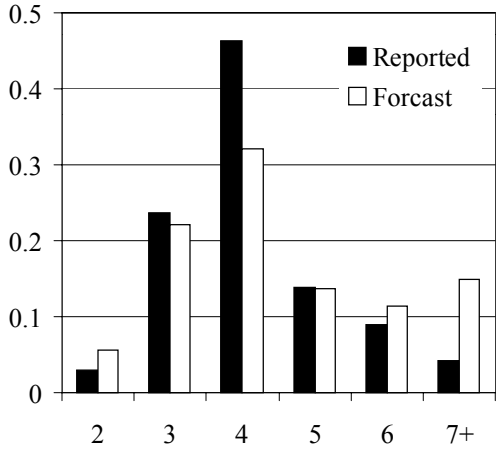

Fig. 16. Reported and forecast age composition for landings (numbers) of cod in Division 4X for 2000 (Jan. – Jul.).

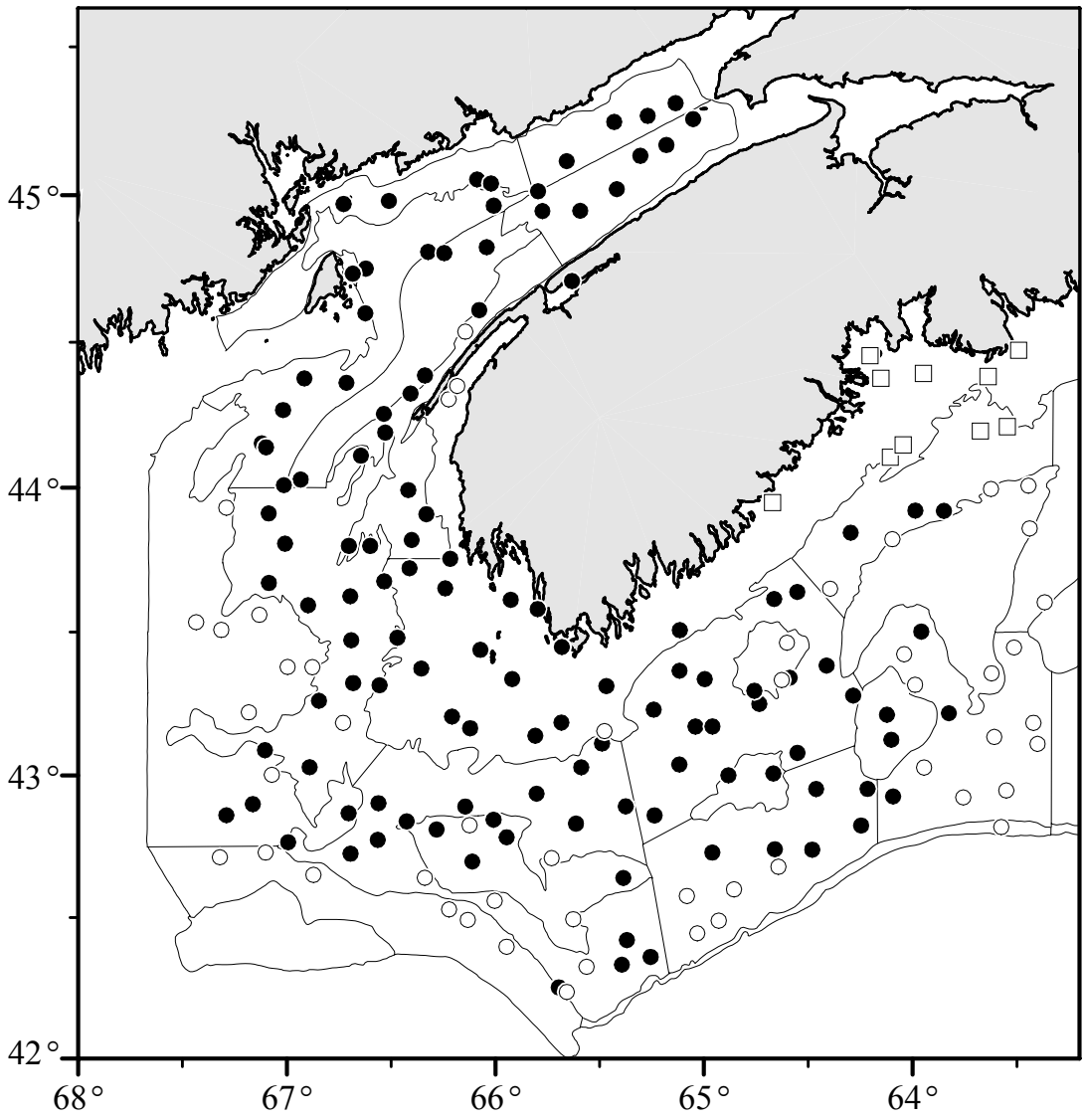

Fig. 17. ITQ survey station locations, 1995 to 2000 (● Stations sampled in all years, ○ Stations added in 1996, □ Stations added in 1998).

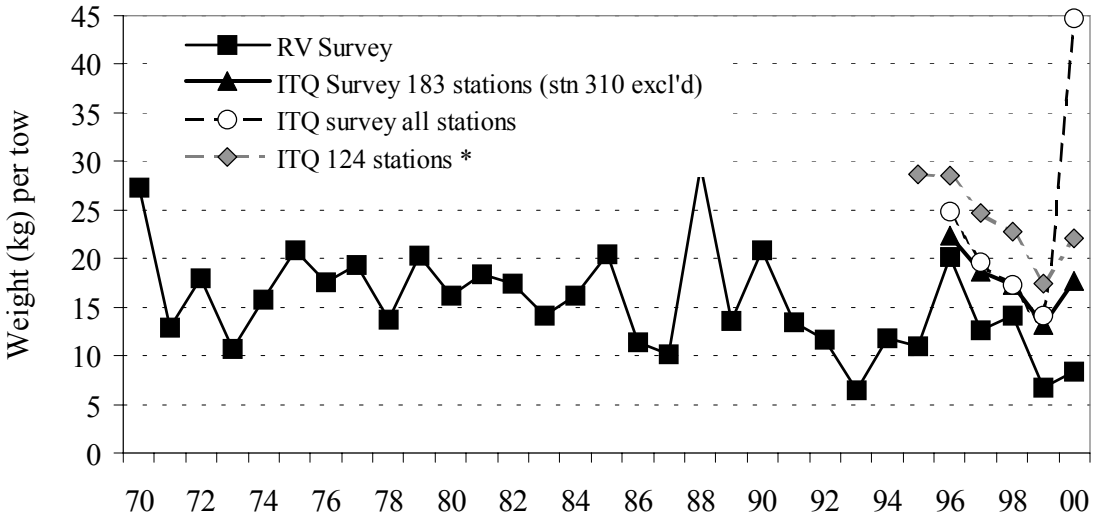

Fig. 18. Stratified mean weight (kg) per tow from the RV and ITQ surveys.
* set of stations sampled every year in all years of the ITQ survey.

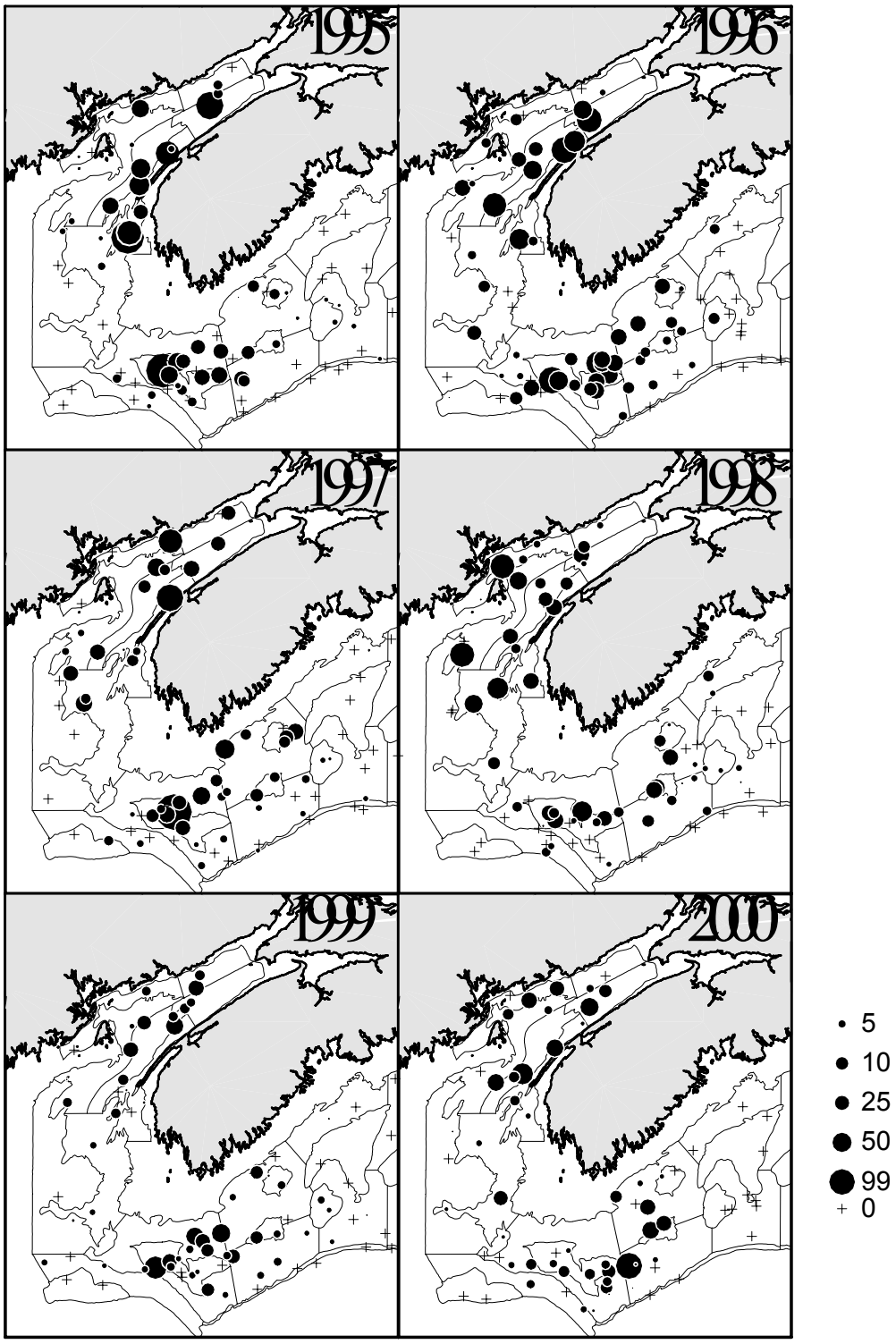

Fig. 19. RV summer groundfish survey 4X cod catches (kg/tow).

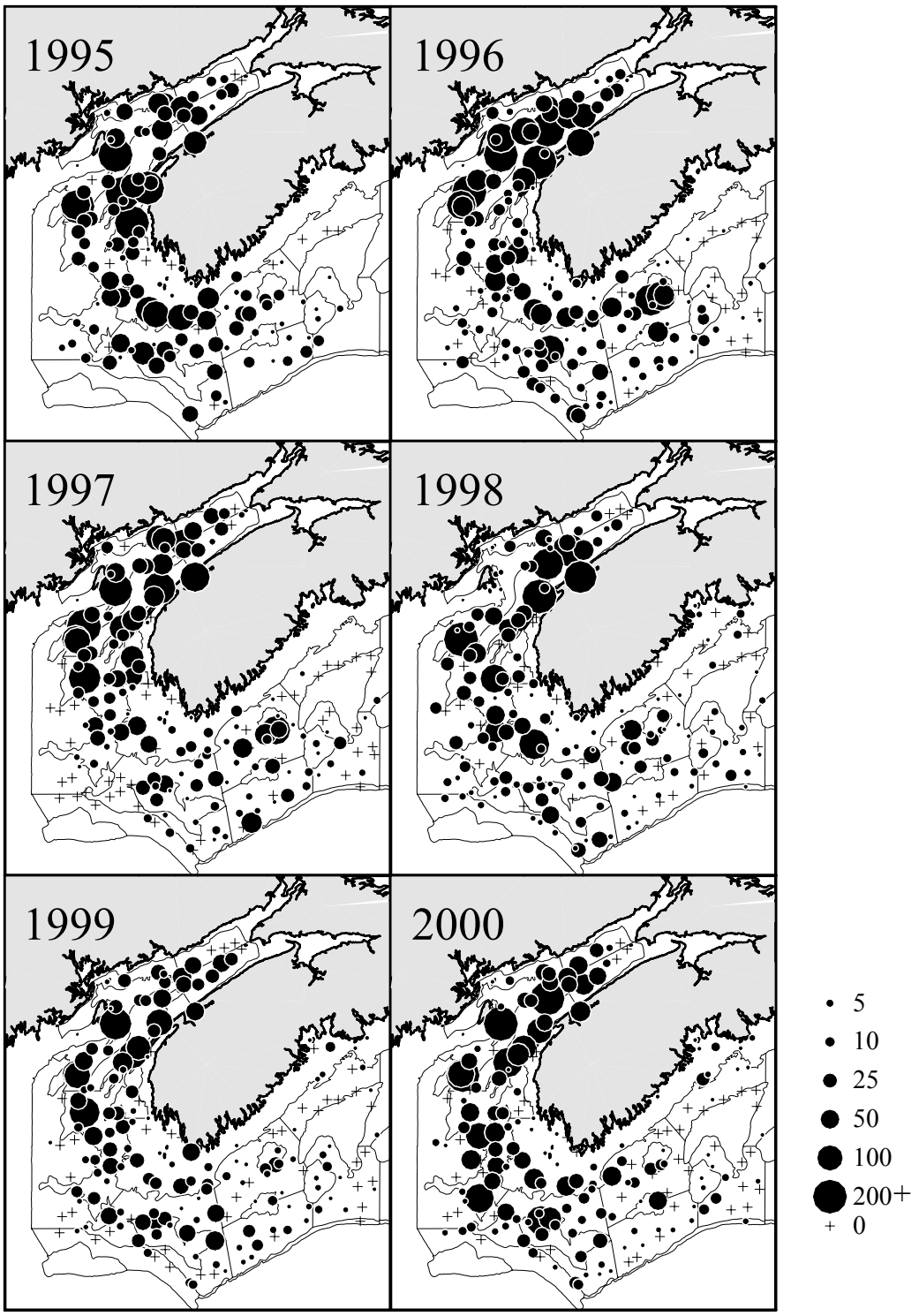

Fig. 20. Summer ITQ groundfish survey 4X cod catches (kg/tow).

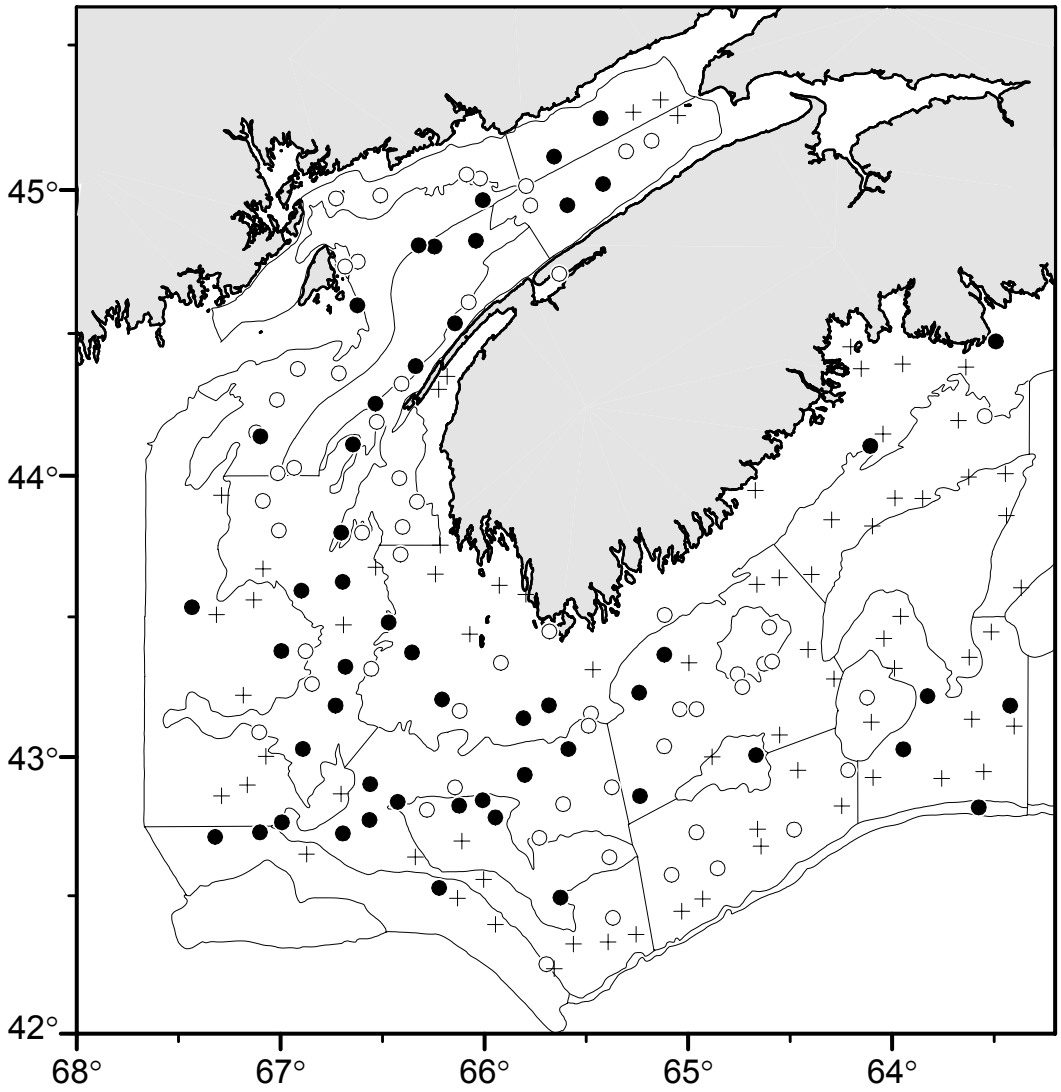

Fig. 21. A comparison of ITQ survey cod catches for 2000 with the median value for each station since 1995. ● 2000 value >median; + 2000 value is within 1 of the median; ○ 2000 value < median.

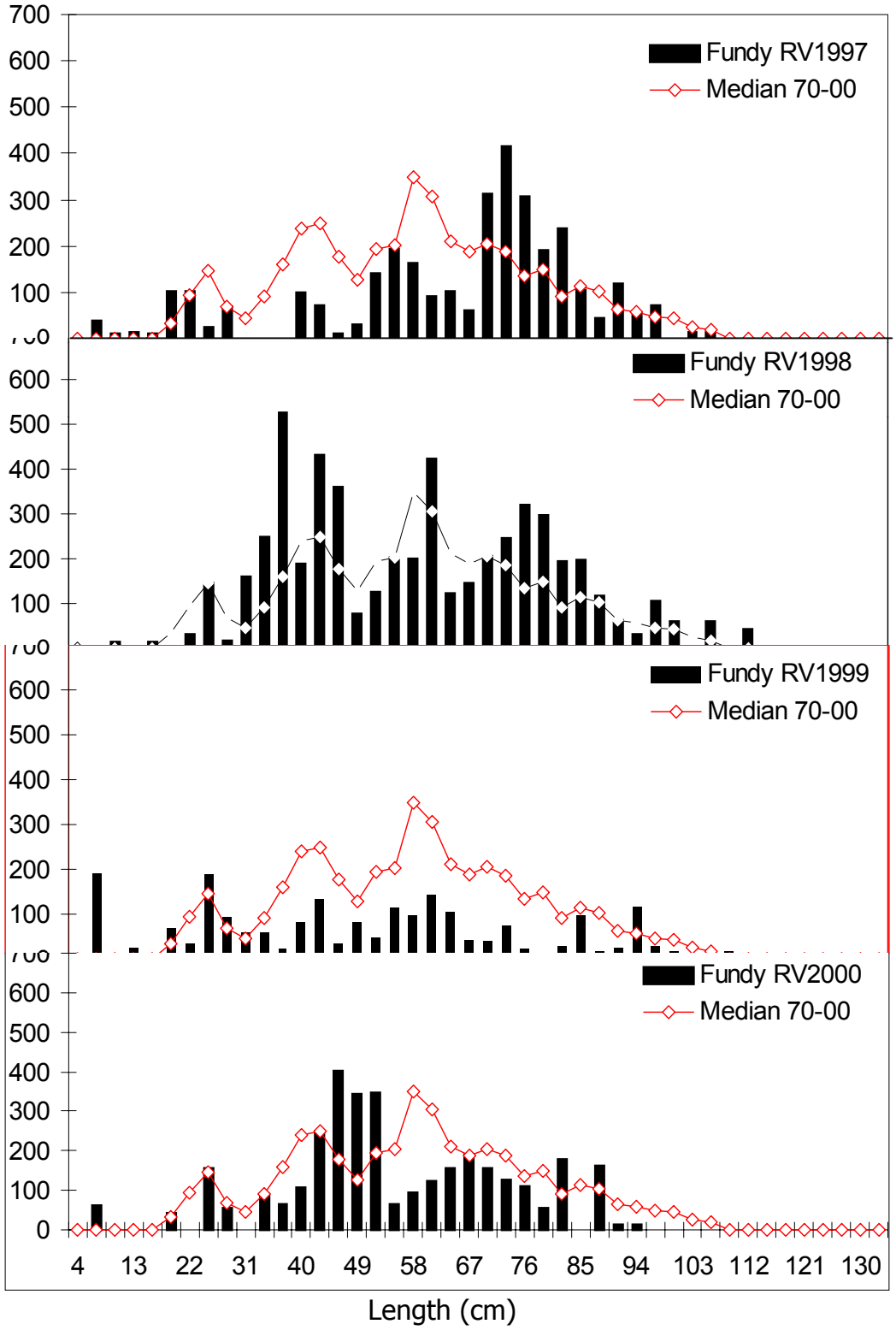

Fig. 22. Bay of Fundy length frequencies from RV summer groundfish survey compared to the 1970-2000 median.

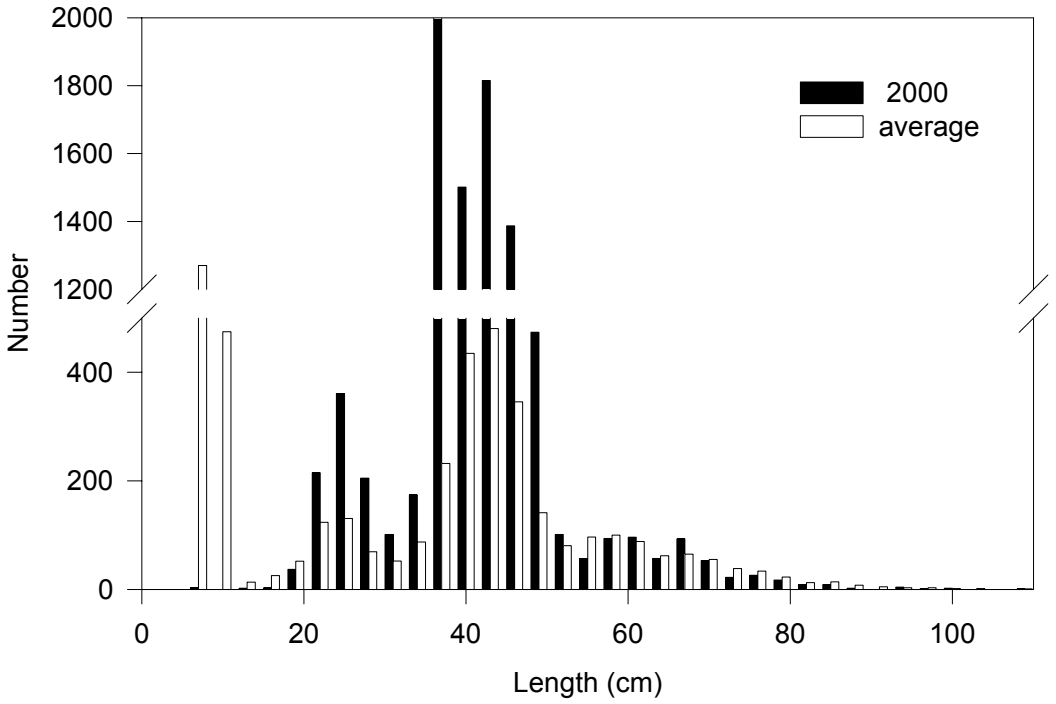

Fig. 23. Length frequency for cod from the 2000 ITQ survey in the Bay of Fundy compared with the average for 1996-2000.

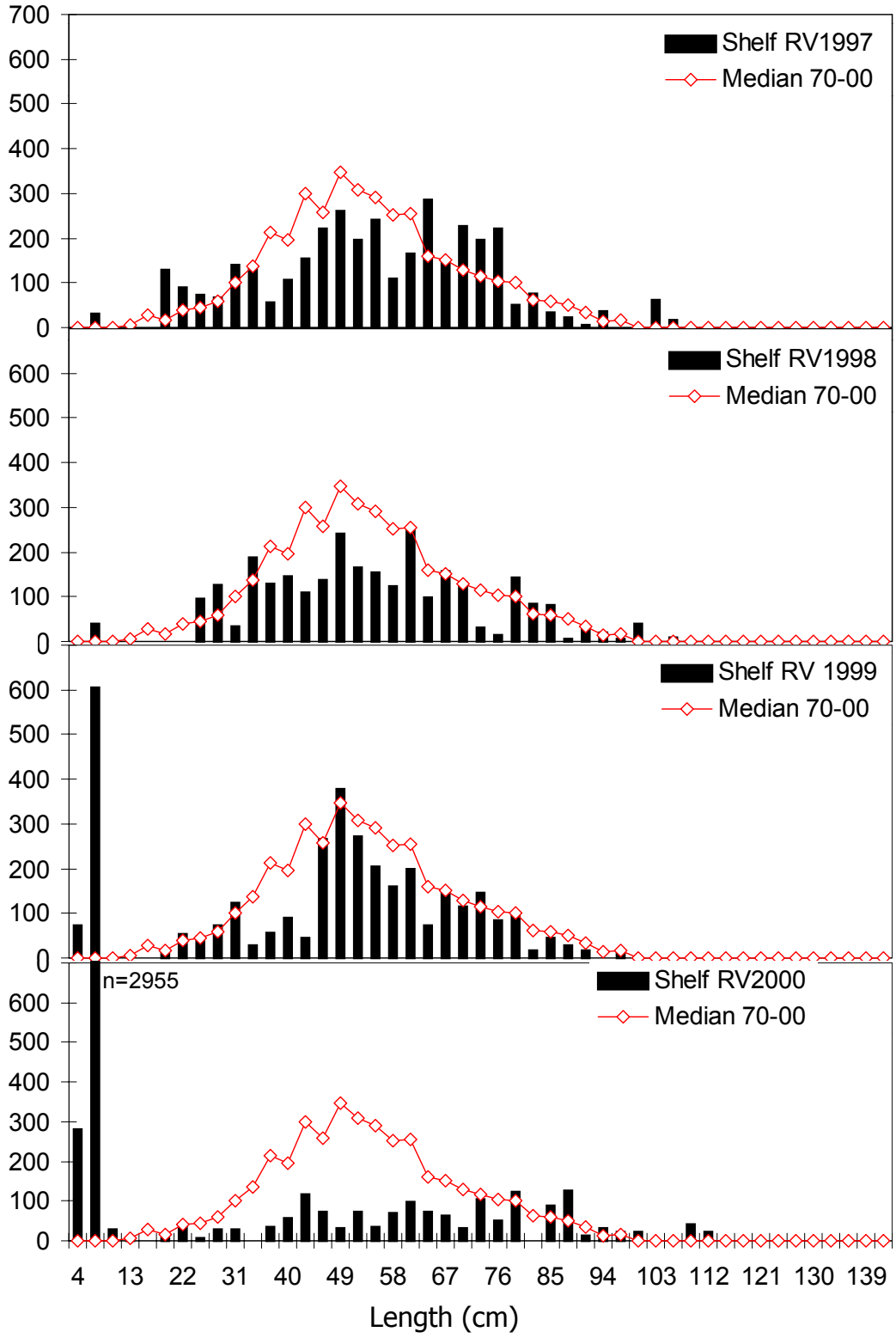

Fig. 24. Scotian shelf length frequencies from RV summer groundfish survey compared to the 1970-2000 median.

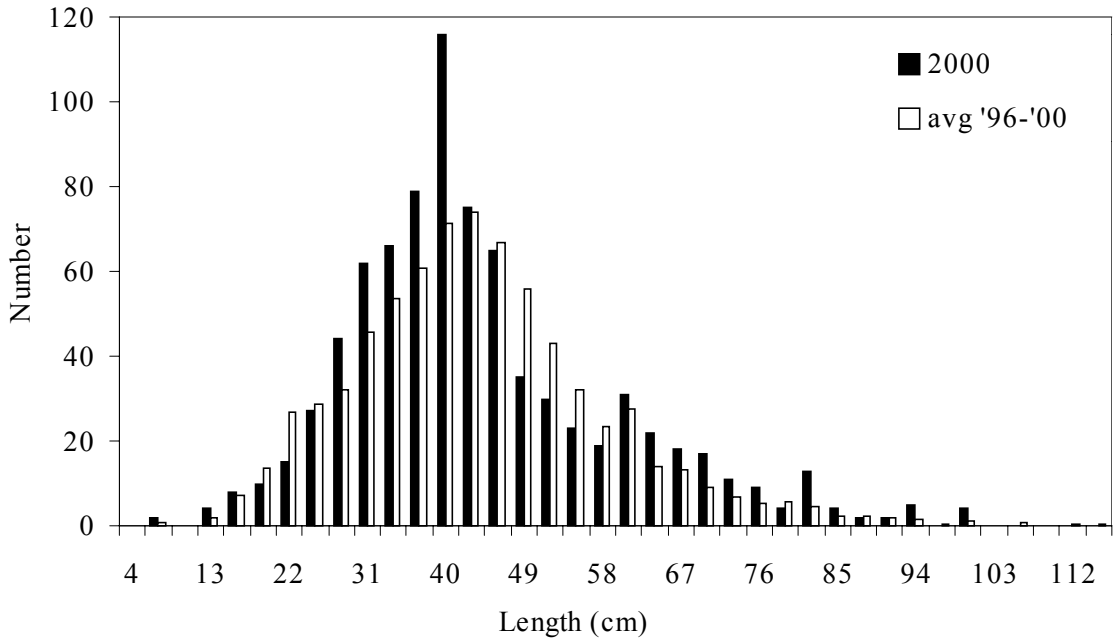

Fig. 25. Length frequency for cod from the 2000 ITQ survey on the Scotian Shelf compared with the average for 1996-2000.

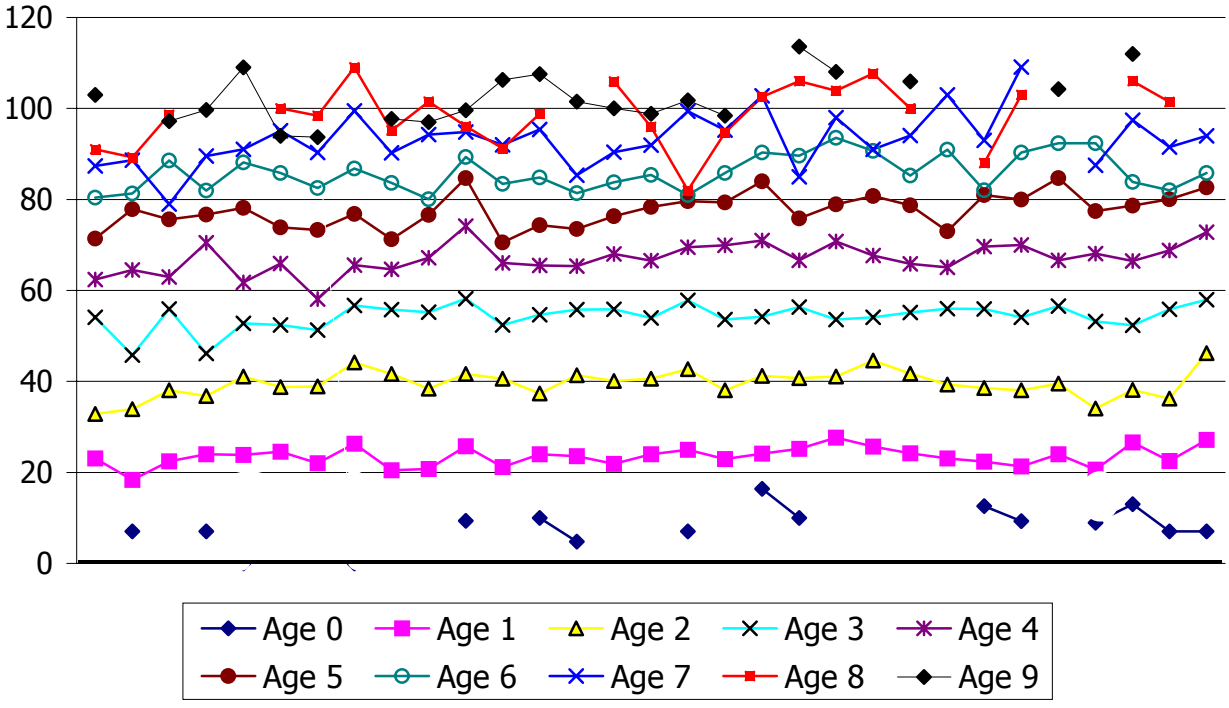

Fig. 26a. Length (cm) at age of Bay of Fundy (strata 484-495) 4X cod from RV summer groundfish survey series.

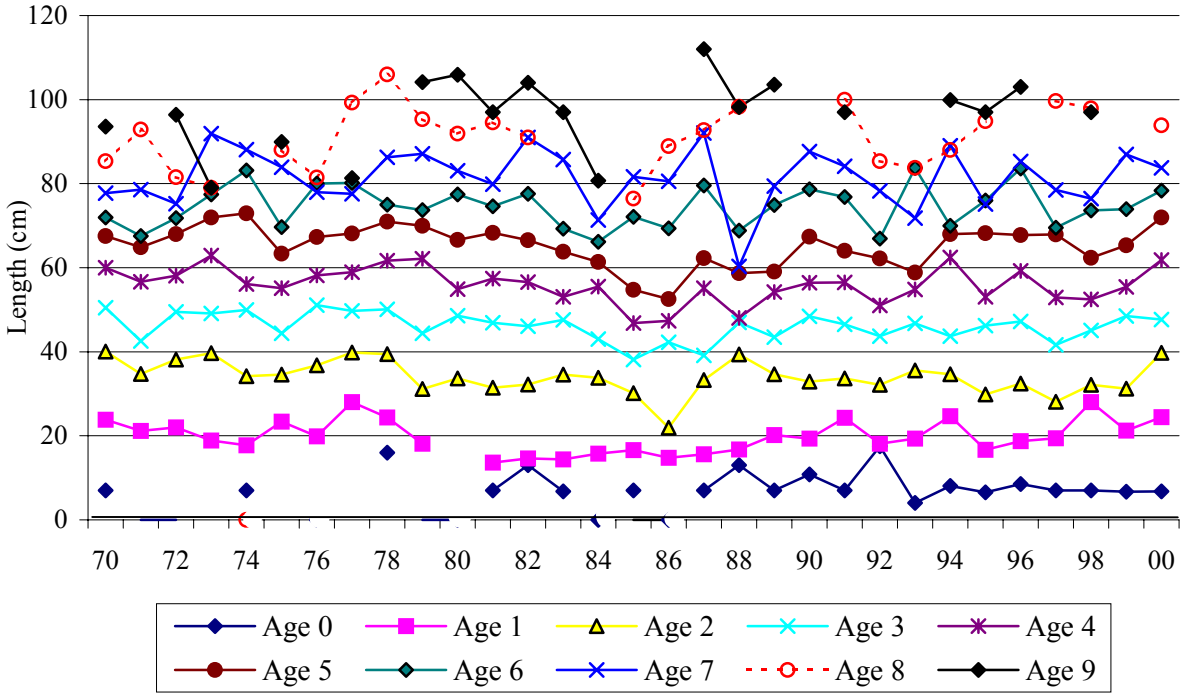

Fig. 26b. Length (cm) at age of Scotian Shelf (strata 470-483) 4X cod from RV summer groundfish survey series.

Fig. 27. Condition of 4X cod at 50 cm from RV summer groundfish survey.

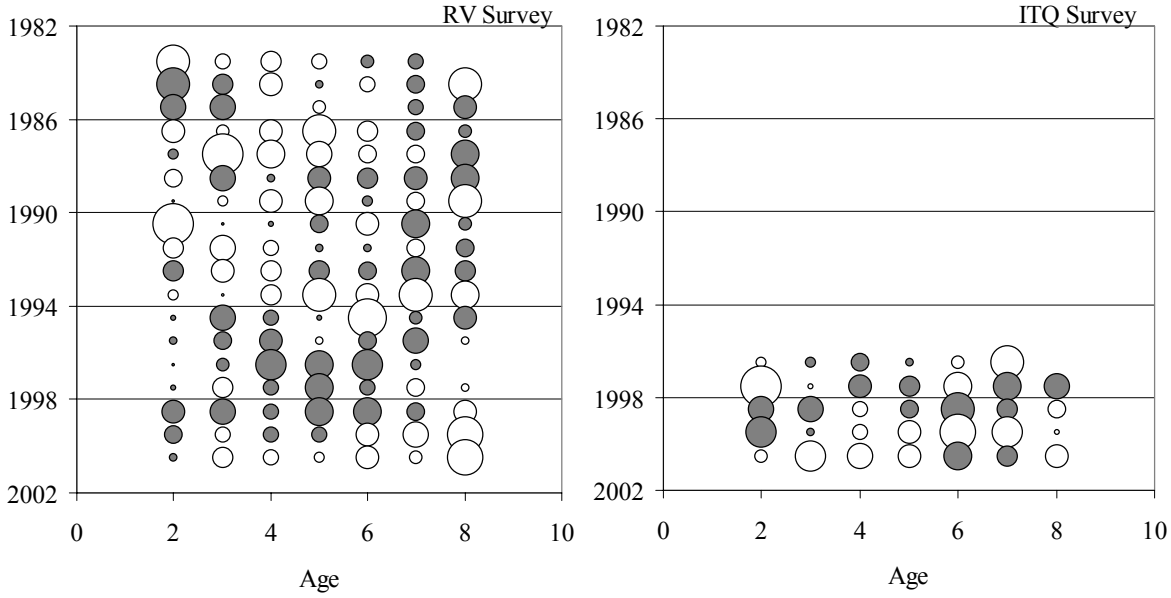

Fig. 28. Residuals by year and age group for each survey index. Solid symbols indicate positive values, open symbols indicate negative values. Bubble area is proportional to magnitude.

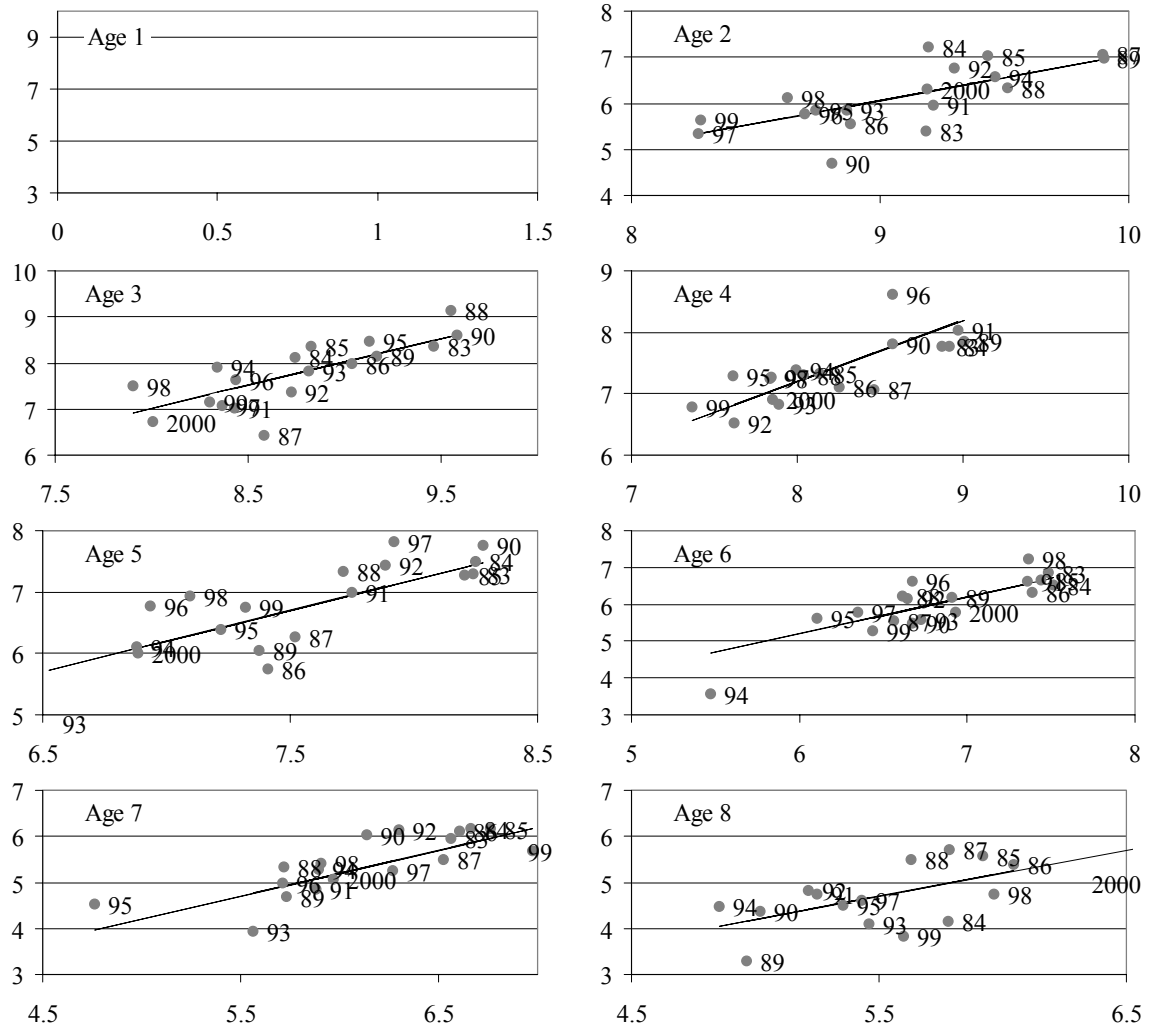

Fig. 29a. Age by age plots of the observed and predicted ln abundance index versus ln population numbers for cod in Division 4X from the RV survey.

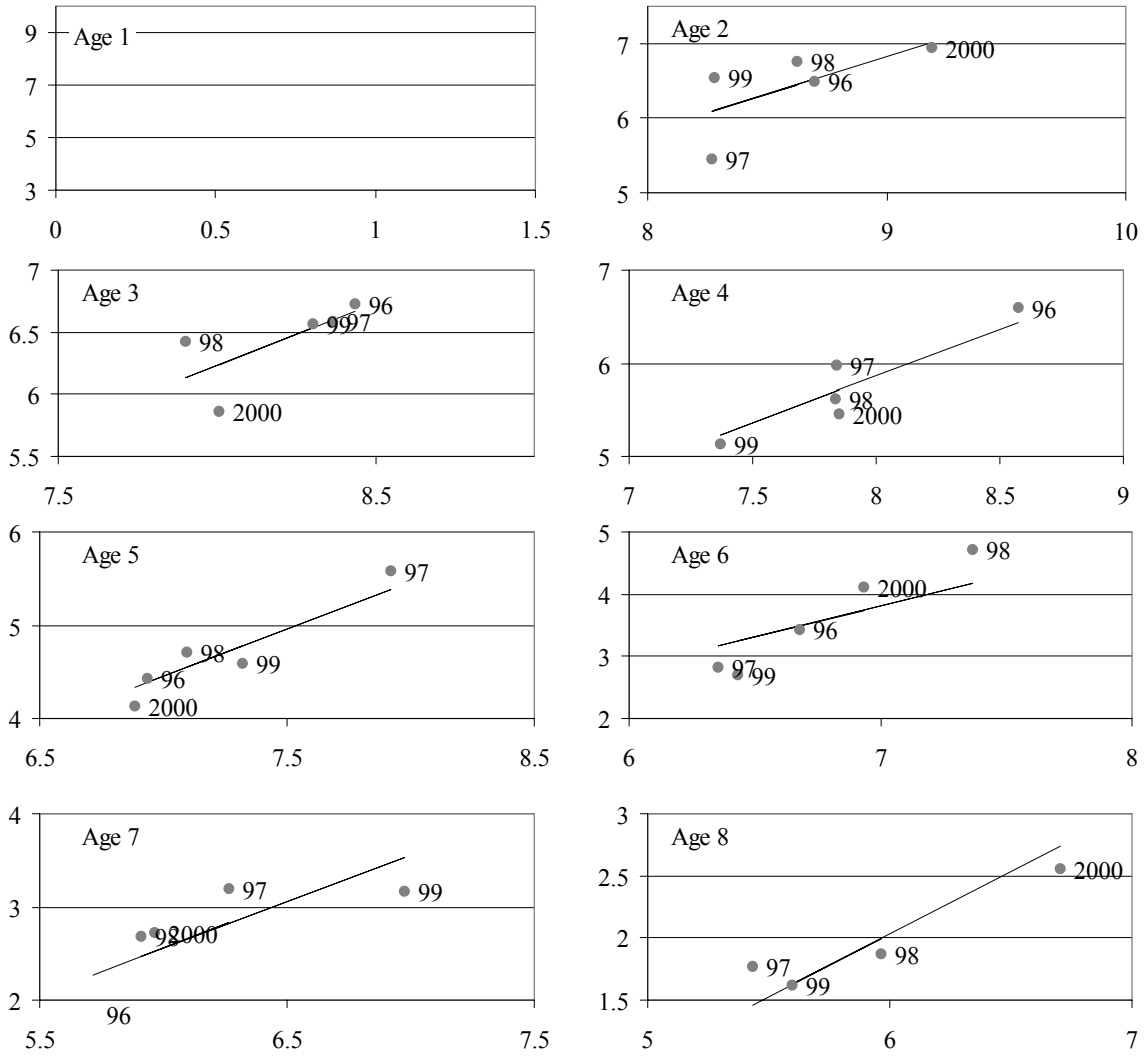

Fig. 29b. Age by age plots of the observed and predicted ln abundance index versus ln population numbers for cod in Division 4X from the ITQ survey.

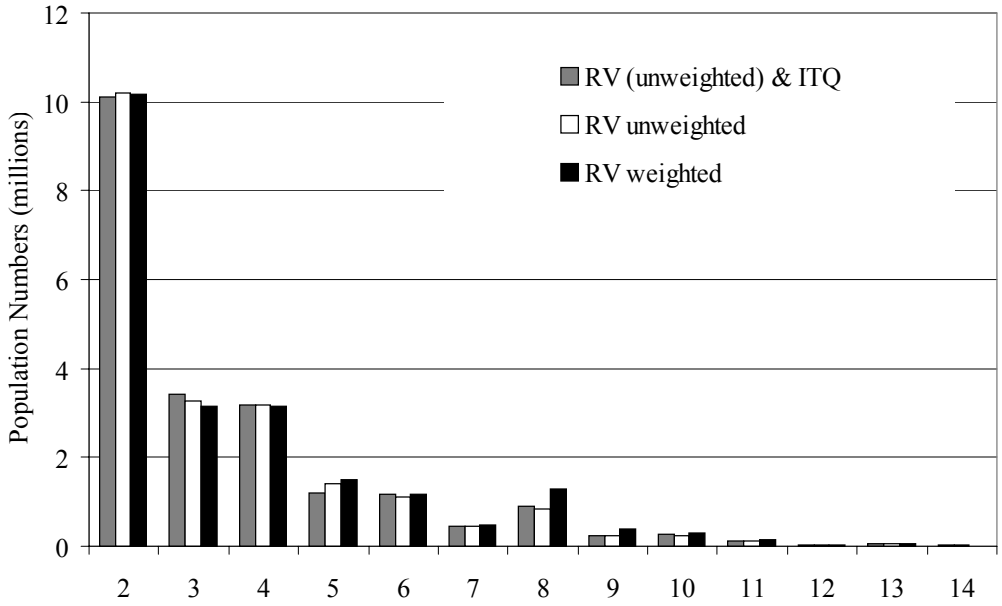

Fig. 30. Impact of weighting of RV indices and inclusion of ITQ survey on population estimates.

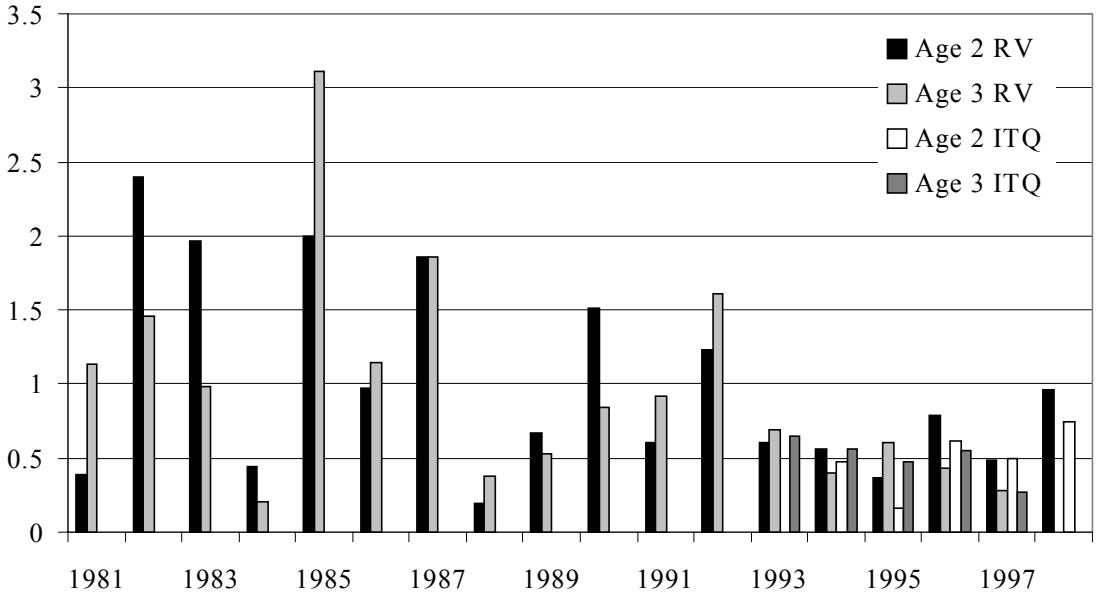

Fig. 31. Scaled recruitment indices of 4X cod from RV summer survey and ITQ survey.

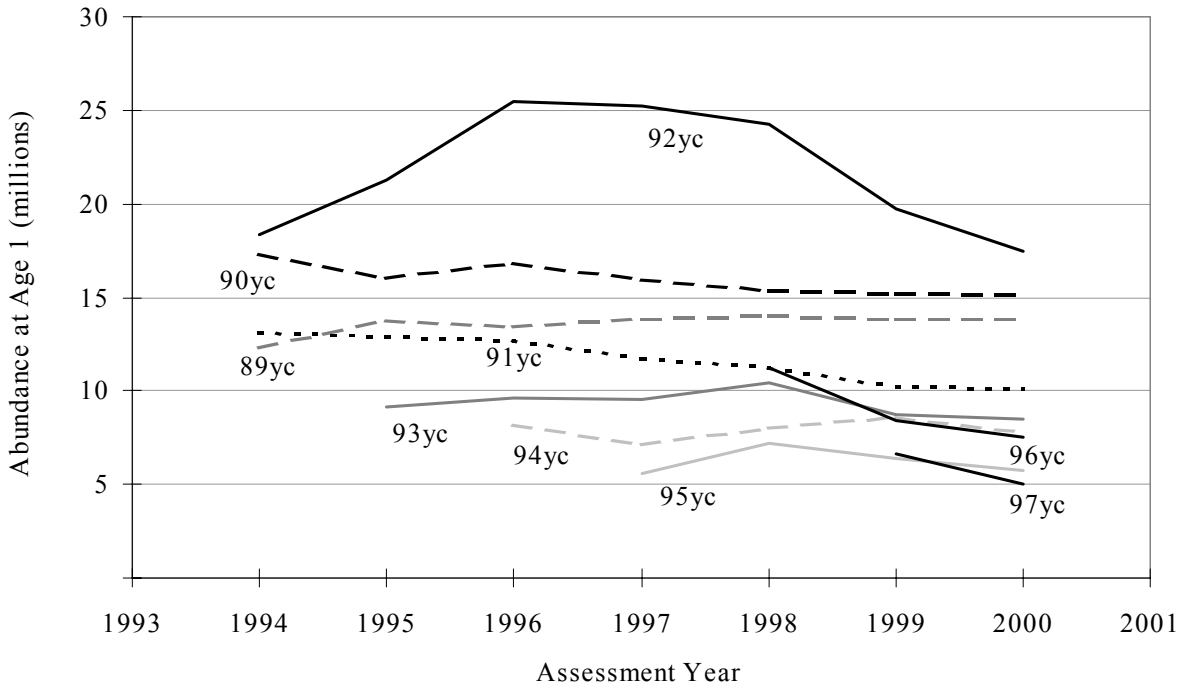

Fig. 32. Successive estimates of year-class abundance for 4X cod as additional years of data were included in the assessment.

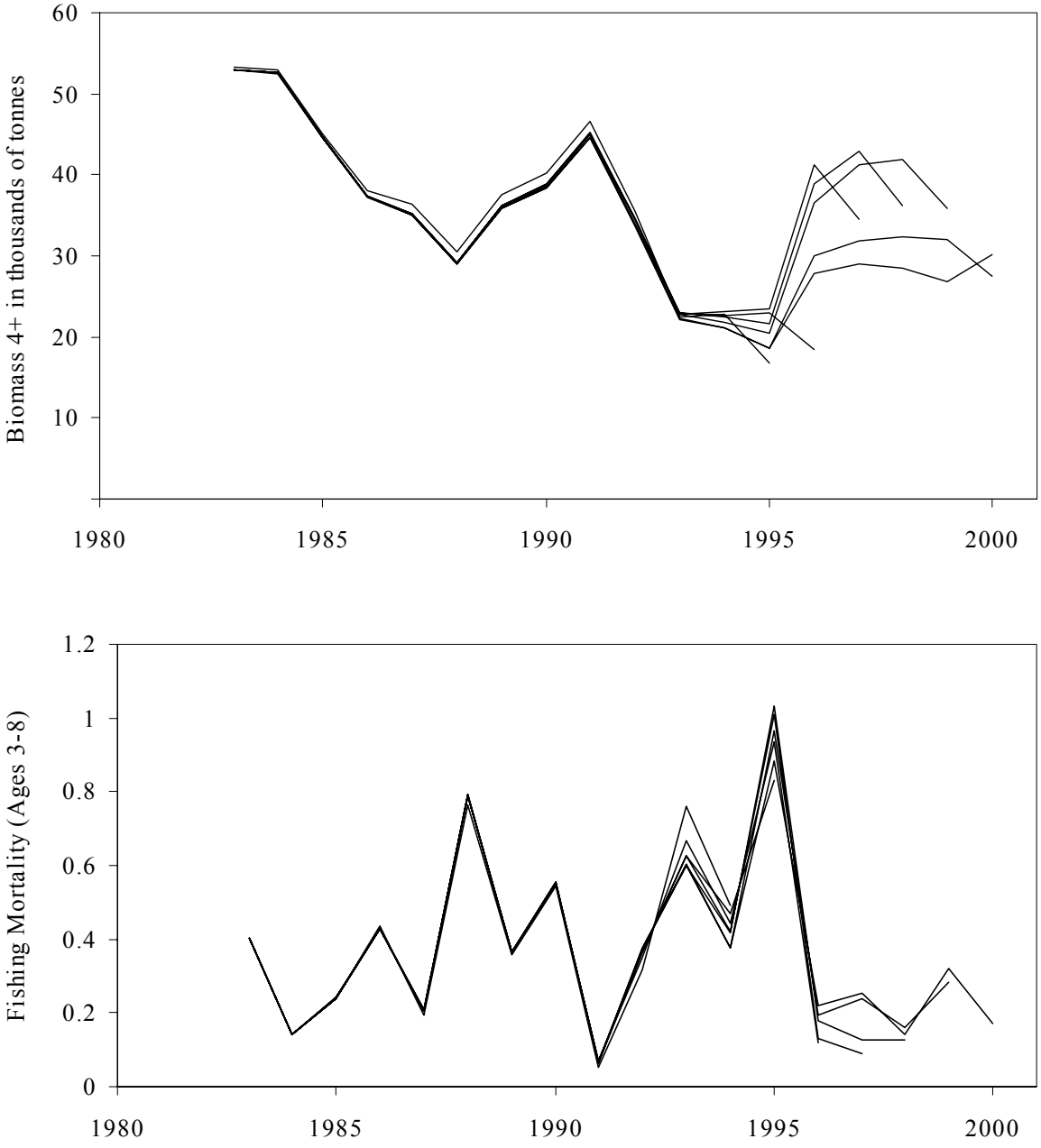

Fig. 33. Restrospective estimates of biomass and fishing mortality for 4X cod as successive years of data were excluded in the assessment.

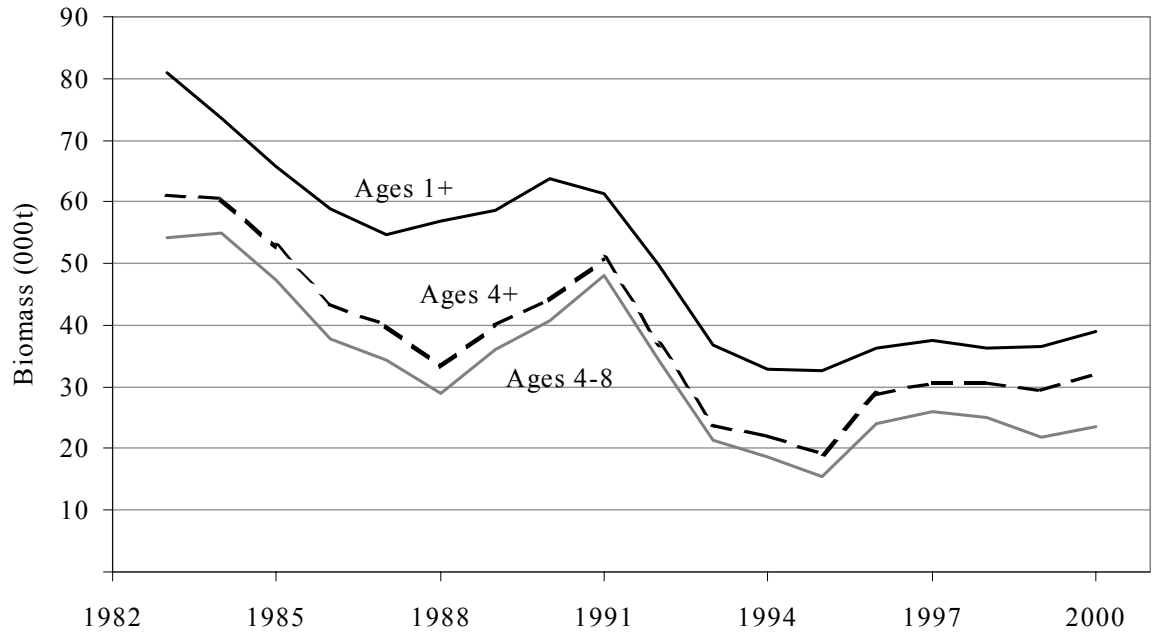

Fig. 34. Biomass for cod in Division 4X.

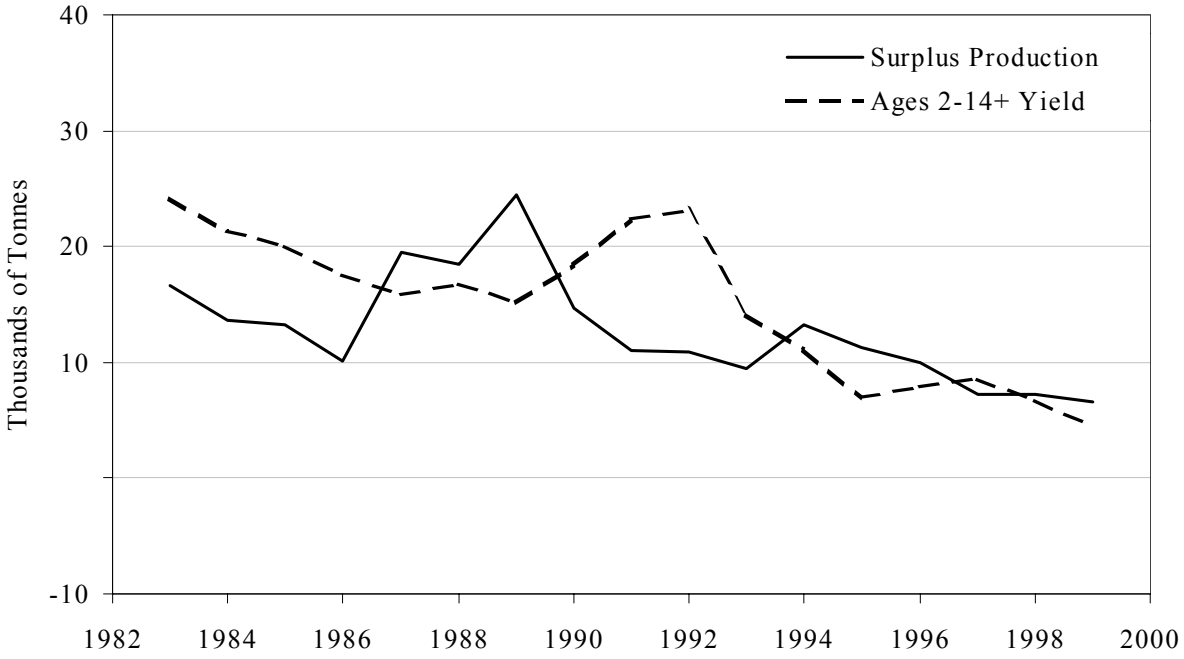

Fig. 35. Surplus production of 4X cod available to the commercial fishery compared to amount harvested.

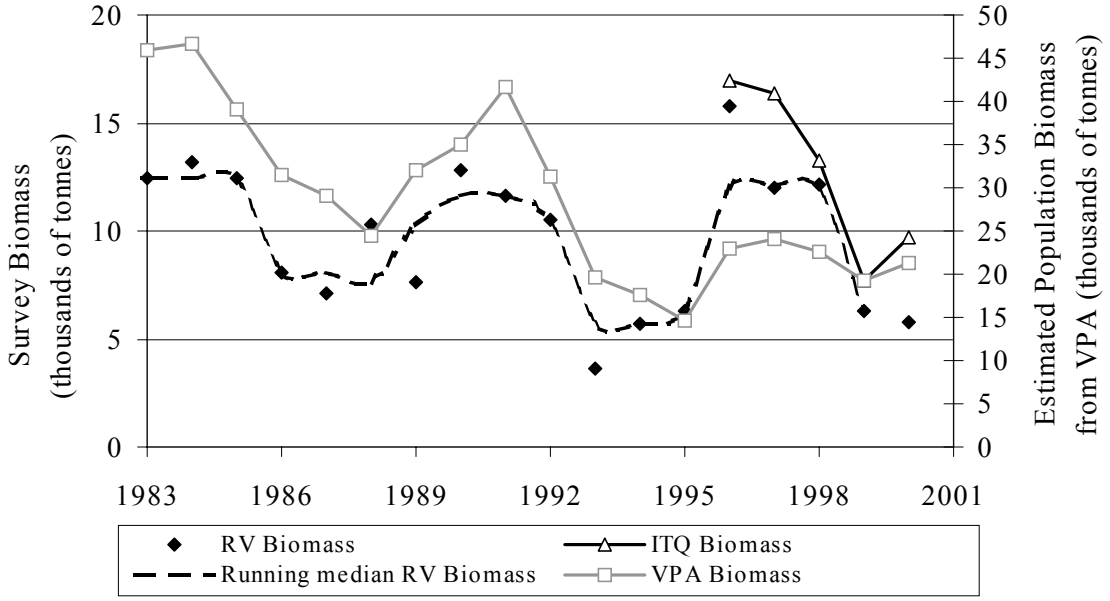

Fig. 36. Comparison of biomass estimates for 4X cod ages 4-8 from surveys and VPA.

Fig. 37. Recruitment (age 1) for cod in Division 4X.

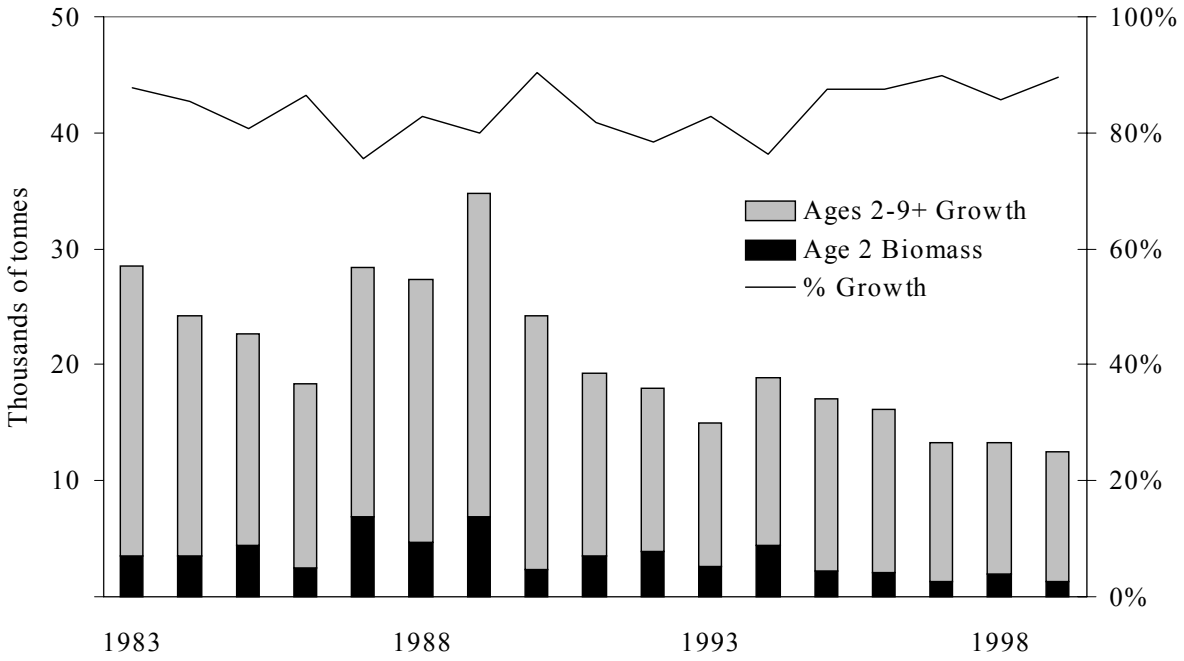

Fig. 38. Amount of productivity attributable to growth of ages 2 to 8 4X cod and the amount contributed by recruitment of age 2 cod.

Fig. 39. Exploitation rate (ages 4-5) of Division 4X cod.

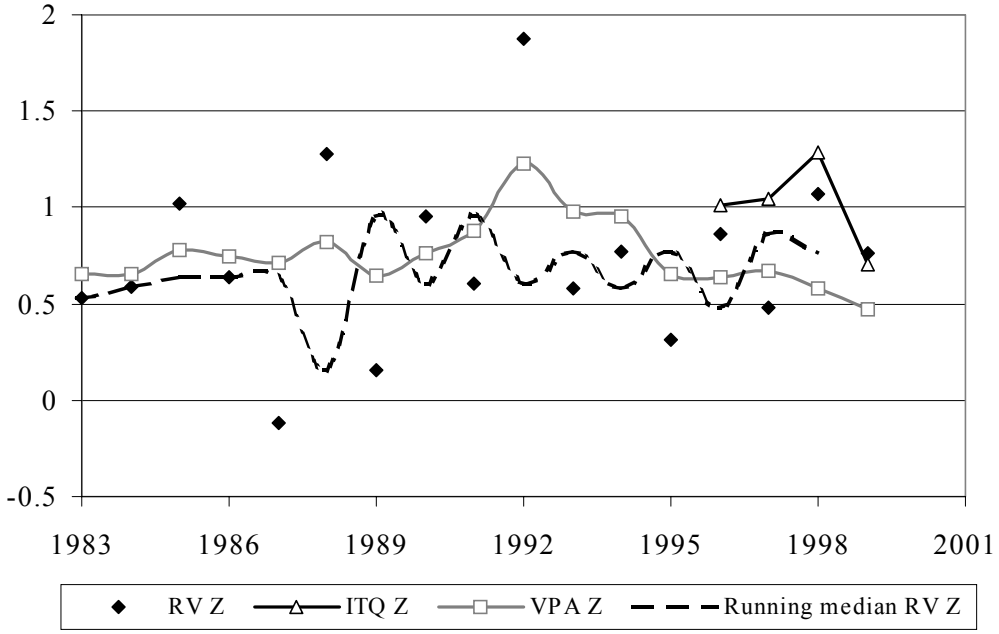

Fig. 40. Comparison of estimates of total mortality (Z) for 4X cod from surveys and VPA.

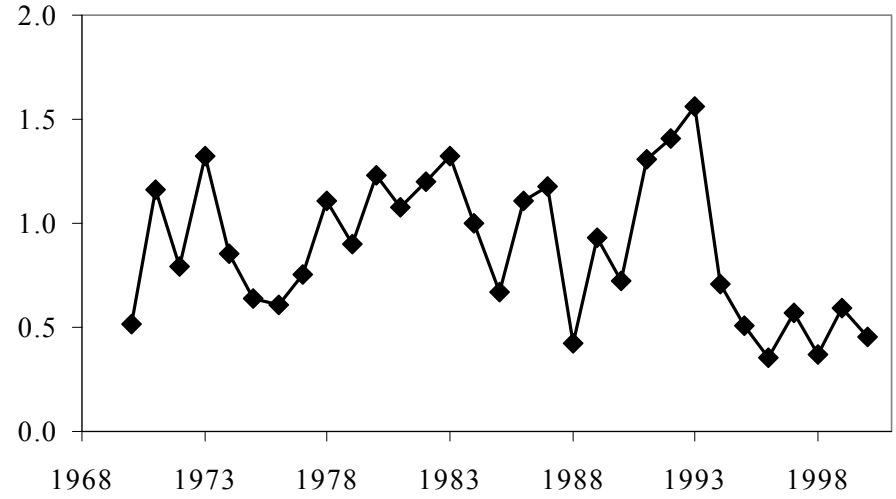

Fig 41. Relative exploitation for 4X cod.

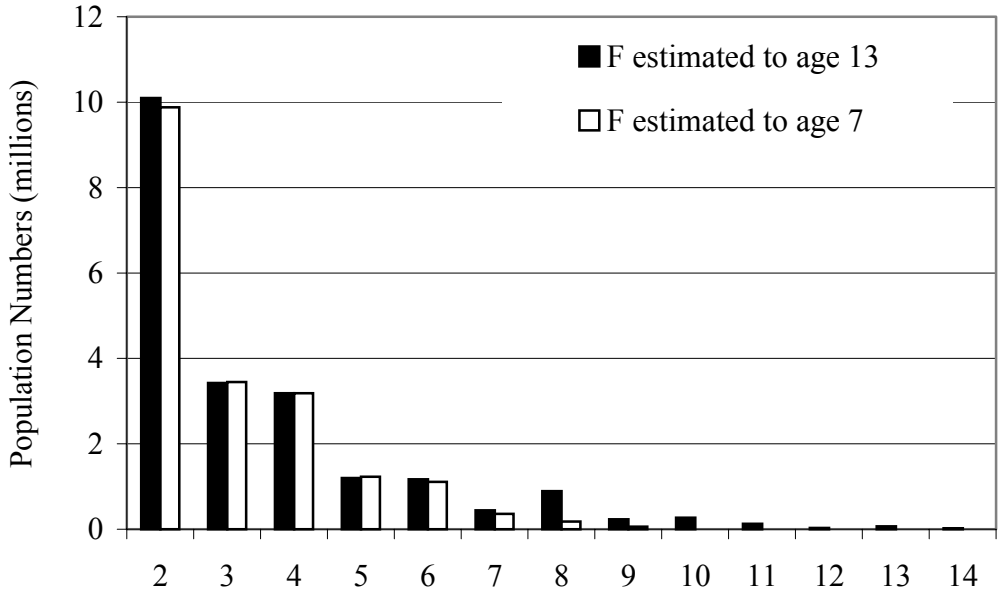

Figure 42. Estimated population numbers for 4X cod in relation to the number of ages for which F is estimated, as opposed to assuming they are fully recruited.

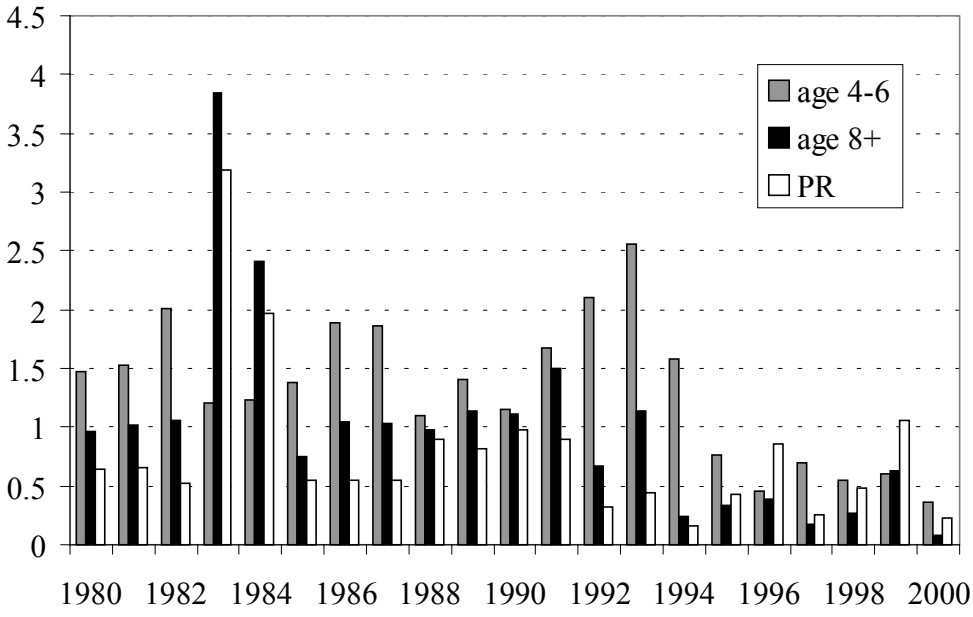

Fig. 43. Relative fishing mortality by age group and partial recruitment (PR) of age 8+ cod in Division 4X.

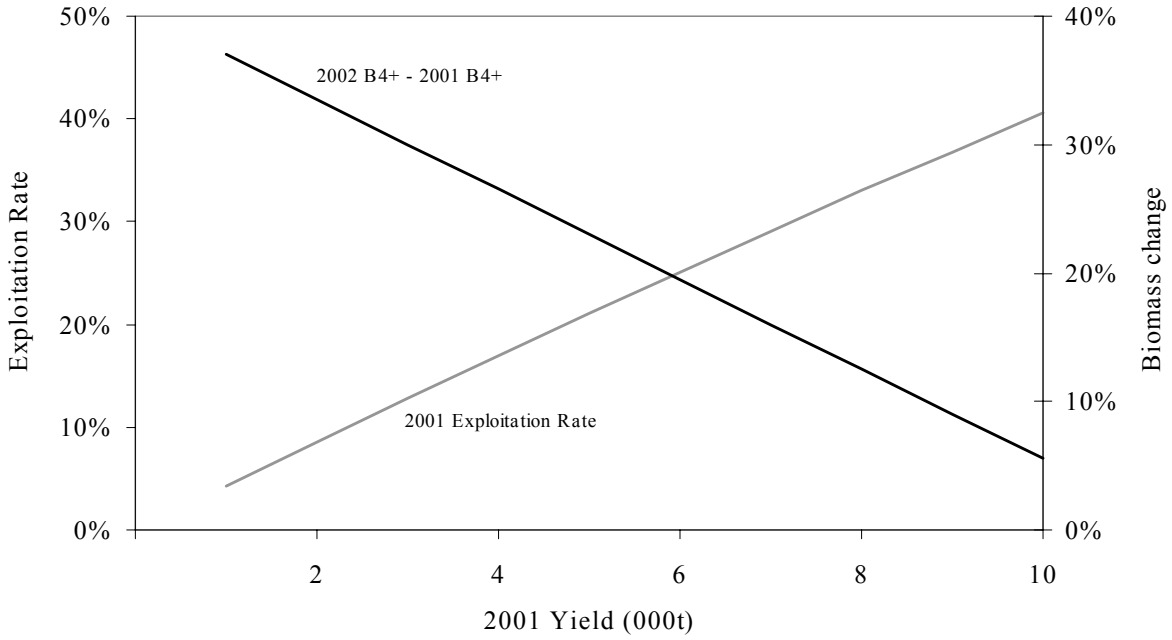

Fig. 44. Expected exploitation rate in 2000 and expected change in biomass from 2000 to 2001 for 4X cod at various quotas.

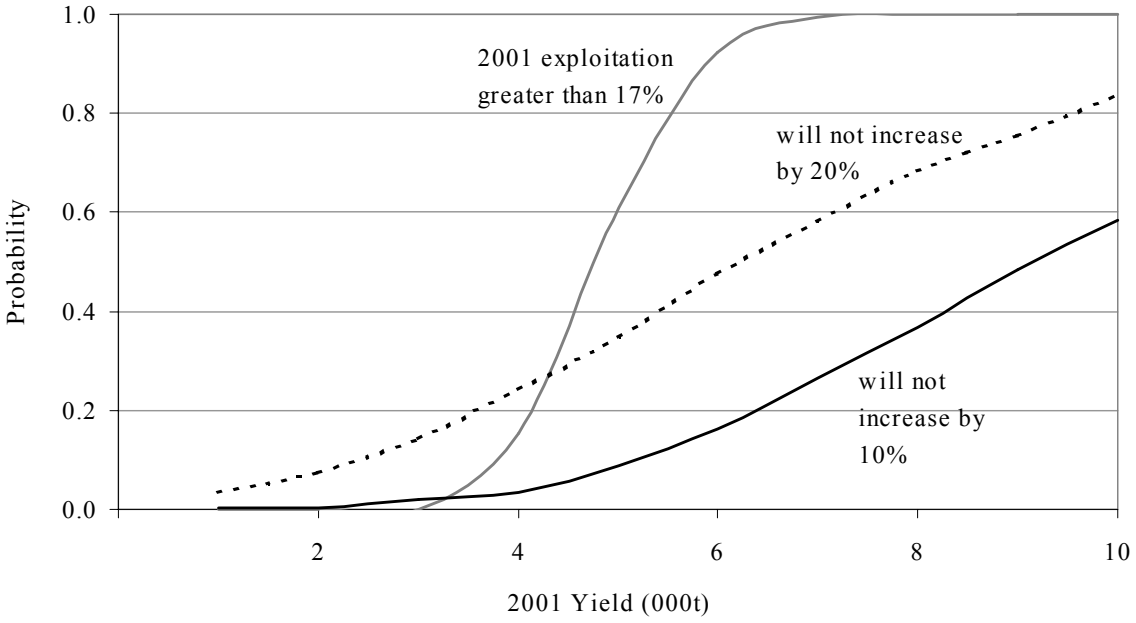

Fig. 45. Probability of fishing mortality exceeding $F_{0.1}$ (exploitation rate = 17%) and of not increasing by 10%-20% between 2001 and 2002.