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Assessment of Cod in Divisiion 4X in 1998

by

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ABSTRACT

Landings of cod from Division 4X have fluctuated since 1948 between 35,500t and the 1995 value of 8,800t. The quota for 1997 was increased to 13,000t, of which 11,500 were landed. The quota for 1998 is 9,300t, 6,500t of which had been landed by the beginning of October. Landings in both 1997 and the first half of 1998 were divided fairly evenly amongst the 1992, 1993 and 1994 year classes. The summer RV survey was higher than in 1997, and continues to indicate that the 1992 year class is particularly strong. The indices for all other ages, however, were below average. The ITQ survey was down substantially from 1997 in weight, but up in numbers, due to relatively good catches of the 1996 year-class.

Based on analyses which indicated either natural mortality (m) or survey catchability (q) may have increased in recent years, a variety of ADAPT formulations were explored. A standard formulation including the Research Vessel (RV) survey and the ITQ survey as indices estimates a 1999 4^+ biomass of 36,000t, similar to 1998. A formulation which estimates natural mortality in the 1990's suggests that m may have increased to 0.4 from 0.2. This formulation estimates biomass higher, but $F_{0.1}$ yield 20% lower than the standard. The most troubling results come from an analysis which suggests with some support from observations of fishing patterns, that survey catchability (q) may have increased in recent years. This analysis estimates age 4^+ biomass for the beginning of 1999 of 20,000t, and estimates the $F_{0.1}$ yield for 1999 as 4,300t.

RÉSUMÉ

Les débarquements de morue de la division 4X ont fluctué et sont passés de 35 500 t, en 1948, à 8 800 t, en 1995. Le quota de 1997 a été porté à 13 000 t et 11 500 t ont été récoltées. Le quota de 1998 a été fixé à 9 300 t et, au début d'octobre, 6 500 t avaient été récoltées. Les débarquements de 1997 et de la première moitié de 1998 étaient constitués, de façon uniforme, d'individus des classes d'âge de 1992, 1993 et 1994. Les captures du relevé d'été par NR étaient supérieures à celles de 1997 et continuent d'indiquer que la classe de 1992 est particulièrement forte. Les indices des autres classes d'âge sont cependant inférieurs à la moyenne. Les résultats du relevé par QIT étaient passablement inférieurs à ceux de 1997, en poids, mais supérieurs en effectifs, cela à cause de captures relativement bonnes d'individus de la classe de 1996.

Diverses formulations du modèle ADAPT ont été examinées en se fondant sur des analyses indiquant que la mortalité naturelle (m) ou la vulnérabilité aux engins du relevé (q) avaient pu s'accroître au cours des dernières années. Une formulation normalisée utilisant comme indices les résultats du relevé par navire de recherche (NR) et du relevé par QIT a permis d'estimer la biomasse des 4+ de 1999 à 36 000 t, valeur semblable à celle de 1998. Une formulation pour l'estimation de la mortalité naturelle au cours des années 1990 porte à croire que la valeur de m ait pu passer de 0,2 à 0,4. Cette formulation donne une biomasse estimée supérieure, mais un rendement au niveau $F_{0.1}$ inférieur de 20 % à la norme. Les résultats les plus aberrants sont ceux d'une analyse qui porte à croire, et en cela sont appuyés par certaines observations du régime de pêche, que la vulnérabilité à la pêche du relevé (q) a augmenté au cours des dernières années. Selon cette analyse, la biomasse des 4+ était de 20 000 t en 1999 et le rendement au niveau $F_{0.1}$ correspondait à 4 300 t pour cette même année.

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 Brown's 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 and foreign 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 effort in the groundfish fishery 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 Brown's 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 because of 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 based on tonnage class unreliable. Furthermore, tagging data 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, and subsequently fell to a low of 9,000t in 1995. The recent reductions in landings are a reflection of the TAC, which declined from 26,000t in 1992 to 9,000t in 1995. The 1997 quota is 9,300t, 6,300t of which were landed by October 1.

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. 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 (6cm) continue to settle in coastal waters in St. Margarets Bay (Tupper and Boutilier, 1995). 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 Brown's 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 which 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 some also recaptured in 5Z. Similarly, some fished tagged on George's Bank are recaptured in 4X, although the proportion of tagged fish moving into 4X has generally been considered small.

DESCRIPTION OF FISHERY

The fishery in 4X takes place year round. Landings generally peaking in June and July, however in recent years landings have been distributed more evenly throughout the year (Table 1). The hook and line fishery accounts for roughly half of the landings, 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 2).

The proportion of landings from the winter-spring fishery, prosecuted predominantly by the otter trawl fleet, declined in the mid-1990's, but increased again in 1998. The increase in 1998 was due to fishing directed primarily for haddock along the Shelf edge around Brown's Bank. Late starts in the fixed gear fishery since 1996 have reduced landings early in the year. In 1997 and 1998 TC1 and 2 hook and line vessels have not caught as high a proportion of their quota in June and July. In some areas this has been a result of poor catch rates; the quota could not be caught in the usual time span. In some areas in 1998 fishermen have held off fishing until fall hoping for better inshore fishing due to the low catches experienced by those who started in early summer.

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(Appendix I). In 1997, the proportion of landings coming from the Bay of Fundy was the highest ever, at 48%. There has been little change in the proportion of 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 (Appendix I). Similarly, the otter trawl fishery until recently was concentrated on the Shelf in the spring and winter, moving into the Bay of Fundy in the summer (Appendix I). This fishery was conducted primarily in the Bay of Fundy throughout the year from 1993-1997, but in 1998 the winter fishery was again primarily on the Shelf.

Fishermen from around 4X are reporting mixed success in the cod fishery in 1998. Representatives from both the otter trawl and longline fleets have reported that fishing has generally been poor for cod east of Browns Bank In coastal areas throughout 4X fishing has been poor this year. In the Digby Neck area, where the hook and line fishery takes place primarily in spring and early summer, handliners had landed only 21% of their quota by mid-October. Fishermen in that area considered 1997 to have been their worst fishing year, and this year is worse still. The fishery appears to have been equally poor for many quota groups in Eastern Nova Scotia and Halifax West areas, with landings for most at less than 50% of their quota. The spring longline fishery off Saint John was also poor. This fishery generally catches predominantly large market and steak cod, this year, however, landings were down, with less than half the quota caught, and there were few large fish. In the Shelburne and Sable Island areas fishing was also reported to be poor along the shore, however those fishing further offshore and in deeper water reported good fishing.

Effort by the otter trawl and the tonnage class (TC) 2 and 3 longline and gillnet fleets has declined since the early 1990's, although effort directed for cod increased slightly in 1996 and 1997(Clark et al, 1998. Based on the effort expended to September 7 in 1998 to land 66% of the combined cod haddock and pollock quotas (61% of the cod), it appears likely that effort will also increase in 1998 (Appendix I). Effort remains substantially lower than seen in the early 1990's, however fishing mortality was considered to be unsustainable at that time. It is of some concern that fishing effort is higher than in 1994, since fishing mortality has been estimated as well above $F_{0.1}$ for cod and pollock in that year.

CATCH AND WEIGHT AT AGE

The 1997 catch at age was based on 37 samples which included otoliths, and 50 additional length frequency samples. This is a further reduction in numbers from 1996, and has necessitated the combining of some cells in the standard age-length key due to lack of data (Tables 4a and b). In the first half of 1998 40 samples are available which include otoliths and an additional 37 length frequency samples (Table 4c and d). This big increase in sampling is due to the involvement of a number of industry groups in commercial sampling. Only selected samples have yet been aged for 1998.

Inter-reader age comparison tests were conducted for both the Bay of Fundy and Scotian Shelf using samples from the 1997 RV survey. Agreement was satisfactory (95%; Appendix II).

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) and the disproportionately low number of samples taken from the Bay of Fundy in many years. 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).

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

In 1997 landings were distributed among ages 3-5 with hook and line vessels catching a higher proportion of young fish (Table 5). Landings of cod over age 5 have declined in recent years (Table 6) and in 1997 the proportions of landed weight comprised by these ages were below their long term averages (Fig. 3). The proportions of 5 year-olds, which accounted for about 30% of the numbers landed, was high in comparison with the long term mean (Fig. 4), however, it is well below the level predicted in the previous assessment (Fig. 5). Catches at ages 5 and over have consistently been lower than anticipated in recent assessments.

In the first half of 1998 landings were dominated by the strong 1992 year-class (age 6: Fig. 6). This year-class accounts for over 30% of the cod landings by number; a much greater proportion of the catch than usual (Fig. 7). Fish over age 5 constitute a lower proportion of the catch than predicted (Fig. 8) with the discrepancy accounted for by ages 4 and 5. As the proportion of old fish in the landings is generally lower in the second half of the year, this under-representation is expected to increase by years end.

Weights at age for commercial landings from both the Scotian Shelf and the Bay of Fundy are higher than average in recent years (Table 7). This may reflect the higher proportion of fish landed later in the year in recent years.

Commercial catch at age data from 1980 to 1998 were used in this assessment. While previous assessments have included landings data from before 1980 (Campana, 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). Furthermore, commercial sampling prior to 1980 was very low, particularly west of Browns Bank, and it has been concluded that the catch history for the Bay of Fundy could not be reliably reconstructed from commercial samples during this period (Clark, 1995). Catch at age has been derived for the Scotian Shelf to 1971, and a VPA for the Scotian Shelf in 4X has been conducted with these data to provide a longer term population and recruitment series (Clark, 1997).

ABUNDANCE INDICES

Annual stratified random surveys have been conducted in 4X during summer since 1970. As in the 4X cod assessments since 1994, calibration of the VPA for this assessment used survey information collected since 1983, when the RV *Alfred Needler* became the standard survey vessel. Uncertainties in relative fishing power between different survey vessels could have contributed to the residual patterns observed in past assessments (predominantly positive since 1983 and negative before 1983). Furthermore, excluding data prior to 1983 eliminated the retrospective pattern which plagued previous assessments (see Gavaris et al, 1994). Based on these considerations, the present assessment was conducted using survey data from 1983-1997.

The 1998 survey showed a distribution of cod similar to that from the previous year (Fig. 9), however, there were few good catches on the Scotian Shelf. Catch per tow decreased in the Scotian Shelf area, but increased slightly in the Bay of Fundy in 1998 (Fig. 10). Catches were average in the Bay of Fundy, and below average on the Scotian Shelf.

The survey abundance estimate is similar to those seen in the late 1970's; however, due to the changes in survey vessels in 1982 and 1983, it is not clear that the generally higher catches observed in years when the survey was conducted using the *Alfred Needler*, is indicative of higher population levels. Population numbers and biomass, as estimated from VPA, peaked from 1977-1982, (Campana, 1991; Clark, 1997) despite the low survey catches. Similarly, the United States fall groundfish survey showed higher cod abundance in 4X in the late 1970's than at present (Fig. 10b). This survey also indicates abundance was high in the early 1960's, and dropped rapidly to a low in 1969.

Survey results have identified the 1992 year-class as well above average (table 8). This year-class has had the highest index in the series at ages 4, 5 and 6, and the second highest at age 3. For all other ages, however, the 1998 survey was below average. The initial indication given by this survey is that the 1996 year-class is also below average, although better than the 3 which precede it.

The age 2 survey index used in the calibration includes sets at depths <50 fathoms, excluding stratum 490 (St. Mary's Bay). When stratum 490 was removed from the analyses,

relative error and bias were reduced in population estimates, and the magnitude of the residuals also decreased (Clark et al., 1995).

The fourth annual 4X ITQ groundfish survey was conducted in July, 1998 using commercial trawlers. The survey employs a fixed station design (although the number of stations has increased over the time series), and involves three vessels using balloon trawls with a 1/2 in. codend liner and rockhopper ground gear. The 4X area was divided into blocks of 100 nm^2 and blocks were selected for sampling prior to sailing. The selection of the exact station location within a block was made by the skipper, allowing them scope to identify a suitable location for trawling (O'Boyle et al., 1995). Once co-ordinates for the sampling location were determined, the location was fixed for subsequent years, eliminating the flexibility which was present in initial selection. Two of the three vessels switched from a 300 to 280 balloon trawl between the first and second year to match what was in use on the vessel fishing in the Bay of Fundy, however the skippers felt this was a minor change and should not effect the catch for these vessels. The potential for differences in fishing power among vessels could complicate some analyses, however, comparisons can be made among years for the 122 stations which were sampled in each year (172 stations for 1996-98; Table 9).

There is a decline in the number of stations where good catches were made in 1998 (Fig. 11). Catches were down in the western Bay of Fundy and in the Roseway and Bacarro Bank areas (Fig. 12)

The mean weight per tow declined in the Bay of Fundy and Scotian Shelf areas in 1998, although numbers per tow increased in all areas (Table 9b). The decline in catch weights for this survey since 1996 is apparent and of similar magnitude for the subset of stations occupied in all years, or those occupied only since 1996 (Table 9c). As the number of stations included in the analysis is increased in a given year from the original subset of stations, the catch per tow declines. Stations added after the first year tend to be ones where cod abundance is relatively low.

The length frequency of the ITQ survey catch for 1998 on the Scotian Shelf (including only those sets made within Needler strata 470 - 481) shows no strong peaks, and is generally low at all lengths (Fig 13). This is similar to what is seen in the RV survey(Fig. 14). The 1992 year-class may be responsible for the higher than usual abundance around 80 cm.

The 1998 ITQ survey results for the Bay of Fundy (including only those sets made within Needler strata 484 - 495) has a strong mode at length 40 cm, corresponding to age 2, but is low at all other lengths. The RV survey results are similar, with high abundance around 40 cm, and abundance at other lengths average or below. In the inshore area, few cod of commercial size were caught. Numbers were generally quite low, with a peak around 23 cm.

The relatively high numbers of small fish caught in the ITQ survey may reflect the differences in gear used in the two surveys. The ITQ survey, unlike the RV, uses rock-hopper ground gear. This gear is more effective at catching small cod, since there is no avenue for escape below the foot gear.

Age disaggregated survey indices were calculated for the ITQ survey using age-length keys from the RV survey. The ALK from the Bay of Fundy was used for the inshore area, since commercial samples taken from the German Bank area, where most of the inshore stations are located, show growth rates similar to the Bay of Fundy cod. These indices track the strong 1992 year-class, numbers for each age peaking on this year-class. Similarly, the 1991 year-class appears weak at all ages. Catches at age 1 were quite variable, and do not appear to predict year-class strength well as calculated at present.

ESTIMATION OF STOCK PARAMETERS

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

$C_{a,t}$ = catch for ages $a=1, 2,..., 12$ during the quarter year time periods beginning at $t=1980,1980.25,1980.5,1980.75,1981,...,1998.25$

$I_{s,a,t}$ = survey abundance index for:
s= RV survey ages $a=2$ *to 10, years* $t = 1983.5$ *to* 1998.5 (excluding 1988.5, ages 3 and 4).
ITQ survey ages a = 2 to 9, years t = 1995.5 to1998.5

The summer survey results were compared to mid-year population abundance. Data from ages 3 and 4 from the 1988 summer survey were excluded from the analysis because catchability at these ages appeared to be anomalously high. These data were influential and their inclusion affected population estimates. Estimates obtained when these data were excluded were considered more appropriate (Gavaris, 1993, Clark et al., 1995).

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 and the fishing mortality rate, F, for age 12 in the final quarter of each year was assumed equal to the average for ages 6, 7 and 8 in the same year and quarter.

A model formulation using ln mid-year population abundances in 1998 (t = *1998.5*) as parameters was employed. Define the model parameters

$\phi_{a,1998.5}$ = ln population abundance for ages a = *2, 3,...,12,* (age 1 abundance assumed equal to the geometric mean recruitment 1991-96), and

κ_a = calibration constants for Canadian summer survey for ages a = *2,3,...,10.*

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

$$Q_{a,t}(\phi,\kappa) = \sum_{a,t} (q_{a,t}(\phi,\kappa))^2 = \sum_{a,t} (\ln(I_{a,t}) - \ln(\kappa_a N_{a,t}(\phi)))^2$$

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 = 1998.5, the population abundances are obtained directly from the parameter estimates,

$$N_{a,1998.5} = exp[\phi_{a,1998.5}].$$

For all other years, y = 1980 to 1998.25, 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 for ages 1 to 10 is obtained by solving the catch equation using a Newton-Raphson algorithm,

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

Analytical approximations of variance and bias for population abundance estimates and corresponding projected yield were derived following Gavaris (1993).

ASSESSMENT RESULTS

For each cohort, the terminal population abundance estimates from ADAPT were adjusted for bias (Table 10a) and used to construct the history of the stock status (Table 11a). Commercial weights at age a from the first quarter, and the last quarter of the previous year for age $a-1$ were averaged to provide a beginning of year weight at age, and these were used to calculate beginning of year population biomass (Table 12a).

Data from the ITQ survey were included in the calibration this year for the first time. The residuals are small for the ITQ survey (Fig. 15a), suggesting it is generally doing a good job of tracking the population. Including indices of abundance from the ITQ survey resulted in a slightly lower MSR (Table 10a) than a calibration using only RV survey indices of abundance. Including these data also resulted in slightly higher estimates of fishing mortality over the past three years, and lowered the estimated population biomass by roughly 7% (Table 12a).

Residuals for the RV indices were generally small in magnitude, with no consistent trend across years (Fig. 15a). Residuals were generally positive for the 1996 survey, and negative for the 1997 survey. Close correspondence occurred between the RV survey indices, scaled by the calibration constants, and results from the sequential population analysis (Fig. 16), with some exceptions; ages 6 and over are all estimated as larger than suggested by the 1998 survey. The results indicate that the 1992 year-class is the third strongest in the time series, on par with the 1980, 1985 and 1987 year-classes (Fig. 17). The 1993 year-classes appear to be below average, and the 1994 and 1995 year-classes are estimated as the lowest in the time series. The 1996 year-class is also below average, but stronger than the three preceding it.

Fishing mortality is estimated at .31 for 1997; this is similar to what was projected in the last assessment, but 10% of the quota on which the projection was based went uncaught. The total fishing mortality rate for ages 4 and older has fluctuated around 0.5 (Table 13a and Fig. 19). F increased rapidly after 1989, peaking over 1.0 in 1992, and has declined since then. The high F's in the early 1990's exceeded thrice $F_{0.1}$ and likely resulted in lost yield due to capture of fish before their full growth potential has been realized. In the first half of 1998, F dropped below 0.2; however, only 28% of the annual quota was landed during this period, and F will increase by year's end.

The beginning of year population biomass for ages 4 and older (spawning stock biomass) increased for 1997 to the highest level since 1991, primarily due to growth by the 1992 cohort. (Table 12a and Fig. 18) and increased again marginally for the beginning of 1998. Biomass at ages 7 and over in 1998 is estimated as roughly 20% of the 3^+ biomass. This seems unrealistically high, given the low proportion of the commercial catch these ages comprise.

Given the reportedly poor fishing inshore in recent years, It is possible a higher proportion of the stock than usual is in the offshore area. Since the RV survey excludes most of the inshore (depth < 50 fm), this would result in higher q's for this survey in recent years. In light of this, and the apparent increase in natural mortality in the adjacent 4VW cod stock, the potential for changes in q or M were investigated.

The potential for changes in q was examined by treating the Needler survey as two separate time series, one from 1983-91, and the second from 1992-98. This allows ADAPT to derive separate q's for each time period. ADAPT was also used to determine m in the period 1992-1998 assuming m was 0.2 in the period 1980-1991.75. This allows ADAPT to derive a relationship between q and m in the earlier period, which provides some stability to q, and allows for the calculation of a new m in recent years. Comparisons of the residuals from these models with residuals from the more standard model is complicated by the addition of parameters; additional parameters will result in a better fit of the model to the observations.

The investigation of potential changes in q provide estimates of q in the 1990's which are higher than in the 1980's (Table 10b). This analysis suggests the population has been overestimated in recent years, and provides an estimate of 4+ biomass roughly 50% of last years projection (Table 12b). This estimates the 1992 year-class abundance at age as lower than many in the 1980's (Table 11b). The high survey catches of this year-class would therefore be a result of increased catchability rather than greater abundance. This also provides lower estimates of abundance for older ages, which in turn eliminates the domed PR estimated in recent assessments (Table 13b). As abundance of old fish is estimated to be low, the low catches observed are now in keeping with expectations. Estimates of F are also higher in recent years for this scenario, remaining near 1 from 1992 to 1994. This, however, seems inconsistent with the marked decline in fishing effort which took place between 1992 and 1994 (Fig A.2).

The investigation of potential changes in natural mortality resulted in an estimate of M in the 1990's of 0.411 (Table 10c), as compared with the standard of 0.2. This analysis also results in a higher estimate of population biomass than the standard assessment (Table 12c), and much higher

estimates of year-class sizes starting about 1986 (Table 11c). It produces lower estimates of F in recent years (Table 13c), and effectively eliminates the domed pattern in partial recruitment. Furthermore, it indicates that fishable biomass has dropped in the last two years, consistent with reports on the nature of the fishery. The high estimates of cohort size (population levels which would be required to allow for high losses due to natural mortality) seems incompatible with the fact that indices at ages 2 and 3 were higher for many cohorts in the early 1980's than they have been in recent years.

Higher natural mortality has been proposed for many of the stocks currently under moratoria due either to increased seal predation, or increased mortality of post-spawning fish due to low condition. Although seal numbers have clearly increased in 4X, they are much less abundant than in 4VW, and seem unlikely to be responsible for a large change in natural mortality. Similarly, there is no suggestion that post-spawning cod in 4X are in very poor condition, and growth rates have not changed for this stock. Thus, it seems unlikely that F has increased as suggested in this formulation.

Of the options presented, all fit some aspects of the data, but all also result in estimates of population parameters which are inconsistent with some observations. The most troubling is the finding that q may have increased and we may be overestimating stock size. In this instance, the model is responding to the fact that indices for a cohort are declining as rapidly in recent years as in the early 1980's, despite the much lower landings. For F to account for this rate of decline (Z) population size must therefore be quite small, and q high.

Analyses of partial recruitment patterns to the fishery were examined in the 4X cod assessment in 1997. These analyses indicated a strongly domed partial recruitment pattern since 1992, and a flat-topped pattern prior to this. The partial recruitment pattern did not appear to have changed for otter trawlers in either the Bay of Fundy or the Scotian Shelf. The overall change appeared to be driven by longliners, for which in past years partial recruitment of cod increased with age, while more recently, partial recruitment peaked at ages 4 and 5, and declined rapidly for older ages. This suggests that the population trends on the Scotian Shelf and inshore Nova Scotian waters where the hook and line fleet is concentrated may be different from those in the Bay of Fundy. The population may be declining more rapidly with age, hence fish over age 5 make up a smaller portion of the population. An analysis of survey Z's by area, however, shows no obvious difference between areas. If q had changed due to a change in the relative abundance of fish in inshore Nova Scotia waters, we would anticipate higher Z's for this area.

There is a weak correlation between spawning stock (age 4+) and recruitment for 4X cod (r^2= 0.25; years 1980-1996; Fig. 20). Using spawning stock biomass calculated with a maturity ogive (Trippel et al, 1997) resulted in a lower correlation (r^2= 0.10) between biomass and recruitment. This is in keeping with results for Icelandic cod, which indicate that the amount of old fish in the population correlates better with recruitment success than does spawning stock biomass (Marteinsdottir and Thorarinsson, 1998). Although stock biomass does not appear to be a good predictor of recruitment, it does appear that at low biomass the probability of average or better recruitment is low, and this probability increases at high spawner biomass.

The 4^+ biomass in 1998 estimated with the assessment formulation which assumes constant q and m is 37,000t, a biomass at which recruitment has tended to be better than has been seen in the past 4 years. The formulation which allows m to change also estimates a healthy 4^+ biomass of 41,000t; however, the formulation which allows q to change estimates 1998 4^+ biomass as 20,000t, a biomass which is associated with the poor recruitment of recent years.

PROGNOSIS

Yield projections indicated that the point estimates for projected yield were biased upward by about 10% and had a standard error of about 25% of the mean. As with population abundance estimates, adjusting for bias was considered more appropriate than using the biased point estimate. The incoming year-classes were assumed to be equal to the geometric mean for the last 5 years (Table 14a). Average partial recruitment values for 1990-95 of 0.0, 0.06, 0.42, and 0.76 respectively for ages 1-4 were used in the projections.

Assuming the remainder of the 9,300t TAC for 1998 is landed (6,400t remain for the last half of 1998), the resulting fully recruited fishing mortality will be about 0.28 for the year. The projected yield for 1999 at $F_{0.1}$ is 7,500t (Table 14a). At this fishing level, the age 4^+ biomass is expected to increase by 7,000t to 43,000t at the beginning of 2000 (Fig. 21). The increase is due primarily to the recruitment of the 1996 year-class which is currently estimated to be stronger than the 3 preceding it. In this projection, 48% of the landed weight is projected to come from ages 7+. This is expected to come primarily from the 1992 year-class, which shows some degree of retrospective decline, suggesting its strength may be overestimated. In the first half of 1998 these cohorts are contributing less than 35% of the landed weight. Given that the proportion of the stock biomass comprised by these cohorts will decrease next year, it seems unlikely that their contribution to the fishery will increase. As a result of this, we may anticipate that the younger ages will be subject to higher exploitation than would be anticipated at $F_{0.1}$. Furthermore, this suggests that the population biomass may be overestimated by roughly 20%.

The formulation in which natural mortality is allowed to vary estimates f for 1998 as 0.27. Projections with this formulation (m=0.4) estimate a 4^+ population biomass increase of 4,000t to 36,000t at the beginning of 2000 with an $F_{0.1}$ harvest for 1999 of 6,400t (Table 14c).

Using the formulation which estimates that survey catchability has increased in recent years produces an estimate of projected yield for 1999 at $F_{0.1}$ of 4,300t and an increase in 4^+ population biomass of 7,000t to 27,000t at the beginning of 2000 (Table 14b). The results from this formulation lack the domed PR seen in the more standard model, and are thus likely to more reliably predict the relative contributions of older ages. Ages 7+ are projected to contribute between 36% and 39% of the landed weight in this formulations.

The scaling factor between survey indices and population numbers, q, could be influenced by a number of factors. If the proportion of fish outside the survey area has decreased, this could result in an increase in q. Similarly, if fish caught outside 4X were misreported to 4X in the past, or cod caught in 4X were under-reported, both of which were suggested in past assessments as potential problems in the mid- to late 1980's (Campana and Hamel, 1991), and these practices have since declined or ended, q would now increase relative to earlier estimates. Thus, there is some

rationale for suggesting q has increased. Despite these facts, there are results produced from this model which seem inconsistent with trends in fishing effort and observations from the surveys.

Further improvements in recruitment are required before any sustained growth in this fishery can be realized. With the concerns expressed about the uncertainty in current stock biomass, it is important to ensure that the recruiting 1996 year-class is not exploited heavily. These fish will generally be less than 19 in. on the Scotian Shelf in 1999, but will range between 17 and 22 in. in the Bay of Fundy. This cohort is expected to contribute only slightly more in numbers to the 1999 fishery than the 1995, 1994, or 1992 cohorts. Substantial deviation from this may be cause for concern. Careful monitoring of the fishery in 1999 could help us distinguish between these alternatives.

To ensure a higher probability of average or better recruitment it is important to ensure that the spawning biomass is high. Given the poor recruitment of recent year-classes, this will require ensuring that fishing mortality is low.

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

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1980	706	2188	1704	2485	3317	5316	3433	3346	2603	2876	1547	1756	31277
1981	1649	2451	2529	1533	2881	4093	3845	4067	2253	3119	1728	1373	31521
1982	757	2390	2569	1491	3415	5109	4734	3258	3540	2890	1244	1737	33134
1983	1713	1654	1648	1888	2743	5713	4554	2832	3183	1787	1037	719	29471
1984	1798	2021	752	817	1796	3471	3688	4567	2773	1668	1201	976	25528
1985	779	1699	956	1268	1974	2586	3199	2650	2737	1801	787	1063	21499
1986	904	1633	1775	1450	1437	1939	2739	1995	2576	1714	771	1107	20040
1987	1208	1837	1242	1059	1870	2778	2663	1821	1679	1403	910	535	19005
1988	2104	1531	535	939	1620	2931	3104	2122	2524	1441	636	1050	20537
1989	2150	2347	1362	1707	1292	3562	1830	1772	1535	1278	637	413	19885
1990	2619	2027	707	778	1560	3104	3751	3123	2598	1689	1158	790	23904
1991	2023	2651	993	1666	2322	3167	3963	2881	2967	2208	1650	1258	27749
1992	2088	1740	1297	1502	1685	3622	3366	2803	2625	2353	1478	1521	26080
1993	657	903	994	996	1617	2312	2834	2221	1804	1048	562	78	16026
1994	734	972	547	847	824	1771	2246	1503	1267	1154	726	454	13045
1995	610	229	317	827	574	1236	1771	774	1071	521	276	561	8767
1996	503	331	446	531	819	1755	1805	1317	880	887	679	619	10572
1997	98	362	378	806	644	1440	1779	1382	1548	1424	710	668	11239
1998	286	348	401	313	511	936	1255	909					

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

	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	1322	2769	4284	1042	2037	2683	61	8356	2360	898	4198	1257	31277
1981	1165	3086	2989	416	1131	2871	114	10302	2555	1235	5174	483	31521
1982	879	3159	4493	563	2217	3154	214	9120	3465	1087	4299	484	33134
1983	638	4735	6306	518	1118	2180	235	5747	2757	883	3750	604	29471
1984	964	4198	5904	302	1513	1248	220	3916	2825	980	3005	453	25528
1985	523	3954	5562	90	1185	1837	161	2617	1740	635	2755	440	21499
1986	573	3663	5123	224	974	1453	196	2479	1918	576	2490	371	20040
1987	312	2645	3504	531	929	1968	241	3075	2175	499	2670	456	19005
1988	454	3966	3542	160	467	903	444	3528	3149	672	3081	171	20537
1989	409	3933	4184	67	713	1254	475	2915	2167	623	2937	208	19885
1990	505	3668	3577	268	170	1933	692	4201	2967	849	4871	203	23904
1991	355	4598	5805	298	751	2225	619	4712	3679	842	3737	128	27749
1992	238	4494	5711	143	726	1811	586	4455	3574	719	3517	106	26080
1993	176	2778	3598	68	241	1387	523	2768	1693	310	2439	45	16026
1994	132	2022	2343	138	82	993	421	2837	1412	231	2367	67	13045
1995	100	1387	1619	112	75	470	507	1632	959	182	1706	18	8767
1996	92	1552	2314	157	103	611	442	1774	1306	201	1914	106	10572
1997	79	2094	2430	136	35	694	471	2013	1255	231	1794	6	11238
1998*	57	916	1295	53	21	281	304	931	458	96	761	7	5180

* January 1 - September 1.

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

	4Xm	4Xn	4Xo	4Xp	4Xq	4Xr	4Xs	4Xu	5Y	Shelf	Fundy	Foreign	Total
1980	5205	3325	9899	1561	3571	4684	2278	47	166	20023	10712	541	31276
1981	4767	2114	12097	1830	2413	5072	2031	419	599	21051	10290	179	31520
1982	5255	2922	10451	2079	3715	4571	2009	538	1349	20956	11933	245	33134
1983	3437	1690	8537	2497	3160	3787	1674	1826	2543	16891	12258	320	29469
1984	2255	2251	6192	1655	2244	2959	1414	3583	2698	14110	11141	277	25528
1985	3006	1199	5438	1026	1999	2301	1511	3608	1364	12236	9216	47	21499
1986	2914	1762	4670	544	1754	1802	1500	4469	557	11748	8224	68	20040
1987	2676	1611	4777	1131	1240	858	1207	5116	360	12783	6179	29	18991
1988	1502	1086	5458	1271	1124	850	1103	7990	142	14814	5711	11	20536
1989	1370	1019	5506	2820	1360	1112	915	5267	478	13855	5994	38	19887
1990	1846	764	7915	1746	2238	1721	1722	5404	326	15551	8119	222	23892
1991	2552	1584	8963	2440	2763	4243	2560	2246	307	17275	10383	91	27749
1992	1523	1818	10347	1455	2919	3352	1503	2876	278	17556	8515	9	26080
1993	1364	1646	4845	1436	1959	2428	1399	760	189	9924	6102		16026
1994	828	561	4414	1128	1662	1883	892	1540	137	8321	4724		13045
1995	293	696	1737	1586	1306	1032	510	1528	79	5349	3418		8767
1996	466	813	2787	1484	1608	1659	930	654	171	6055	4517		10572
1997	453	837	2213	1327	1793	2240	1070	1303	183	5943	5479		11422
1998	223	594	947	1224	726	634	412	317	103				5180

January 1 - September 1.

Table 4a. Construction of Age-length keys for 4X cod for 1997.

Area	Fundy (4Xqrs5Y)				Shelf (4Xmnop)			
Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
No. Samples	3	7	2	3	5	7	4	6
No. Aged	116	344	100	137	209	244	166	242
Landings (t)	487	1590	2018	1282	351	1181	2778	1551

Table 4b. Construction of length frequencies for 4X cod for 1997, 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	6	1174	474	Fundy Q1
LL					0	Q1 F#	12	
GN					0		0	
OT	1	Shelf			5	1174	217	Shelf Q1
LL					1	288	134	
GN					0		0	
OT	2	Fundy	0.0084	3.041	13	2967	1097	Fundy Q2
LL					2	491	187	
GN					3	633	125	
OT	2	Shelf			8	1756	327	Shelf Q2
LL					8	1407	792	
GN					4	733	143	
OT	3	Fundy	0.0087	3.0233	4	806	1143	Fundy Q3
LL					0	LL Q2 F#	359	
GN					2	374	470	
OT	3	Shelf			2	519	218	Shelf Q3
LL					12	2225	1506	
GN					3	490	332	
OT	4	Fundy	0.0063	3.1152	7	1671	1143	Fundy Q4
LL					0	LL Q2 F#	86	
GN					0	GN Q3 F#	53	
OT	4	Shelf			3	750	202	Shelf Q4
LL					3	755	1215	
GN					1	240	134	

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

Table 4c. Construction of Age-length keys for 4X cod for 1998.

Area	Fundy (4Xqrs5Y)				Shelf (4Xmnop)			
Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
No. Samples	2 (0)	20 (8)			13 (8)	5 (2)		
No. Aged	-	195			311	69		
Landings (t)	140	745			895	973		

ALK's for Q1 and Q2 were combined due to low numbers aged.

Table 4d. Construction of length frequencies for 4X cod for 1998, 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	3	669	136	Fundy Q2
LL					0	LL Q2 F#	4	
GN					0		0	
OT	1	Shelf			17	3831	470	Shelf H1
LL					2	398	139	
GN					0		0	
OT	2	Fundy	0.0084	3.041	5	911	497	Fundy Q2
LL					31	2132	187	
GN					2	321	60	
OT	2	Shelf			4	918	221	Shelf Q2
LL					11	2510	284	
GN					2	406	216	

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

Table 5a. Landed numbers of 4X cod at age by gear type for 1997.

Age	1	2	3	4	5	6	7	8	9	10	11	12
LL+HL	0	25	679	948	576	82	42	11	1	3	1	2
OT	0	33	407	500	468	90	28	4	1	2	0	1
GN	0	1	40	107	149	27	12	1	0	1	0	0

Table 5b. Landed numbers of 4X cod at age by gear type for 1998 (Jan. - July).

Age	1	2	3	4	5	6	7	8	9	10	11	12
LL+HL	0	2	109	114	75	79	6	2	0	0	0	0
OT	0	2	111	191	127	128	10	6	1	0	0	0
GN	0	0	1	6	7	26	6	3	0	0	0	0

Table 6. Catch at age (number in thousands) for cod in Division 4X.

Age	1	2	3	4	5	6	7	8	9	10	11	12	1+	2+	3+	4+
1980	0	837	6054	2358	1742	1135	442	261	91	60	19	17	13016	13016	12178	6124
1981	0	818	3870	4265	1844	1045	587	297	184	75	39	19	13042	13042	12225	8355
1982	0	904	2885	4414	3060	912	393	279	146	86	41	25	13145	13145	12240	9356
1983	9	1031	3689	2433	2057	1205	459	204	120	76	36	10	11329	11320	10289	6600
1984	33	917	2393	3081	1930	965	465	176	63	49	29	18	10118	10086	9169	6776
1985	0	711	1674	1569	2324	1284	514	194	71	53	18	7	8419	8419	7708	6034
1986	0	251	2789	1941	994	1008	409	200	93	50	23	20	7778	7778	7527	4738
1987	0	861	902	2053	1087	523	511	236	140	66	33	9	6421	6421	5560	4659
1988	0	403	3517	1659	1553	656	178	192	85	53	28	6	8329	8329	7925	4408
1989	17	655	2560	3656	632	562	163	79	60	19	10	10	8423	8406	7751	5191
1990	0	144	2863	2805	2462	497	279	78	40	38	14	15	9234	9234	9090	6227
1991	2	391	1535	5092	1777	1364	215	156	32	16	28	15	10622	10621	10229	8694
1992	0	751	3391	1878	3276	878	513	63	50	16	9	4	10828	10828	10077	6685
1993	0	881	3490	2045	660	672	186	90	14	14	5	0	8056	8056	7176	3686
1994	0	475	2280	2233	887	195	181	42	18	0	2	0	6314	6314	5838	3558
1995	0	135	2146	1081	582	130	28	40	11	5	0	0	4158	4158	4023	1877
1996	0	50	883	2594	441	212	29	16	8	2	1	1	4237	4237	4187	3304
1997	0	59	1126	1556	1193	199	82	16	2	6	1	3	4243	4243	4184	3058
1998*	0	4	221	312	209	232	21	11	1	0	0	0	1011	1011	1007	786

* Landings for January - July 1.

Table 7. 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
Scotian Shelf	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
	1988		0.94	1.30	1.90	2.69	3.98	5.23	8.06	9.88	10.93	13.05	16.04
	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
	Mean	0.78	0.87	1.23	1.80	2.61	3.73	5.07	7.19	9.23	11.53	13.77	14.99
Bay of Fundy	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	
	1988		0.86	1.46	2.24	4.09	5.36	8.99	10.14	8.89	14.69		
	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
	Mean	0.44	0.97	1.64	2.63	4.18	5.80	7.63	9.54	11.13	13.65	13.28	16.52

Table 8. Summer groundfish survey indices for cod in Division 4X.

Age	2	3	4	5	6	7	8	9	10
1983	223.1	4225.9	2369.4	1479.8	945.9	389.2	0.0	76.6	37.4
1984	1385.4	3390.5	2361.9	1819.5	687.6	482.2	62.6	58.4	25.5
1985	1138.9	4330.7	1527.3	1450.9	766.2	483.0	267.4	164.5	12.8
1986	258.3	2920.2	1226.1	314.4	548.8	448.1	216.6	97.1	19.2
1987	1157.7	617.9	1180.5	527.9	260.4	244.9	303.8	75.0	40.1
1988	563.6			1776.3	496.4	209.9	243.6	91.2	38.3
1989	1073.1	3420.4	2548.6	420.4	488.6	108.4	27.1	81.5	37.3
1990	110.4	5522.7	2462.9	2321.3	240.5	413.7	79.7	41.6	0.0
1991	389.8	1130.6	3086.4	1094.2	751.3	127.8	115.6	18.9	21.1
1992	873.5	1568.9	680.7	1710.3	470.6	460.3	124.4	84.8	0.0
1993	349.9	2518.3	924.9	129.5	265.0	52.2	61.3	0.0	6.4
1994	711.5	2739.3	1605.4	448.5	35.8	194.5	87.5	69.7	0.0
1995	349.9	4778.6	1477.0	598.3	274.0	94.2	91.4	34.2	41.8
1996*	322.7	2047.6	5527.3	880.3	753.2	147.6	0.0	55.8	15.2
1997	211.2	1188.6	1443.6	2461.6	321.5	194.0	100.2	0.0	56.9
1998	456.0	1808.4	1418.0	1022.1	1370.5	225.2	115.9	6.3	0.0

Includes only stations within 4X occupied during survey N246; stations resampled during N247 were excluded. See Clark and Brown,1996.

Table 9a. ITQ Survey indices for cod in Division 4X.

Age	2	3	4	5	6	7	8	9	10
1995	672.0	1060.8	241.3	110.0	20.7	4.0	7.9	0.5	0.5
1996	808.7	761.9	735.6	70.7	26.0	6.4	0.0	1.7	0.0
1997	303.0	513.9	311.7	233.1	14.4	20.5	2.3	2.0	4.0
1998	810.3	553.6	233.6	84.6	94.8	12.5	4.0	0.0	0.0

Table 9b. ITQ survey cod catches at repeated stations by region.

	Scotian Shelf		Bay of Fundy		Inshore	
Year	weight	number	weight	number	weight	number
1995	14.12	11.05	42.31	23.64	39.65	39.96
1996	15.50	14.32	46.19	27.81	22.90	16.05
1997	9.54	7.09	47.44	21.17	12.40	10.15
1998	6.50	9.90	28.94	42.29	12.50	17.15

Table 9c. ITQ Survey catch per tow at repeated stations, and all stations in each year.

	4X all common sets		4X - common '96-'98		4X - All sets	
Year	weight	number	weight	number	weight	number
1995	30.05	21.24			28.80	20.45
1996	29.24	20.10	24.88	16.66	25.15	16.67
1997	25.44	13.33	20.23	10.96	20.23	10.99
1998	16.64	24.31	12.82	19.16	11.88	17.97

Table 10a. Statistical properties of estimates for population abundance and survey calibration constants for 4X cod using the RV and ITQ indices. M=.2

Age		Par. Est.	Std. Err.	Rel. Err.	Bias	Rl. Bias
	2	9740.00	4310.00	0.442	1010.00	0.104
	3	4140.00	1330.00	0.322	237.00	0.057
	4	3210.00	997.00	0.311	155.00	0.048
	5	2080.00	679.00	0.327	101.00	0.049
	6	3400.00	1020.00	0.299	140.00	0.041
	7	581.00	170.00	0.293	23.10	0.04
	8	436.00	120.00	0.276	15.20	0.035
	9	104.00	30.50	0.292	3.91	0.037
	10	64.40	26.70	0.415	4.41	0.069
	11	82.80	25.70	0.31	3.14	0.038
RV	2	0.0462	0.0069	0.148	0.0003	0.007
	3	0.3310	0.0497	0.15	0.0026	0.008
	4	0.3770	0.0565	0.15	0.0031	0.008
	5	0.4090	0.0595	0.146	0.0034	0.008
	6	0.4300	0.0632	0.147	0.0038	0.009
	7	0.5520	0.0822	0.149	0.0059	0.011
	8	0.5910	0.0928	0.157	0.0077	0.013
	9	0.5480	0.0858	0.156	0.0078	0.014
	10	0.4870	0.0819	0.168	0.0085	0.017
ITQ	2	0.0843	0.0280	0.333	0.0040	0.047
	3	0.1080	0.0337	0.312	0.0043	0.04
	4	0.0829	0.0256	0.309	0.0034	0.041
	5	0.0514	0.0161	0.314	0.0023	0.045
	6	0.0308	0.0097	0.315	0.0014	0.047
	7	0.0285	0.0094	0.329	0.0015	0.054
	8	0.0186	0.0069	0.372	0.0013	0.071
	9	0.0186	0.0071	0.38	0.0016	0.083

MEAN SQUARED RESIDUALS = 0.316555

Table 10b. Statistical properties of estimates for population abundance and survey calibration constants for 4X cod using the ITQ index 95-98, and the Needler as two indices; 83-91 and 92-98. M=0.2

Age		Par. Est.	Std. Err.	Rel. Err.	Bias	Rl. Bias
popn.	2	7930	3600	0.454	932	0.118
	3	3340	1120	0.334	230	0.069
	4	2350	790	0.336	151	0.064
	5	1310	486	0.371	96.3	0.073
	6	1900	662	0.349	127	0.067
	7	237	89	0.376	18.1	0.076
	8	125	47.1	0.377	8.82	0.071
	9	21.6	10	0.463	1.89	0.087
	10	19.1	11.1	0.58	2.52	0.131
N	2	0.0457	0.0085	0.185	0.0008	0.017
83-91	3	0.324	0.0636	0.196	0.0062	0.019
	4	0.338	0.0664	0.196	0.0065	0.019
	5	0.395	0.0732	0.185	0.0068	0.017
	6	0.437	0.0809	0.185	0.0075	0.017
	7	0.576	0.107	0.185	0.0098	0.017
	8	0.512	0.1	0.196	0.0098	0.019
	9	0.515	0.0952	0.185	0.0088	0.017
	10	0.394	0.0773	0.196	0.0076	0.019
N	2	0.0568	0.0135	0.238	0.0009	0.016
92-98	3	0.408	0.0917	0.225	0.0058	0.014
	4	0.539	0.12	0.223	0.0079	0.015
	5	0.597	0.135	0.226	0.0094	0.016
	6	0.686	0.157	0.229	0.0104	0.015
	7	1.01	0.244	0.242	0.0205	0.02
	8	1.49	0.378	0.254	0.0447	0.03
	9	1.54	0.445	0.289	0.0718	0.047
	10	2.06	0.627	0.305	0.105	0.051
ITQ	2	0.104	0.0346	0.334	0.0041	0.04
	3	0.135	0.0417	0.31	0.0043	0.032
	4	0.111	0.034	0.306	0.0036	0.032
	5	0.0816	0.0255	0.312	0.0029	0.035
	6	0.0598	0.0188	0.314	0.0021	0.035
	7	0.0729	0.025	0.343	0.0032	0.044
	8	0.0667	0.0257	0.385	0.0047	0.071
	9	0.0618	0.0245	0.396	0.0056	0.09

MEAN SQUARE RESIDUALS= 0.307925

Table 10c. Statistical properties of estimates for population abundance and survey calibration constants for 4X cod using the RV index 1983-1998. M=0.2 for 1980-1990; m estimated for 1991-1998.

Age		Par. Est.	Std. Err.	Rel. Err.	Bias	Rl. Bias
	2	14000	8400	0.599	2560	0.182
	3	5460	2330	0.427	521	0.095
	4	3430	1370	0.398	263	0.077
	5	2320	929	0.401	169	0.073
	6	3610	1300	0.36	222	0.062
	7	656	228	0.347	41	0.062
	8	398	134	0.336	24	0.06
	9	73.3	25.5	0.347	4.59	0.063
	10	29.6	19.6	0.663	5.34	0.181
	11	50.2	18.9	0.377	3.24	0.064
m		0.411	0.0669	0.163	0.0035	-0.008
q	2	0.0325	0.0062	0.191	0.0005	0.015
	3	0.257	0.0448	0.174	0.0029	0.011
	4	0.309	0.0512	0.166	0.0031	0.01
	5	0.342	0.0539	0.158	0.0032	0.009
	6	0.369	0.0577	0.157	0.0034	0.009
	7	0.483	0.0765	0.158	0.0057	0.012
	8	0.519	0.0873	0.168	0.0081	0.016
	9	0.494	0.0819	0.166	0.0089	0.018
	10	0.451	0.0788	0.175	0.01	0.022

Mean Squared Residuals=0.322250

Table 11a. Estimated bias adjusted beginning of year population numbers ('000s) for 4X cod using the RV (1983-1998) and ITQ indices.

Age	1	2	3	4	5	6	7	8	9	10	11	1+	2+	3+	4+
1980	22714	23414	22935	8678	4924	2963	1452	748	305	221	39	88393	65679	42265	19330
1981	26193	18596	18385	13253	4958	2456	1404	792	380	169	127	86713	60520	41924	23539
1982	14051	21445	14460	11516	6984	2374	1074	624	381	148	71	73128	59077	37632	23172
1983	13885	11504	16722	9225	5427	2950	1122	527	260	181	44	61847	47962	36458	19736
1984	17368	11359	8458	10309	5316	2542	1324	505	247	105	81	57614	40246	28887	20429
1985	9463	14188	8430	4736	5647	2615	1214	669	255	147	43	47407	37944	23756	15326
1986	26832	7748	10950	5361	2450	2512	978	529	373	145	72	57950	31118	23370	12420
1987	18411	21968	6114	6428	2619	1104	1151	439	252	223	72	58781	40370	18402	12288
1988	27389	15074	17175	4174	3403	1175	436	487	151	82	124	69670	42281	27207	10032
1989	9364	22424	11970	10881	1886	1390	374	198	228	47	20	58782	49418	26994	15024
1990	13674	7650	17765	7510	5653	990	644	166	93	134	21	54300	40626	32976	15211
1991	15554	11195	6130	11950	3606	2422	358	279	66	40	75	51675	36121	24926	18796
1992	11008	12733	8804	3621	5192	1342	750	96	86	25	19	43676	32668	19935	11131
1993	23178	9013	9716	4071	1246	1314	311	159	22	26	7	49063	25885	16872	7156
1994	10309	18977	6555	4805	1487	430	475	87	49	6	8	43188	32879	13902	7347
1995	8661	8440	15090	3299	1922	414	176	226	33	23	4	38288	29627	21187	6097
1996	6666	7091	6784	10390	1724	1053	221	120	148	17	14	34228	27562	20471	13687
1997	11785	5457	5759	4739	6138	1011	670	155	84	114	12	35924	24139	18682	12923
1998	12000	9648	4412	3675	2449	3932	644	474	112	66	88	37500	25500	15852	11440

Table 11b. Estimated bias adjusted beginning of year population numbers ('000s) for 4X cod using the ITQ . and Needler (1983-91; 1992-98) indices.

Age	1	2	3	4	5	6	7	8	9	10	11	1+	2+	3+	4+
1980	22713	23411	22925	8676	4924	2963	1452	748	305	221	39	88377	65664	42253	19328
1981	26184	18596	18383	13246	4957	2455	1404	792	380	169	127	86693	60509	41913	23530
1982	14004	21437	14459	11513	6978	2373	1074	624	381	148	71	73062	59058	37621	23162
1983	13883	11466	16716	9225	5425	2945	1121	527	260	181	44	61793	47910	36444	19728
1984	17346	11357	8426	10304	5316	2541	1320	504	247	105	81	57547	40201	28844	20418
1985	9447	14169	8429	4710	5643	2615	1213	666	254	147	43	47336	37889	23720	15291
1986	26773	7734	10934	5360	2429	2508	978	528	371	144	72	57831	31058	23324	12390
1987	18353	21920	6103	6416	2618	1086	1148	439	251	220	71	58625	40272	18352	12249
1988	26795	15026	17135	4166	3392	1174	421	485	151	81	122	68948	42153	27127	9992
1989	9073	21938	11931	10848	1879	1382	374	186	227	47	20	57905	48832	26894	14963
1990	13229	7412	17367	7478	5627	984	638	165	83	133	21	53137	39908	32496	15129
1991	14187	10831	5934	11624	3580	2400	353	273	65	32	74	49353	35166	24335	18401
1992	9760	11614	8505	3461	4925	1321	732	92	81	24	12	40527	30767	19153	10648
1993	18717	7991	8801	3827	1116	1097	294	145	19	22	6	42035	23318	15327	6526
1994	8437	15324	5718	4055	1288	324	297	73	37	3	5	35561	27124	11800	6082
1995	6945	6908	12100	2614	1309	251	89	80	22	13	2	30333	23388	16480	4380
1996	5366	5686	5530	7941	1164	551	88	48	29	8	6	26417	21051	15365	9835
1997	9445	4393	4608	3712	4134	552	260	46	25	16	5	27196	17751	13358	8750
1998	12000	7733	3540	2734	1608	2291	268	137	23	19	8	30361	18361	10628	7088

Table 11c. Estimated bias adjusted beginning of year population numbers ('000s) for 4X cod using the RV index, and estimating m (1992-1998).

Age	1	2	3	4	5	6	7	8	9	10	11	1+	2+	3+	4+
1980	22751	23431	23021	8692	4931	2964	1455	748	306	221	39	88559	65808	42377	19356
1981	26578	18627	18399	13324	4970	2461	1405	794	380	169	127	87234	60656	42029	23630
1982	14162	21760	14484	11527	7042	2384	1078	625	382	148	71	73663	59501	37741	23257
1983	14120	11595	16981	9246	5436	2997	1130	531	260	182	44	62522	48402	36807	19826
1984	18192	11551	8532	10520	5333	2550	1363	511	250	106	82	58990	40798	29247	20715
1985	10342	14863	8588	4797	5820	2629	1220	701	260	149	43	49412	39070	24207	15619
1986	31272	8467	11502	5490	2500	2653	989	534	399	149	74	64029	32757	24290	12788
1987	24245	25603	6703	6880	2724	1144	1267	448	256	244	75	69589	45344	19741	13038
1988	43030	19850	20151	4657	3773	1261	469	582	158	85	141	94157	51127	31277	11126
1989	16981	35230	15881	13317	2281	1693	445	225	306	53	23	86435	69454	34224	18343
1990	29639	13887	28250	10712	7648	1313	892	223	115	198	26	92903	63264	49377	21127
1991	36321	19588	9053	16329	4785	3085	457	369	85	44	100	90216	53895	34307	25254
1992	27159	24002	12611	4717	6668	1708	930	122	114	30	16	78077	50918	26916	14305
1993	62266	17949	15197	5444	1550	1789	426	213	30	36	8	104908	42642	24693	9496
1994	25053	41150	11093	7214	1941	500	649	131	68	9	12	87820	62767	21617	10524
1995	18021	16557	26777	5464	2964	558	173	281	52	29	5	70881	52860	36303	9526
1996	14281	11910	10825	15904	2733	1494	264	92	153	26	15	57697	43416	31506	20681
1997	21346	9438	7827	6404	8358	1444	815	151	48	95	15	55941	34595	25157	17330
1998	14761	14107	6183	4217	2921	4526	785	470	86	30	58	48144	33383	19276	13093

Table 12a. Estimated population biomass (000 t) at the beginning of the year for 4X cod from the RV (1983-98) and ITQ indices.

Age	1	2	3	4	5	6	7	8	9	10	11	1+	2+	3+	4+
1980	10448	16624	25458	14666	11571	9896	6694	4593	2672	2592	529	105743	95295	78671	53213
1981	12049	13203	20407	22398	11651	8203	6472	4863	3329	1982	1722	106280	94231	81028	60621
1982	6463	15226	16051	19462	16412	7929	4951	3831	3338	1736	963	96362	89899	74673	58622
1983	6387	8168	18561	15590	12753	9853	5172	3236	2278	2123	597	84719	78332	70164	51602
1984	7989	8065	9388	17422	12493	8490	6104	3101	2164	1232	1098	77546	69556	61492	52103
1985	4353	10073	9357	8004	13270	8734	5597	4108	2234	1724	583	68038	63685	53611	44254
1986	12343	5501	12155	9060	5758	8390	4509	3248	3267	1701	976	66907	54565	49063	36909
1987	8469	15597	6787	10863	6155	3687	5306	2695	2208	2616	976	65359	56890	41293	34507
1988	12599	10703	19064	7054	7997	3925	2010	2990	1323	962	1681	70308	57709	47006	27942
1989	4307	15921	13287	18389	4432	4643	1724	1216	1997	551	271	66738	62431	46510	33223
1990	6290	5432	19719	12692	13285	3307	2969	1019	815	1572	285	67383	61093	55662	35942
1991	4355	8128	6866	21594	9700	8906	1649	1848	537	494	1102	65177	60822	52694	45829
1992	3082	9244	9860	6543	13966	4935	3455	636	700	309	279	53009	49927	40683	30823
1993	6490	6543	10882	7356	3352	4832	1433	1053	179	321	103	42543	36053	29510	18628
1994	2887	13777	7342	8683	4000	1581	2188	576	399	74	117	41624	38737	24960	17619
1995	2425	6127	16901	5961	5170	1522	811	1497	269	284	59	41026	38601	32473	15572
1996	1866	5148	7598	18775	4638	3872	1018	795	1204	210	206	45329	43463	38315	30717
1997	3300	3962	6450	8563	16511	3717	3087	1026	684	1407	176	48883	45584	41622	35172
1998	3360	7004	4941	6641	6588	14458	2967	3139	911	814	1292	52116	48756	41752	36811

Table 12b. Estimated population biomass (000 t) at the beginning of the year for 4X cod using the ITQ and Needler (1983-91; 1992-98) indices.

Age	1	2	3	4	5	6	7	8	9	10	11	1+	2+	3+	4+
1980	10448	16622	25447	14662	11571	9896	6694	4593	2672	2592	529	105726	95278	78656	53210
1981	12045	13203	20405	22386	11649	8200	6472	4863	3329	1982	1722	106256	94211	81008	60603
1982	6442	15220	16049	19457	16398	7926	4951	3831	3338	1736	963	96312	89870	74649	58600
1983	6386	8141	18555	15590	12749	9836	5168	3236	2278	2123	597	84658	78272	70131	51576
1984	7979	8063	9353	17414	12493	8487	6085	3095	2164	1232	1098	77462	69483	61420	52067
1985	4346	10060	9356	7960	13261	8734	5592	4089	2225	1724	583	67930	63585	53525	44169
1986	12316	5491	12137	9058	5708	8377	4509	3242	3250	1689	976	66753	54437	48946	36809
1987	8442	15563	6774	10843	6152	3627	5292	2695	2199	2581	963	65132	56690	41127	34352
1988	12326	10668	19020	7041	7971	3921	1941	2978	1323	950	1654	69793	57467	46799	27779
1989	4174	15576	13243	18333	4416	4616	1724	1142	1989	551	271	66035	61861	46285	33042
1990	6085	5263	19277	12638	13223	3287	2941	1013	727	1560	285	66299	60214	54951	35674
1991	3972	7863	6646	21005	9630	8825	1626	1808	529	395	1087	63386	59414	51550	44904
1992	2733	8432	9526	6254	13248	4857	3372	609	659	296	176	50163	47430	38998	29473
1993	5241	5801	9857	6915	3002	4034	1354	960	155	271	88	37679	32439	26637	16780
1994	2362	11125	6404	7327	3465	1191	1368	483	301	37	73	34138	31776	20651	14247
1995	1945	5015	13552	4723	3521	923	410	530	179	160	29	30988	29043	24028	10476
1996	1502	4128	6194	14349	3131	2026	405	318	236	99	88	32477	30974	26846	20653
1997	2645	3189	5161	6708	11120	2030	1198	305	203	197	73	32829	30185	26995	21835
1998	3360	5614	3965	4940	4326	8424	1235	907	187	234	117	33310	29950	24336	20371

Table 12c. Estimated population biomass (000 t) at the beginning of the year for 4X cod using the RV index, and estimating m from 1992-98.

Age	1	2	3	4	5	6	7	8	9	10	11	1+	2+	3+	4+
1980	10465	16636	25553	14689	11588	9900	6708	4593	2681	2592	529	105934	95468	78832	53279
1981	12226	13225	20423	22518	11680	8220	6477	4875	3329	1982	1722	106676	94450	81225	60802
1982	6515	15450	16077	19481	16549	7963	4970	3838	3346	1736	963	96885	90371	74921	58844
1983	6495	8232	18849	15626	12775	10010	5209	3260	2278	2135	597	85466	78970	70738	51889
1984	8368	8201	9471	17779	12533	8517	6283	3138	2190	1243	1112	78835	70466	62265	52795
1985	4757	10553	9533	8107	13677	8781	5624	4304	2278	1748	583	69944	65187	54634	45102
1986	14385	6012	12767	9278	5875	8861	4559	3279	3495	1748	1003	71263	56877	50866	38099
1987	11153	18178	7440	11627	6401	3821	5841	2751	2243	2862	1017	73334	62181	44003	36563
1988	19794	14094	22368	7870	8867	4212	2162	3573	1384	997	1912	87232	67438	53345	30977
1989	7811	25013	17628	22506	5360	5655	2051	1382	2681	622	312	91020	83209	58196	40568
1990	13634	9860	31358	18103	17973	4385	4112	1369	1007	2323	353	104477	90843	80983	49625
1991	10170	14221	10139	29507	12872	11344	2105	2444	692	543	1469	95504	85334	71113	60974
1992	7605	17425	14124	8524	17937	6280	4285	808	928	370	235	78520	70916	53490	39366
1993	17434	13031	17021	9837	4170	6578	1963	1410	244	444	117	72250	54816	41785	24764
1994	7015	29875	12424	13036	5221	1839	2990	867	553	111	176	74108	67093	37218	24794
1995	5046	12020	29990	9873	7973	2052	797	1861	423	358	73	70467	65421	53401	23411
1996	3999	8647	12124	28739	7352	5493	1216	609	1245	321	220	69965	65966	57319	45195
1997	5977	6852	8766	11572	22483	5310	3755	1000	391	1172	220	67498	61521	54669	45902
1998	4133	10242	6925	7620	7857	16642	3616	3112	700	370	852	62070	57937	47695	40770

Table 13a. Estimated bias adjusted fishing mortality and exploitation rate for 4X cod using the RV (1983-98) and ITQ indices.

Age	1	2	3	4	5	6	7	8	9	10	11	avg f*	% exp.
1980	0	0.0418	0.3485	0.36	0.4958	0.547	0.406	0.4775	0.392	0.356	0.7235	0.4285	31.813
1981	0	0.0518	0.268	0.4408	0.536	0.627	0.6113	0.5328	0.743	0.664	0.4073	0.4913	35.468
1982	0	0.049	0.2495	0.5525	0.6618	0.5493	0.512	0.6765	0.544	1.0085	1.0015	0.5835	40.453
1983	0.0008	0.1078	0.2838	0.3513	0.5583	0.601	0.5985	0.5558	0.702	0.6008	2.1648	0.459	33.617
1984	0.0023	0.0983	0.3798	0.4018	0.5098	0.5388	0.4828	0.4853	0.3205	0.6973	0.5043	0.453	33.264
1985	0	0.0593	0.2525	0.459	0.6105	0.7835	0.6305	0.383	0.3628	0.509	0.6105	0.5871	40.638
1986	0	0.0368	0.3325	0.5165	0.5975	0.5803	0.6015	0.5418	0.318	0.502	0.4365	0.5547	38.945
1987	0	0.0463	0.1818	0.436	0.6018	0.7298	0.6595	0.867	0.9275	0.3855	0.6998	0.52	37.071
1988	0	0.0308	0.2565	0.5943	0.6953	0.9435	0.5893	0.5575	0.9728	1.1983	0.2963	0.6703	44.764
1989	0.002	0.033	0.2663	0.4548	0.445	0.569	0.616	0.5585	0.3328	0.5948	0.7503	0.4677	34.119
1990	0	0.0215	0.1965	0.5335	0.6478	0.817	0.638	0.7273	0.6358	0.376	1.3005	0.5976	41.176
1991	0	0.04	0.326	0.6338	0.7885	0.972	1.1173	0.9768	0.7698	0.5728	0.538	0.7101	46.62
1992	0	0.0703	0.5713	0.8668	1.174	1.2628	1.3515	1.2713	1.0095	1.1188	0.7145	1.0807	60.937
1993	0	0.1185	0.5043	0.8068	0.8635	0.8168	1.0713	0.984	1.155	0.9188	1.7243	0.8297	51.803
1994	0	0.0293	0.4865	0.7163	1.0788	0.6913	0.5453	0.7668	0.5445	0.1065	0.2818	0.7664	49.135
1995	0	0.0185	0.1733	0.4485	0.4023	0.4255	0.1895	0.2213	0.4428	0.3035	0.1975	0.4226	31.455
1996	0	0.008	0.159	0.3263	0.3338	0.251	0.1543	0.1568	0.062	0.144	0.0735	0.3182	24.831
1997	0	0.0128	0.2493	0.4603	0.245	0.2508	0.1473	0.125	0.0298	0.0575	0.1173	0.3156	24.658
1998	0	0	0.046	0.1705	0.229	0.1775	0.0855	0.038	0.023	0.006	0.002		

*** avg f = fully recruited fishing mortality.**

Table 13b. Estimated bias adjusted fishing mortality for 4X cod using the ITQ and Needler (1983-91; 1992-98) indices.

Age	1	2	3	4	5	6	7	8	9	10	11	avg. f	% exp.
1980	0	0.0418	0.3488	0.36	0.4958	0.547	0.406	0.4775	0.392	0.356	0.7238	0.4286	31.819
1981	0	0.0518	0.268	0.441	0.537	0.627	0.6113	0.533	0.743	0.664	0.4073	0.4915	35.481
1982	0	0.049	0.2495	0.5525	0.6628	0.5495	0.5123	0.6765	0.5443	1.0085	1.002	0.5838	40.471
1983	0.0008	0.1083	0.2838	0.3513	0.5588	0.6023	0.5998	0.5563	0.7025	0.6015	2.1668	0.4592	33.628
1984	0.0023	0.0983	0.3818	0.4023	0.5098	0.539	0.4848	0.4863	0.3208	0.698	0.5053	0.4532	33.28
1985	0	0.0593	0.2528	0.462	0.611	0.7838	0.6313	0.3858	0.3643	0.5095	0.6113	0.5889	40.733
1986	0	0.0368	0.3335	0.5165	0.605	0.5815	0.6015	0.5433	0.3208	0.5045	0.4373	0.5566	39.043
1987	0	0.0463	0.1818	0.437	0.602	0.7465	0.6618	0.8673	0.9323	0.3905	0.707	0.5223	37.195
1988	0	0.0308	0.2573	0.596	0.698	0.9448	0.6165	0.561	0.9743	1.2163	0.3018	0.6736	44.917
1989	0.0023	0.034	0.267	0.4565	0.447	0.5735	0.6173	0.6065	0.336	0.5965	0.7795	0.4696	34.231
1990	0	0.0223	0.2015	0.5365	0.6523	0.8248	0.648	0.731	0.743	0.3815	1.31	0.6017	41.387
1991	0.0003	0.0418	0.339	0.6588	0.797	0.9868	1.1463	1.0118	0.7785	0.7775	0.55	0.7321	47.619
1992	0	0.0775	0.5985	0.932	1.302	1.3035	1.423	1.389	1.1135	1.1528	1.5015	1.1702	63.707
1993	0	0.1348	0.5748	0.8888	1.0378	1.1048	1.1898	1.1673	1.6258	1.2183	1.9908	0.9618	56.881
1994	0	0.0363	0.5828	0.9308	1.4338	1.0888	1.1138	1.0155	0.8098	0.2103	0.4923	1.0382	59.54
1995	0	0.0228	0.221	0.6093	0.6655	0.8453	0.4178	0.8205	0.7913	0.6005	0.4678	0.6342	43.016
1996	0	0.0103	0.1985	0.453	0.5453	0.5525	0.443	0.4473	0.3678	0.3425	0.1793	0.4688	34.185
1997	0	0.016	0.322	0.6365	0.39	0.5215	0.4368	0.4985	0.1035	0.493	0.3453	0.4989	35.899
1998	0	0	0.058	0.2325	0.3605	0.3145	0.212	0.135	0.1145	0.0215	0.017		

***avg. f = fully exploited fishing mortality.**

Table 13c. Estimated bias adjusted fishing mortality and exploitation rate for 4X cod using the RV index, and estimating m from 1992-98.

Age	1	2	3	4	5	6	7	8	9	10	11	avg f.*	%exp.
1980	0	0.0418	0.347	0.3588	0.4948	0.5465	0.405	0.477	0.392	0.356	0.723	0.4278	31.772
1981	0	0.0518	0.2678	0.4378	0.5348	0.6255	0.611	0.531	0.743	0.663	0.406	0.4887	35.324
1982	0	0.0483	0.249	0.5518	0.6543	0.5463	0.509	0.675	0.541	1.007	0.999	0.5805	40.299
1983	0.0008	0.1068	0.279	0.3503	0.557	0.5875	0.593	0.551	0.699	0.595	2.15	0.4564	33.461
1984	0.0023	0.0963	0.3758	0.392	0.5075	0.537	0.466	0.478	0.316	0.691	0.496	0.445	32.797
1985	0	0.0565	0.2473	0.4518	0.5858	0.7775	0.626	0.362	0.354	0.498	0.6	0.5733	39.923
1986	0	0.0338	0.3135	0.5008	0.5815	0.539	0.592	0.535	0.294	0.484	0.422	0.534	37.834
1987	0	0.0395	0.1643	0.401	0.5703	0.692	0.577	0.839	0.903	0.345	0.654	0.4803	34.846
1988	0	0.0233	0.214	0.5138	0.6015	0.8415	0.534	0.443	0.898	1.11	0.255	0.5829	40.422
1989	0.0013	0.0205	0.1938	0.3545	0.3523	0.4405	0.489	0.472	0.237	0.505	0.624	0.3654	27.913
1990	0	0.0138	0.134	0.3918	0.4935	0.6403	0.47	0.557	0.557	0.27	1.048	0.6607	44.304
1991	0	0.026	0.2378	0.4815	0.6155	0.7845	0.908	0.757	0.625	0.605	0.433	0.7613	48.913
1992	0	0.0428	0.4258	0.6983	0.9015	0.9758	1.058	0.993	0.755	0.904	1.131	0.8599	53.02
1993	0	0.0668	0.3308	0.6173	0.7175	0.6003	0.762	0.737	0.836	0.671	1.355	0.6505	43.81
1994	0	0.0153	0.294	0.4753	0.832	0.649	0.422	0.511	0.417	0.08	0.22	0.5523	38.813
1995	0	0.0108	0.1068	0.2788	0.2708	0.3348	0.214	0.194	0.297	0.263	0.173	0.2924	23.089
1996	0	0.0055	0.1108	0.2293	0.2238	0.1923	0.145	0.234	0.065	0.106	0.074	0.2387	19.323
1997	0	0.0088	0.2045	0.371	0.1993	0.195	0.137	0.15	0.06	0.08	0.109	0.2709	21.605
1998	0	0	0.0345	0.156	0.2025	0.1635	0.075	0.041	0.033	0.014	0.003		

***avg. f = fully exploited fishing mortality.**

Table 14a. Projections for cod in Division 4X, using the RV (1983-1998) and ITQ indices. M=0.2.

	Beg. Yr. Wt.			Mid-yr. Wt.		Catch Biomass		Catch Numbers		F		Population Numbers			Population Biomass		
Age	1998.5	1999	2000	1998.5	1999	1998.5	1999	1998.5	1999	1998.5	1999	1998.5	1999	2000	1998.5	1999	2000
1	0.38	0.28	0.28	0.48	0.38	0	0	0	0	0	0	10858	12000	12000	4126	3360	3360
2	0.89	0.73	0.73	0.91	0.89	141	79	155	89	0.038	0.01	8730	9825	9825	7770	7172	7172
3	1.39	1.12	1.12	1.45	1.39	483	788	333	567	0.188	0.084	3901	7752	7964	5422	8683	8919
4	2.07	1.81	1.81	2.21	2.07	950	852	430	412	0.32	0.152	3054	3213	5836	6322	5816	10563
5	3.09	2.69	2.69	3.17	3.09	1023	1200	323	388	0.376	0.2	1976	2355	2260	6107	6336	6078
6	4.2	3.68	3.68	4.31	4.2	2292	1026	532	244	0.376	0.2	3256	1482	1579	13677	5453	5810
7	5.58	4.61	4.61	5.87	5.58	535	2246	91	402	0.376	0.2	558	2442	993	3116	11256	4579
8	7.45	6.62	6.62	7.46	7.45	512	514	69	69	0.376	0.2	421	419	1637	3133	2771	10834
9	10.52	8.14	8.14	9.91	10.52	163	547	16	52	0.376	0.2	100	315	281	1057	2567	2284
10	12.6	12.34	12.34	11.95	12.6	117	156	10	12	0.376	0.2	60	75	211	756	929	2608
11	15.58	14.69	14.69	14.09	15.58	183	115	13	7	0.376	0.2	80	45	50	1241	660	742
1+						6400	7523								52725	55003	62950
2+						6400	7523								48599	51643	59590
3+						6259	7444								40829	44471	52418
4+						5776	6656								35407	35788	43499

Table 14b. Projections for cod in Division 4X, using theITQ 95-98 index, and the Needler 83-91 and 92-98 indices. M=0.2.

	Beg. Yr. Wt.			Mid-yr. Wt.		Catch Biomass		Catch Numbers		F		Population Numbers			Population Biomass		
Age	1998.5	1999	2000	1998.5	1999	1998.5	1999	1998.5	1999	1998.5	1999	1998.5	1999	2000	1998.5	1999	2000
1	0.38	0.28	0.28	0.48	0.38	0	0	0	0	0	0	10858	12000	12000	4126	3360	3360
2	0.89	0.73	0.73	0.91	0.89	207	79	228	89	0.067	0.01	7225	9825	9825	6430	7172	7172
3	1.39	1.12	1.12	1.45	1.39	691	642	477	462	0.337	0.084	3225	6321	7964	4482	7080	8919
4	2.07	1.81	1.81	2.21	2.07	1219	654	551	316	0.573	0.152	2320	2465	4758	4803	4462	8612
5	3.09	2.69	2.69	3.17	3.09	1138	803	359	260	0.674	0.2	1315	1576	1734	4062	4241	4664
6	4.2	3.68	3.68	4.31	4.2	2325	588	540	140	0.674	0.2	1976	849	1057	8298	3125	3889
7	5.58	4.61	4.61	5.87	5.58	391	1174	67	210	0.674	0.2	244	1276	569	1361	5883	2624
8	7.45	6.62	6.62	7.46	7.45	264	193	35	26	0.674	0.2	130	158	855	965	1043	5663
9	10.52	8.14	8.14	9.91	10.52	56	145	6	14	0.674	0.2	21	84	106	217	681	860
10	12.6	12.34	12.34	11.95	12.6	67	28	6	2	0.674	0.2	20	13	56	257	165	692
11	15.58	14.69	14.69	14.09	15.58	42	34	3	2	0.674	0.2	11	13	9	170	194	131
1+						6400	4340								35173	37405	46587
2+						6400	4340								31047	34045	43227
3+						6193	4261								24617	26873	36055
4+						5501	3619								20134	19794	27136

Table 14c. Projections for cod in Division 4X, using the RV index 1983-1998. M=0.2 for 1980-1990; M estimated for 1991-1998

	Beg. Yr. Wt.			Mid-yr. Wt.		Catch Biomass		Catch Numbers		F		Population Numbers			Population Biomass		
Age	1998.5	1999	2000	1998.5	1999	1998.5	1999	1998.5	1999	1998.5	1999	1998.5	1999	2000	1998.5	1999	2000
1	0.38	0.28	0.28	0.48	0.38	0	0	0	0	0	0	9700	12000	12000	3686	3360	3360
2	0.89	0.73	0.73	0.91	0.89	218	58	240	65	0.041	0.01	13020	7942	8044	11587	5797	5872
3	1.39	1.12	1.12	1.45	1.39	632	967	436	695	0.205	0.084	4916	10443	5270	6834	11696	5903
4	2.07	1.81	1.81	2.21	2.07	1113	878	504	424	0.349	0.152	3460	3632	6436	7162	6575	11649
5	3.09	2.69	2.69	3.17	3.09	1093	1106	345	358	0.411	0.2	2043	2379	2092	6312	6400	5626
6	4.2	3.68	3.68	4.31	4.2	2176	860	505	205	0.411	0.2	2991	1362	1306	12562	5012	4805
7	5.58	4.61	4.61	5.87	5.58	460	1674	78	300	0.411	0.2	464	1994	748	2588	9193	3446
8	7.45	6.62	6.62	7.46	7.45	411	346	55	47	0.411	0.2	327	309	1094	2433	2047	7245
9	10.52	8.14	8.14	9.91	10.52	120	345	12	33	0.411	0.2	71	218	170	752	1773	1381
10	12.6	12.34	12.34	11.95	12.6	65	90	5	7	0.411	0.2	32	48	120	405	588	1475
11	15.58	14.69	14.69	14.09	15.58	112	50	8	3	0.411	0.2	47	21	26	734	315	384
1+						6400	6374								55055	52756	51147
2+						6400	6374								51369	49396	47787
3+						6182	6316								39782	43598	41915
4+						5550	5349								32948	31902	36012

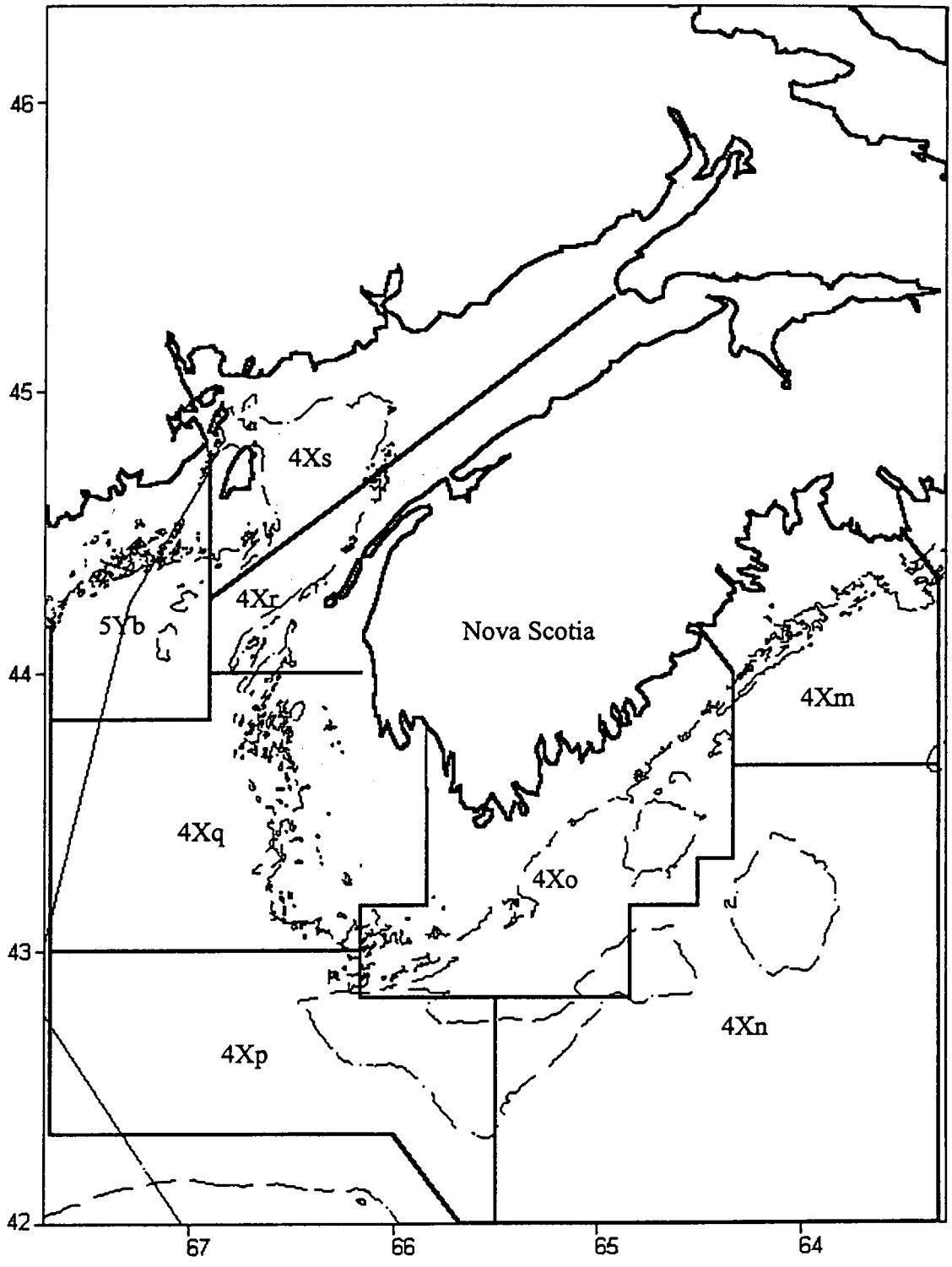

Fig. 1. Canadian Statistical unit areas in NAFO Divisions 4X and 5Y. Shaded area is the Bay of Fundy region.

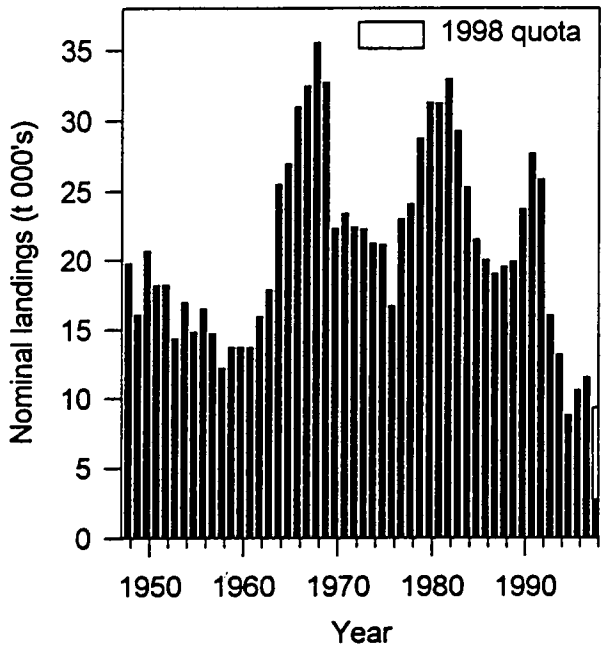

Fig. 2. Nominal landings of cod in Division 4X including catches by Canada in Division 5Y. For 1998, quota and mid-year landings shown.

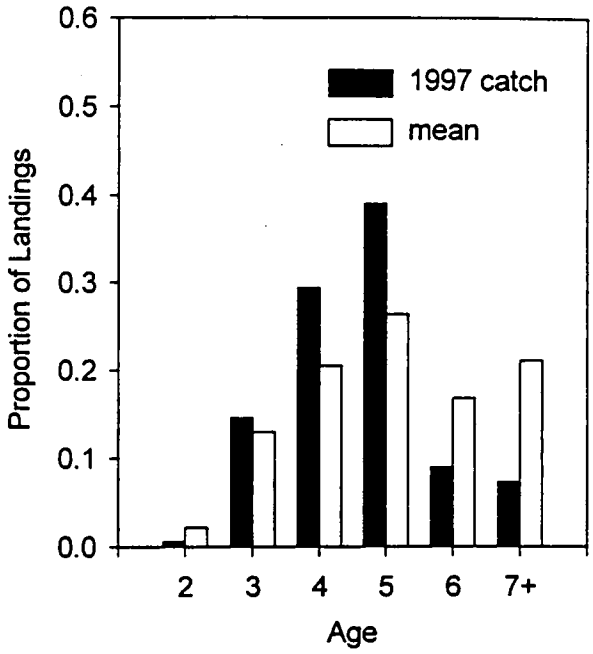

Fig. 3. Division 4X cod catch (t) at age for 1997 compared to the 1980-96 mean.

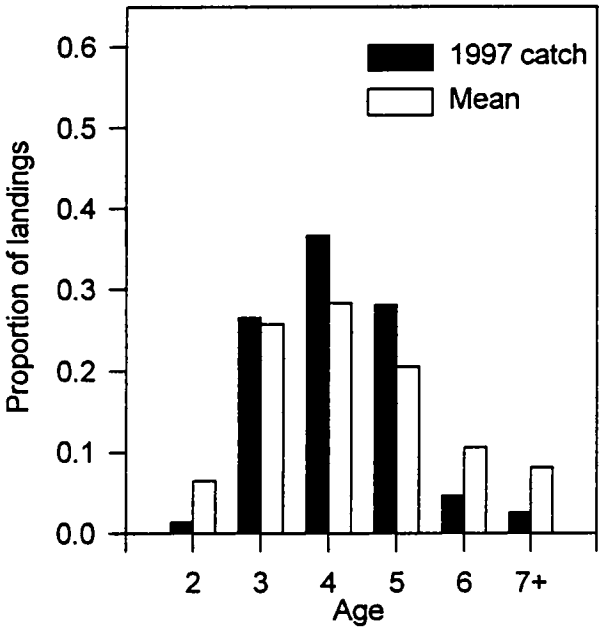

Fig. 4. 4X cod catch at age (in numbers) for 1997 compared to the mean for 1980-96.

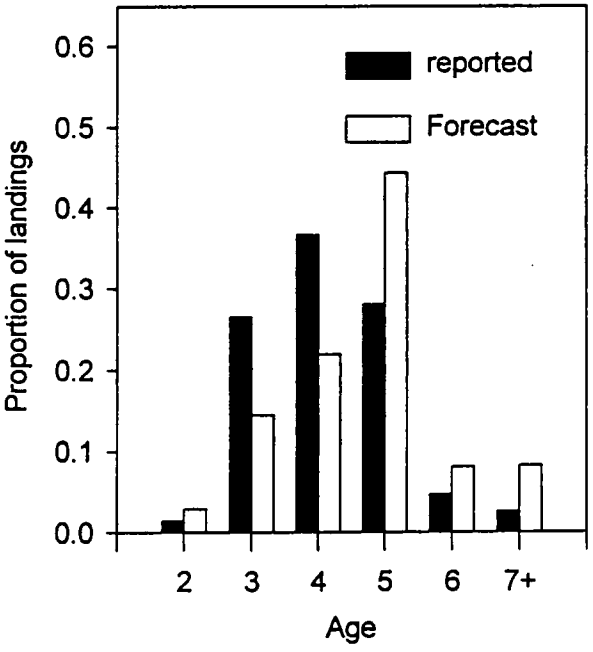

Fig. 5. Reported and forecast landings of cod in Division 4X for 1997 proportioned by age.

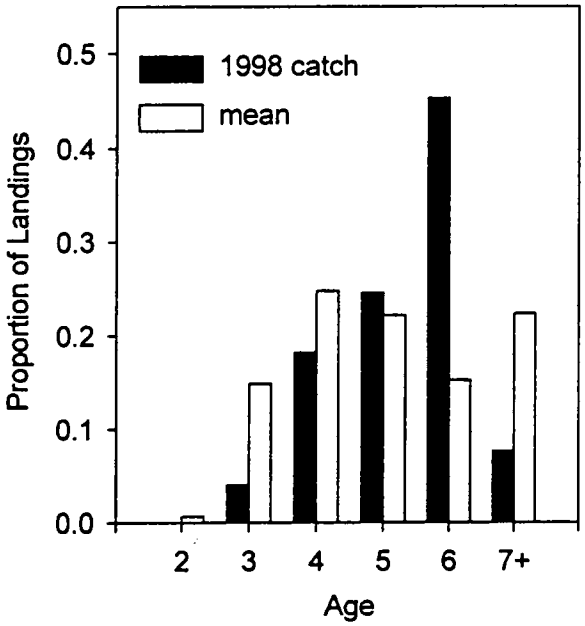

Fig. 6. Division 4X cod catch (t) at age for 1998 compared to the 1980-97 mean (Jan.-July).

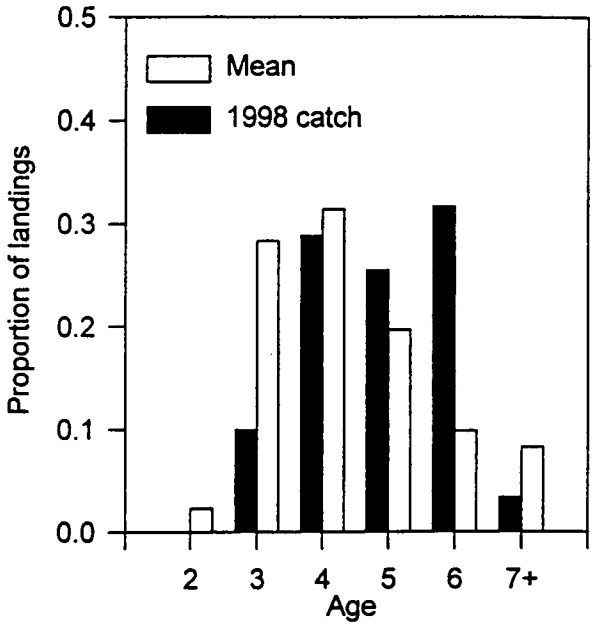

Fig. 7. 4X cod catch at age (in numbers) for 1998 compared to the mean for 1980 -1997 (January - July).

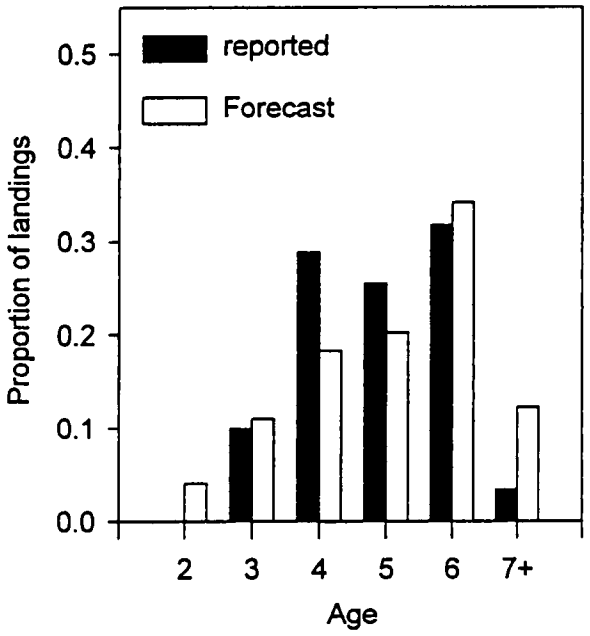

Fig. 8. Reported and forecast landings at age of cod in Division 4X for 1998 (Jan. - July)

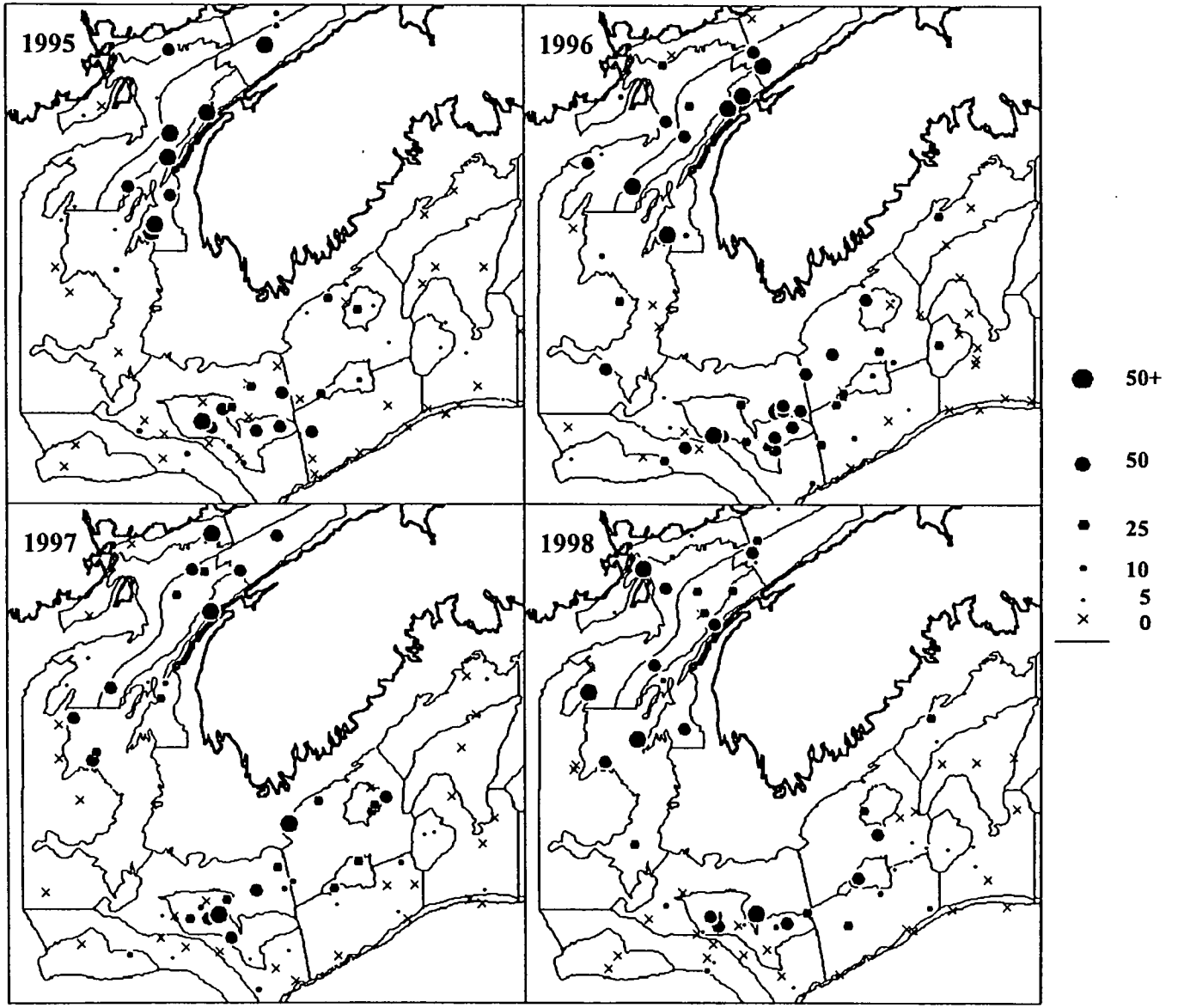

Fig. 9. Summer RV groundfish survey 4X cod catches (Kg/tow)

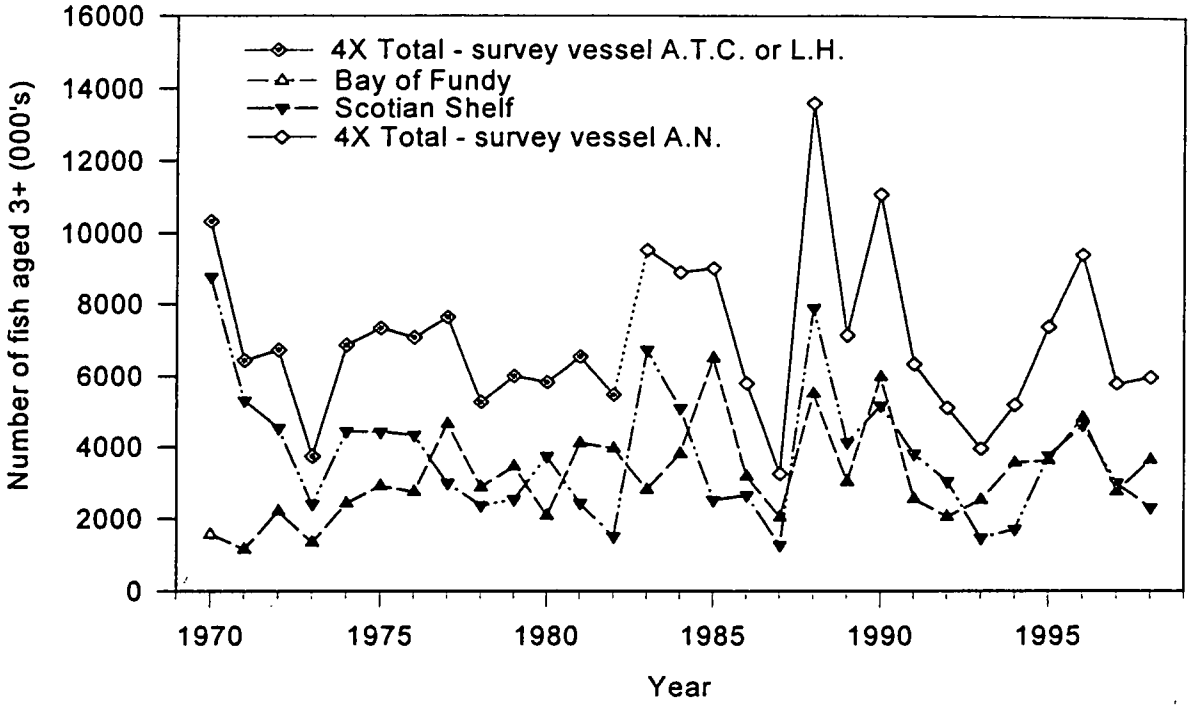

Fig 10. Summer groundfish survey indices for 4X cod by region.

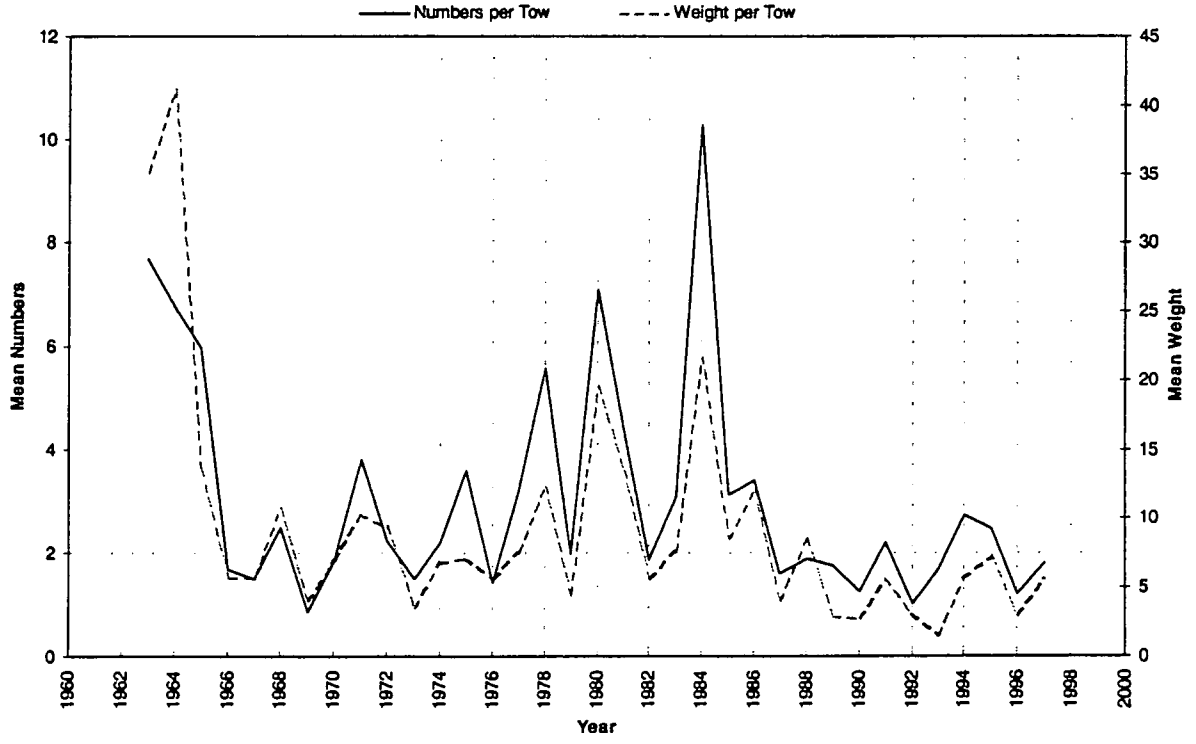

Fig. 10b. U.S. fall groundfish survey catches of cod in Division 4X.

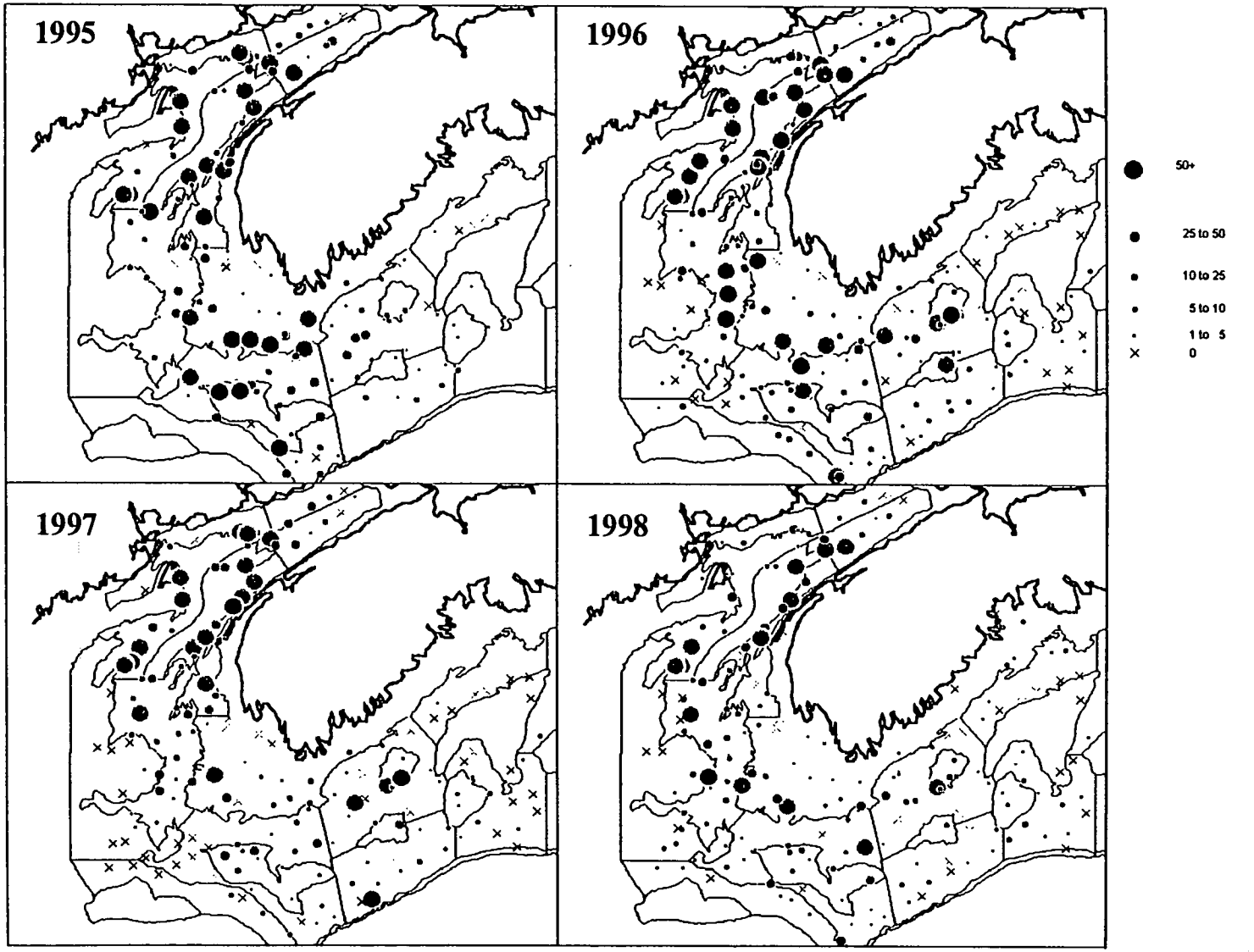

Fig. 11. Summer ITQ groundfish survey 4X cod catches (Kg/tow). Stations represented by light symbols are repeated in each year; dark symbols represent stations occupied only in some years.

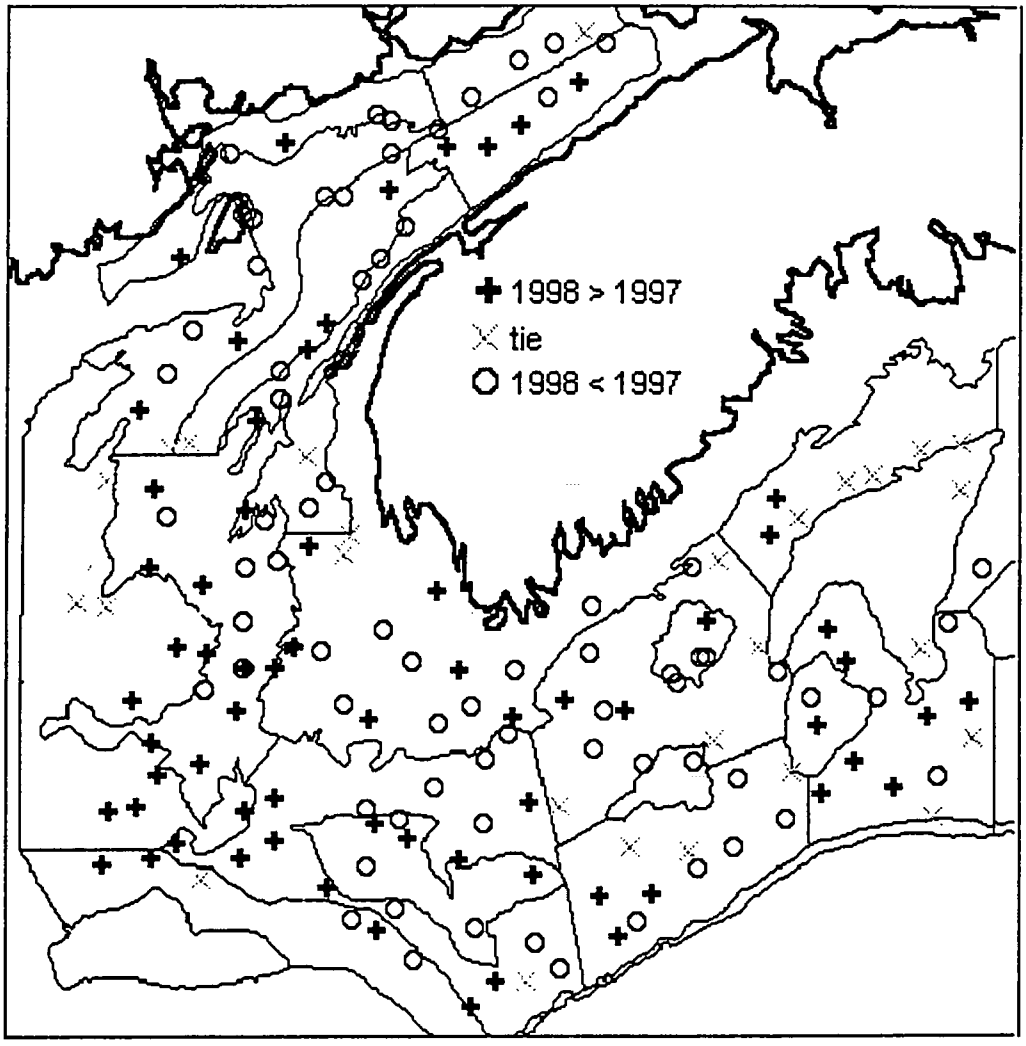

Fig. 12. A Comparison of ITQ survey cod catches at repeated stations for 1997 and 1998.

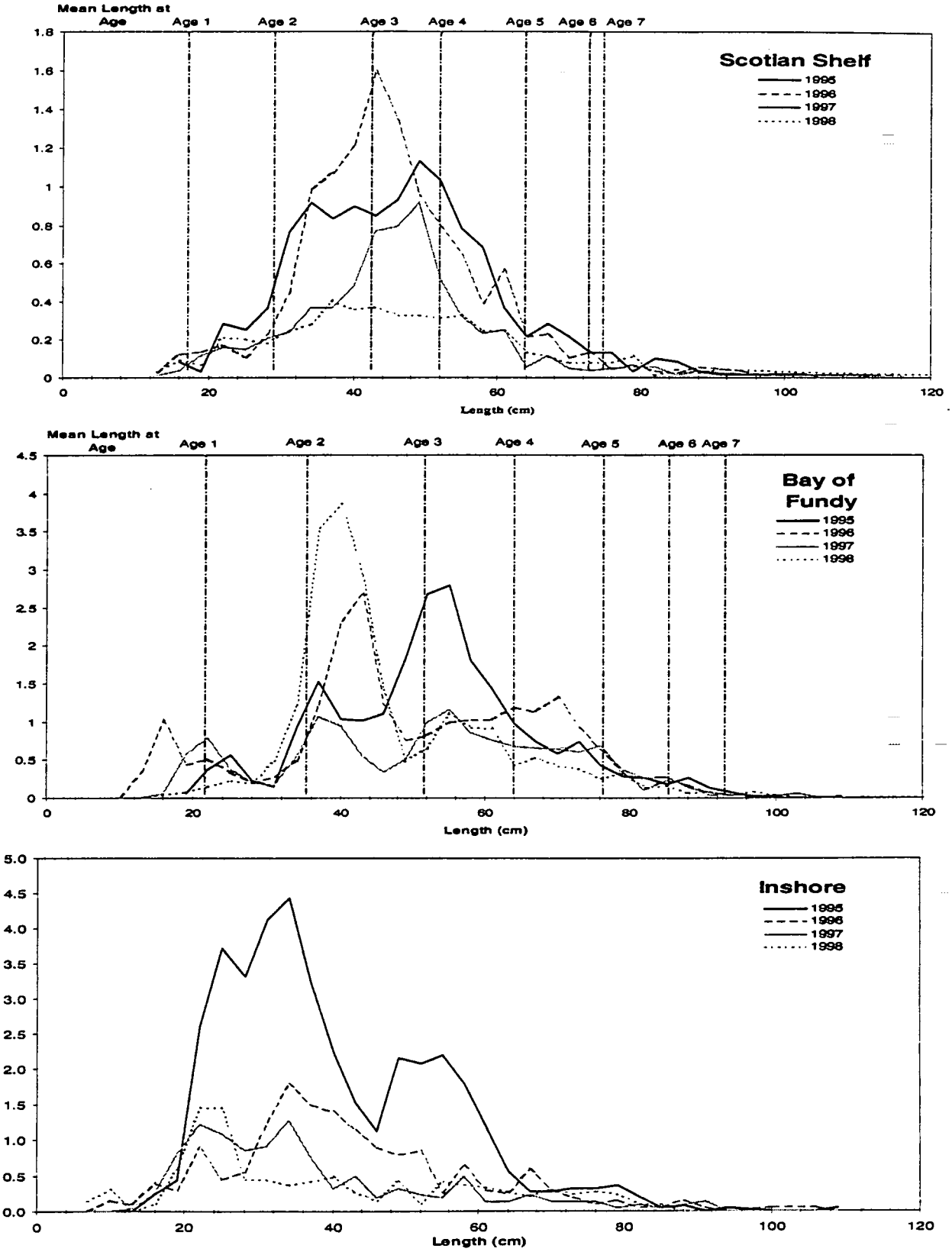

Fig.13. Length frequencies from the ITQ surveys in Division 4X.

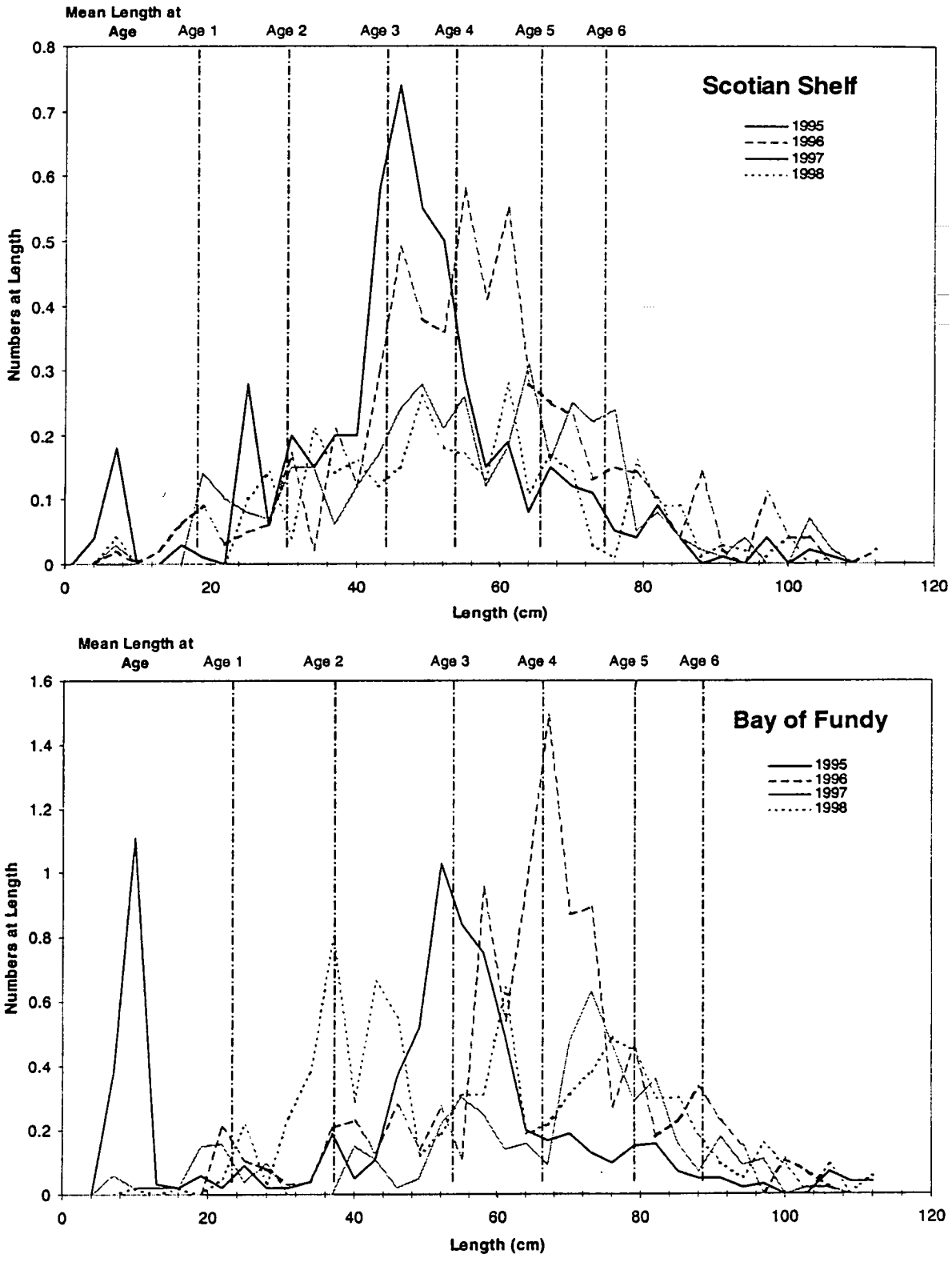

Fig.14. Length frequencies from the summer RV groundfish surveys in Division 4X.

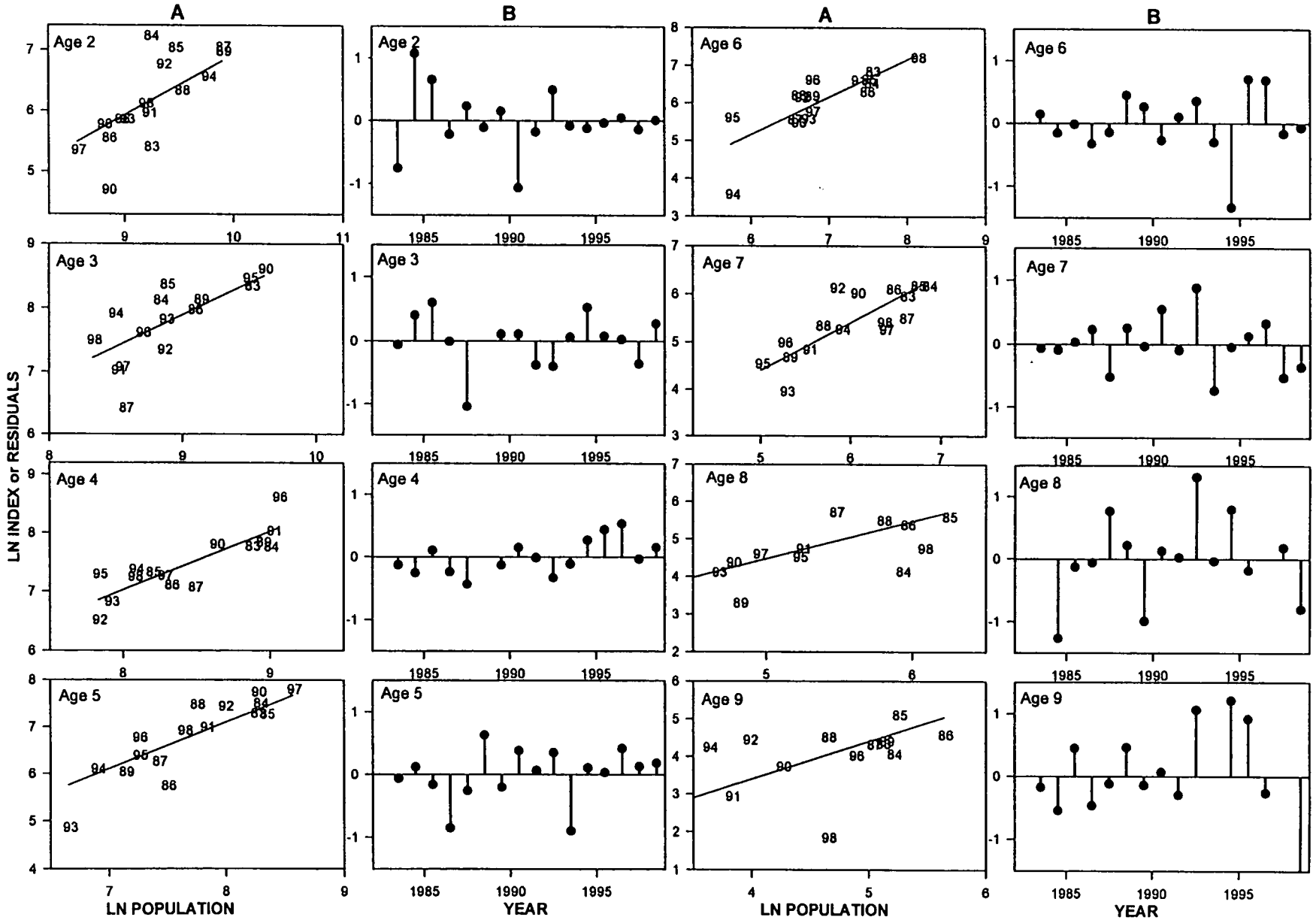

Fig. 15a. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for cod in Division 4X and the Canadian portion of 5Y.RV index 1983-1998, ITQ index 1995-1998.

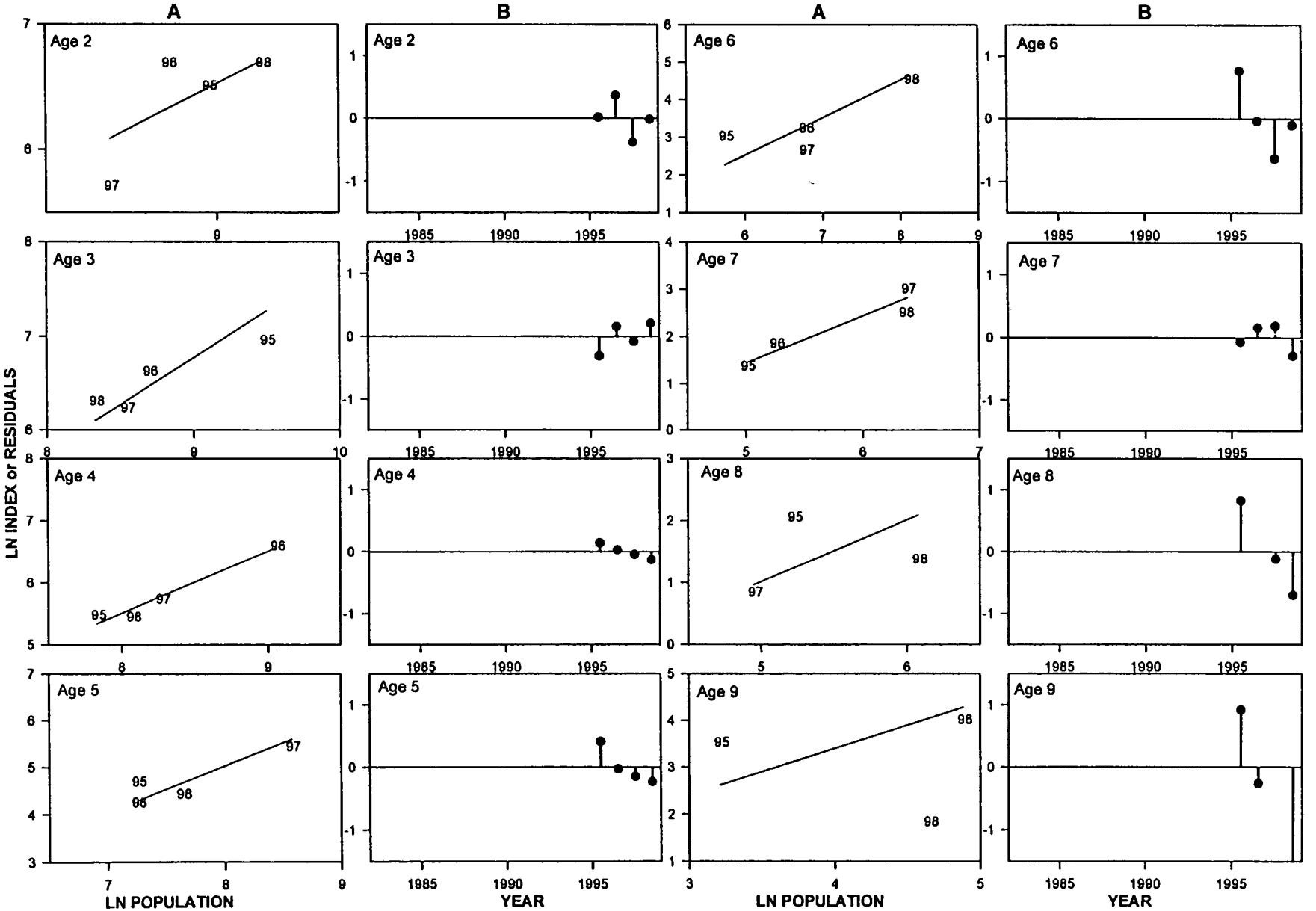

Fig. 15a (cont). Age by age plots of A) the observed and predicted ln ITQ abundance index versus ln population numbers, and B) residuals plotted against year for cod in Division 4X and the Canadian portion of 5Y.RV index 1983-1998, IITQ index 1995-1998.

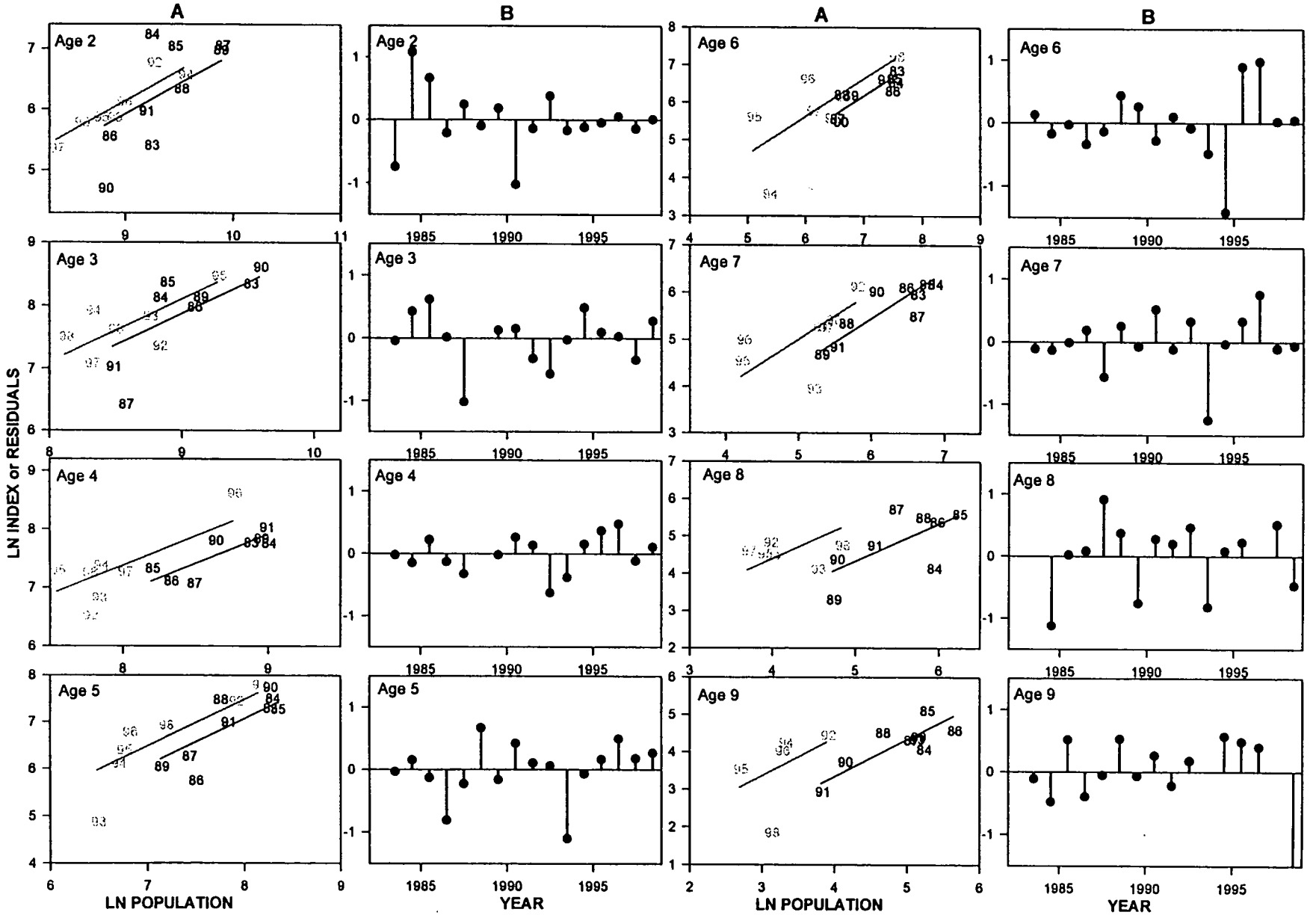

Fig. 15b. Age by age plots of A) the observed and predicted ln RV abundance index versus ln population numbers, and B) residuals plotted against year for cod in Division 4X and the Canadian portion of 5Y. RV1 1983-1991, RV2 1992-1998, ITQ 1995-1998.

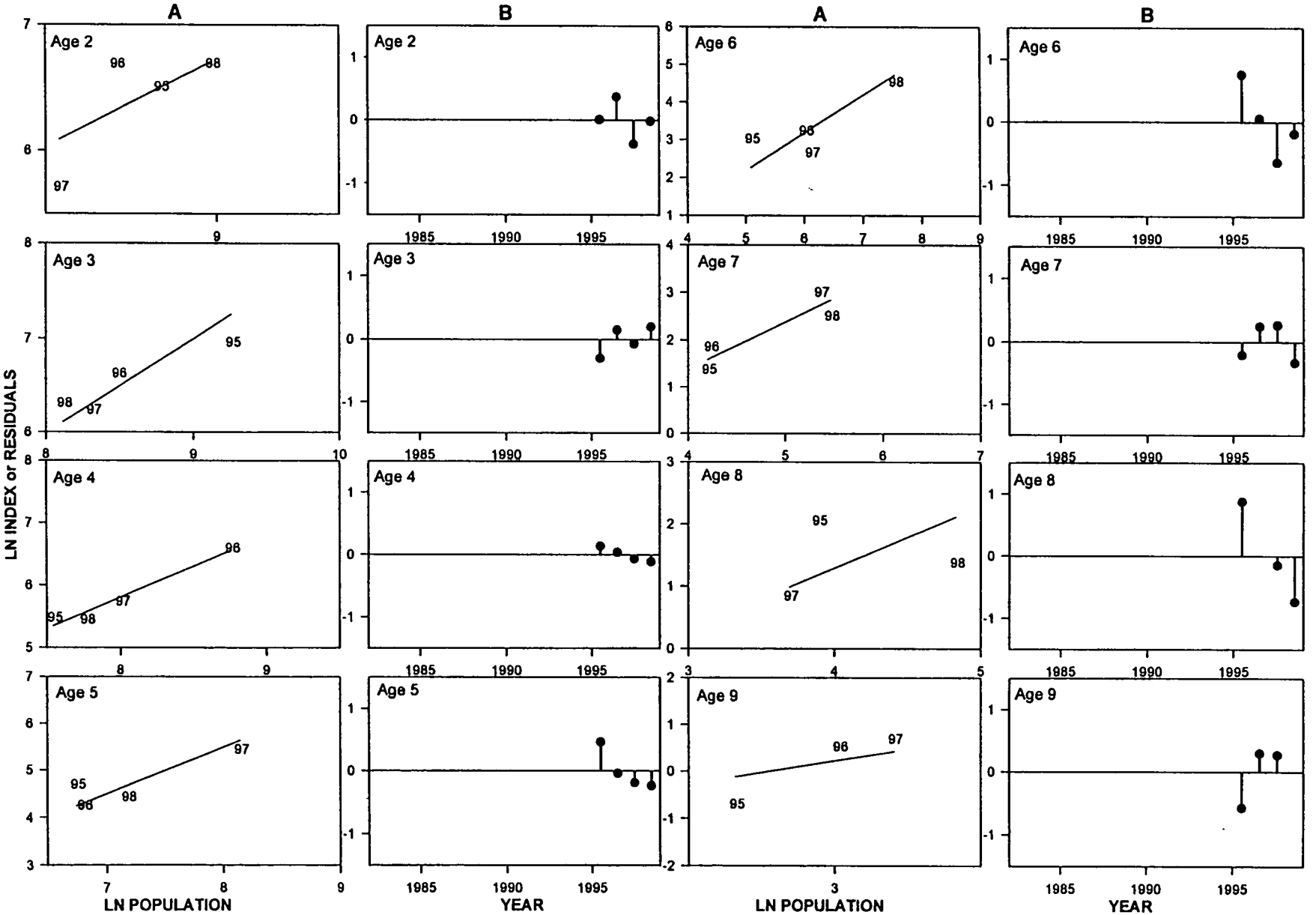

Fig. 15b (cont.). Age by age plots of A) the observed and predicted ln ITQ abundance index versus ln population numbers, and B) residuals plotted against year for cod in Division 4X and the Canadian portion of 5Y.RV1 1983-91, RV2 1992-98, ITQ 1995-98.

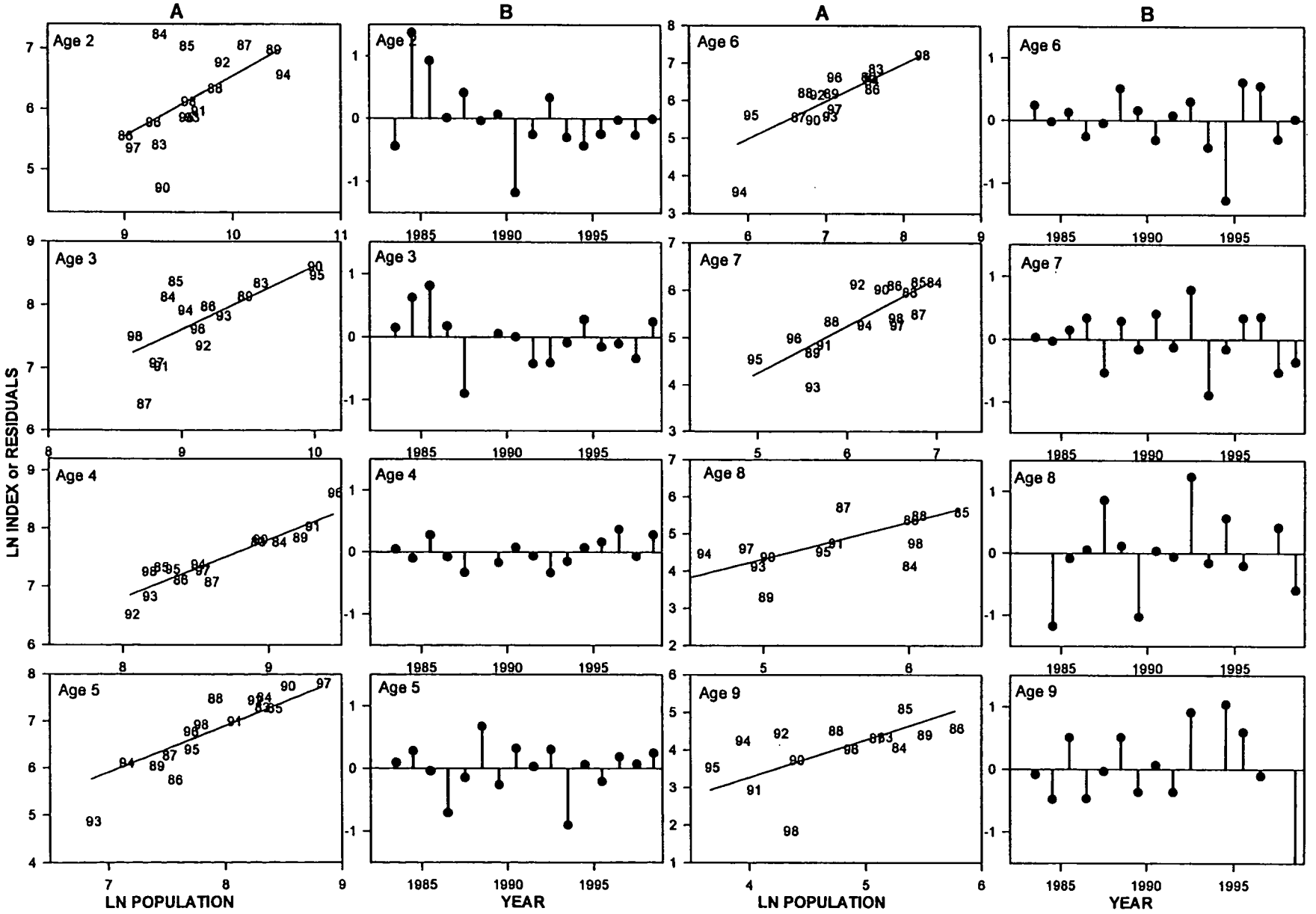

Fig. 15c. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for cod in Division 4X and the Canadian portion of 5Y. m fixed (.2) 1983-1990, and estimated 1991-1998.

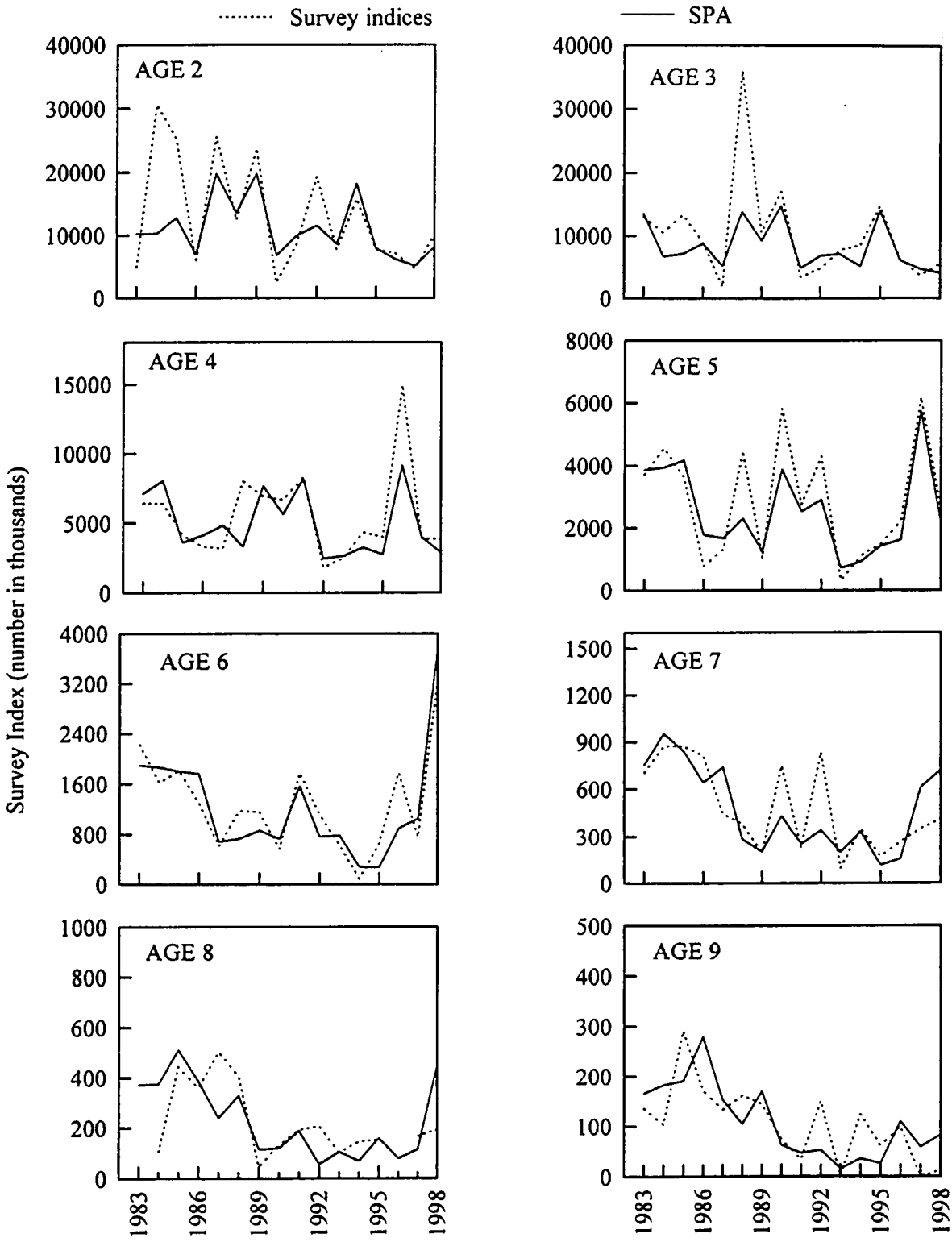

Fig. 16. Mid-year population numbers from sequential population analysis (SPA) and research survey indices (adjusted by calibration constants) for 4X cod.

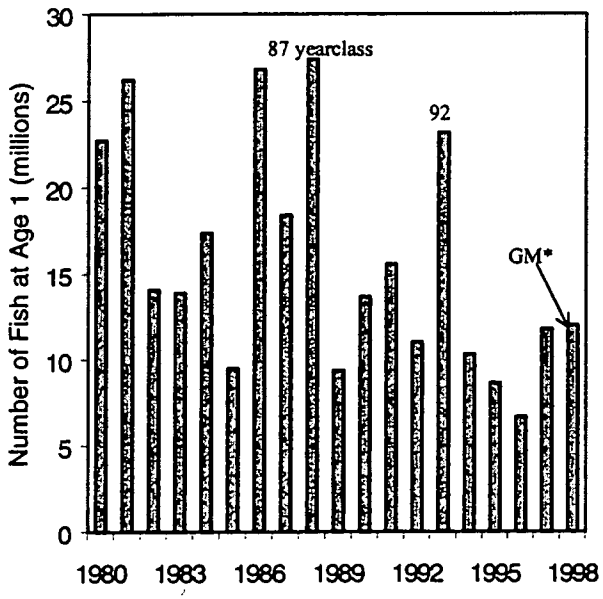

Fig. 17. Recruitment (age 1) for cod in Division 4X, calculated using the RV and ITQ indices. M=0.2.

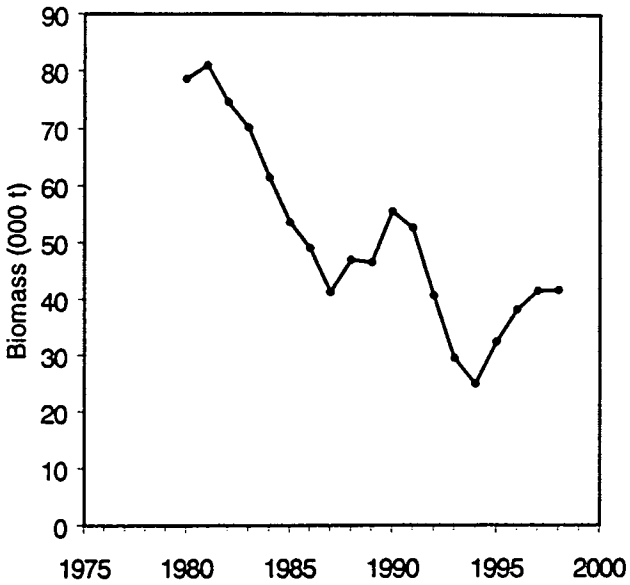

Fig. 18. Beginning of year biomass (3+) for cod in Division 4X, using the ITQ and RV indices.

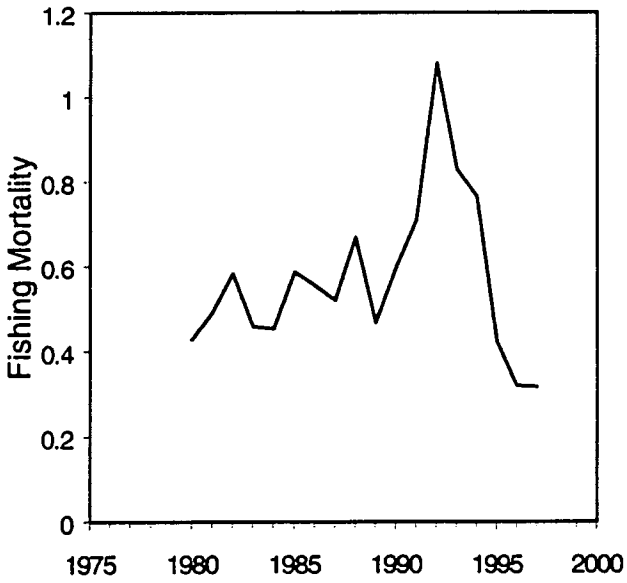

Fig. 19. Fully recruited fishing mortality for 4X cod, using the ITQ and RV indices.

* GM=Geometric Mean (1990-1995)

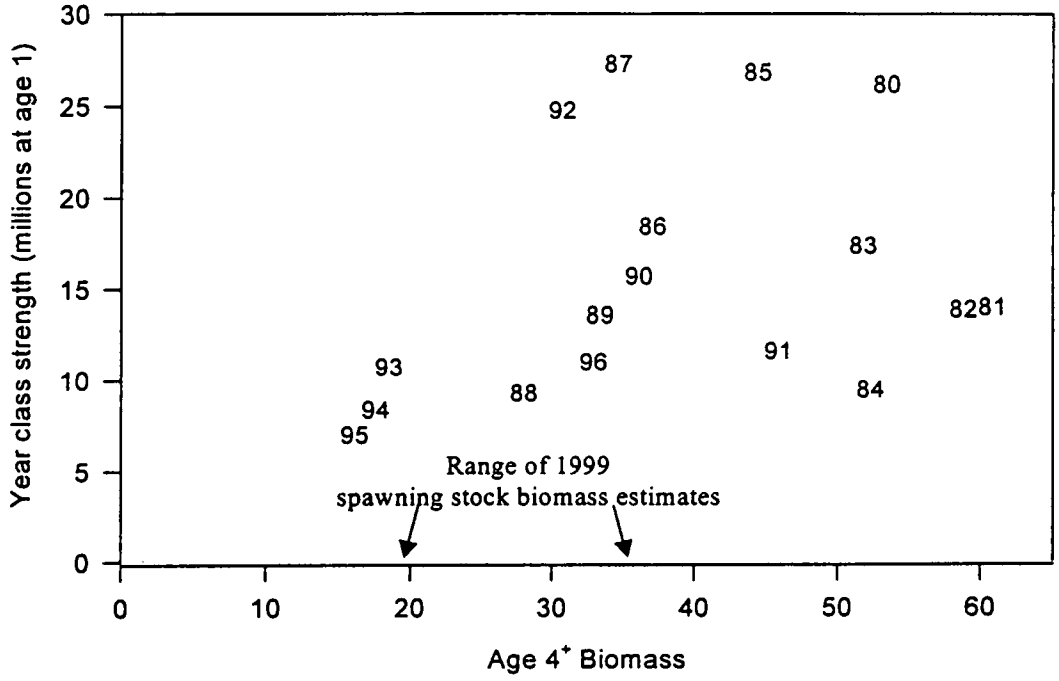

Fig. 20. Stock recruitment relationship for 4X cod.

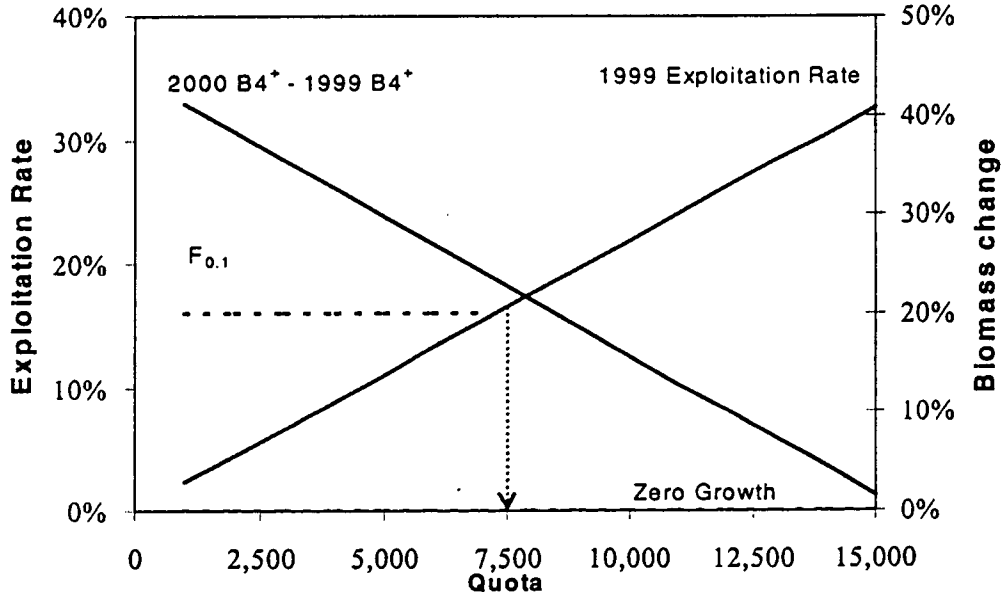

Fig 21. Yield and resultant exploitation rate for 4X cod in 1999, and its impact on age 4+ biomass.

Appendix 1. Trends in landings and effort in the 4X cod fishery.

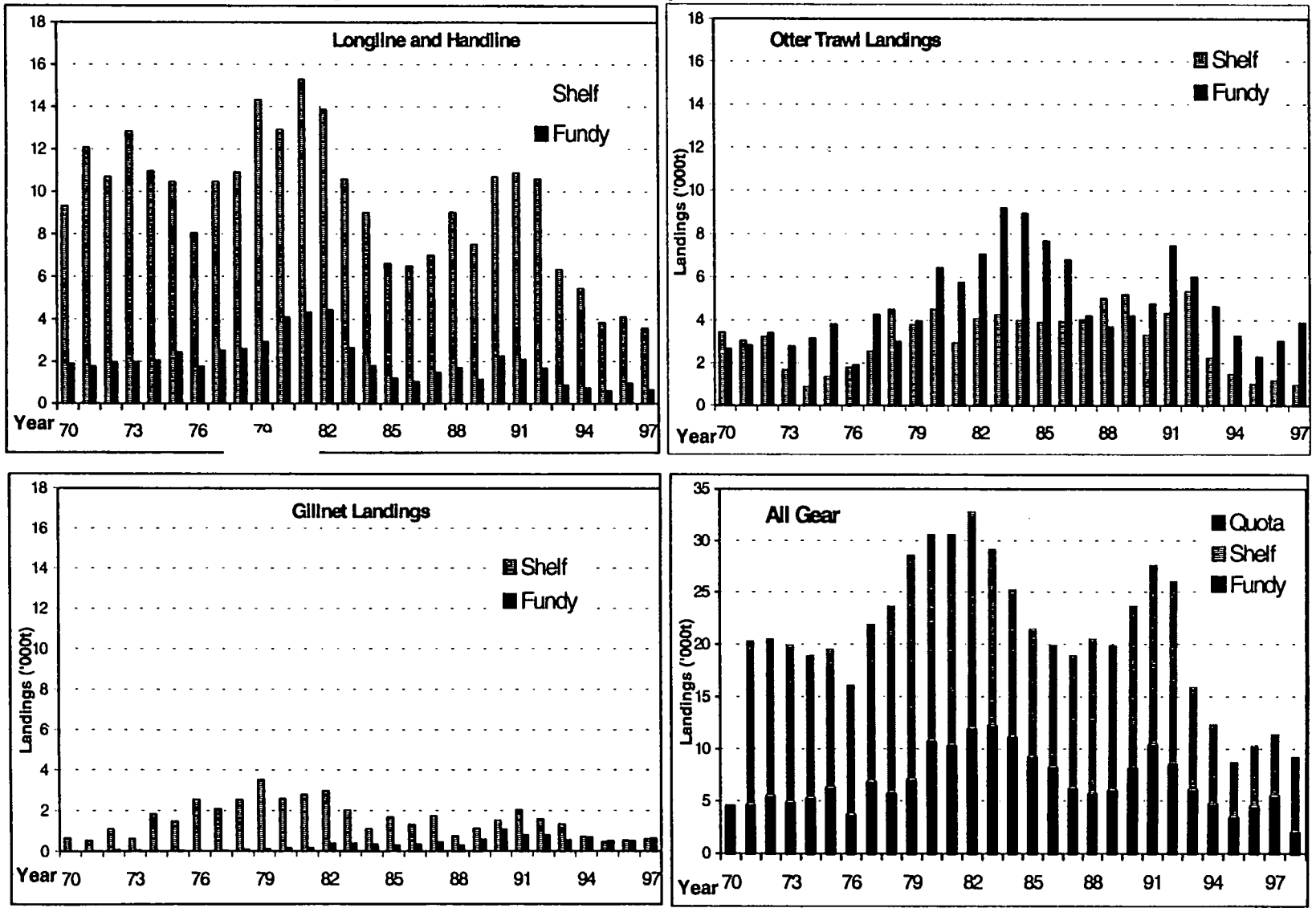

Fig AI.1 Annual landings of 4X cod by gear type and area.

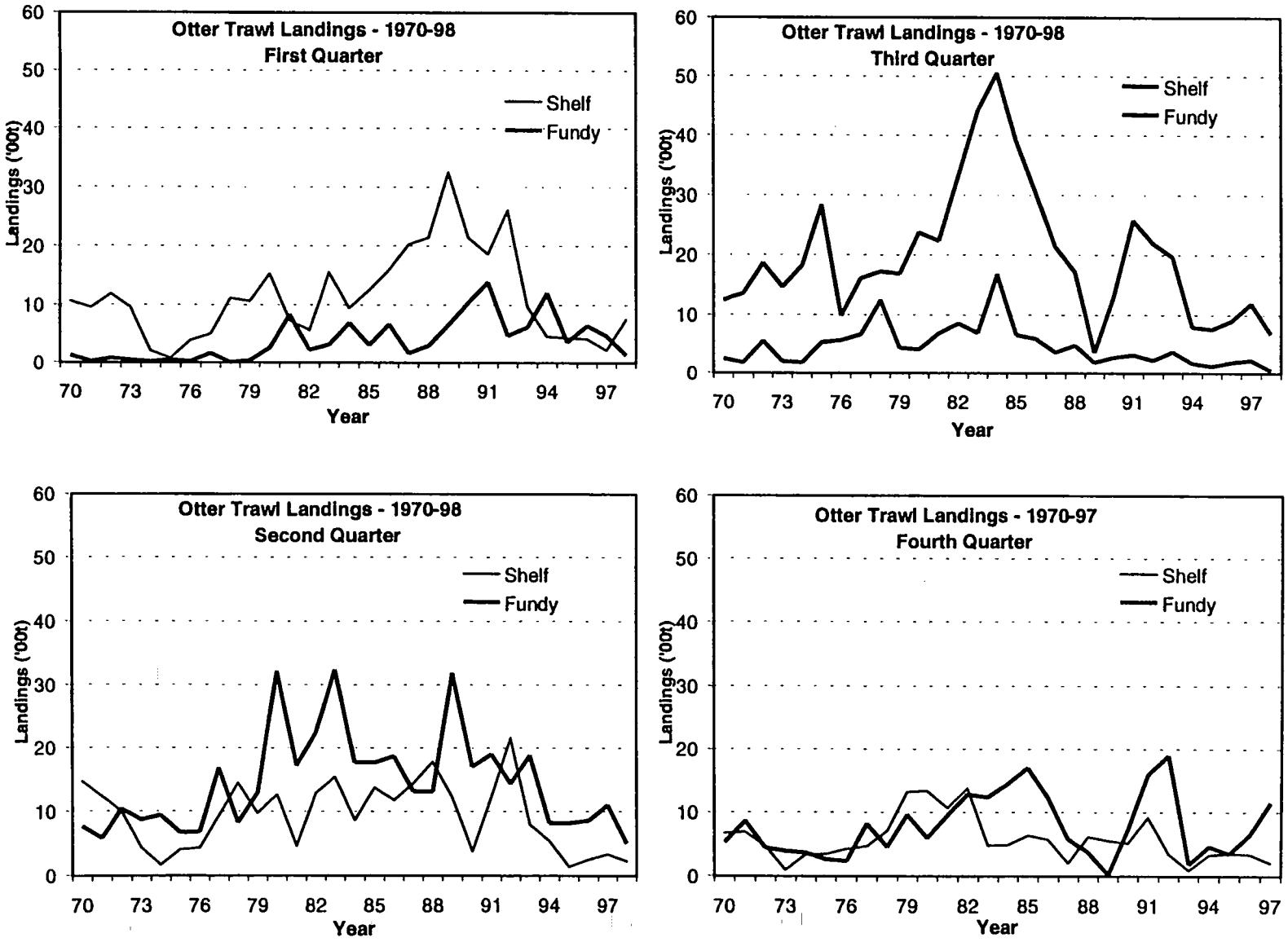

Fig. AI.2. Landings of 4X cod by otter trawl by area and quarter.

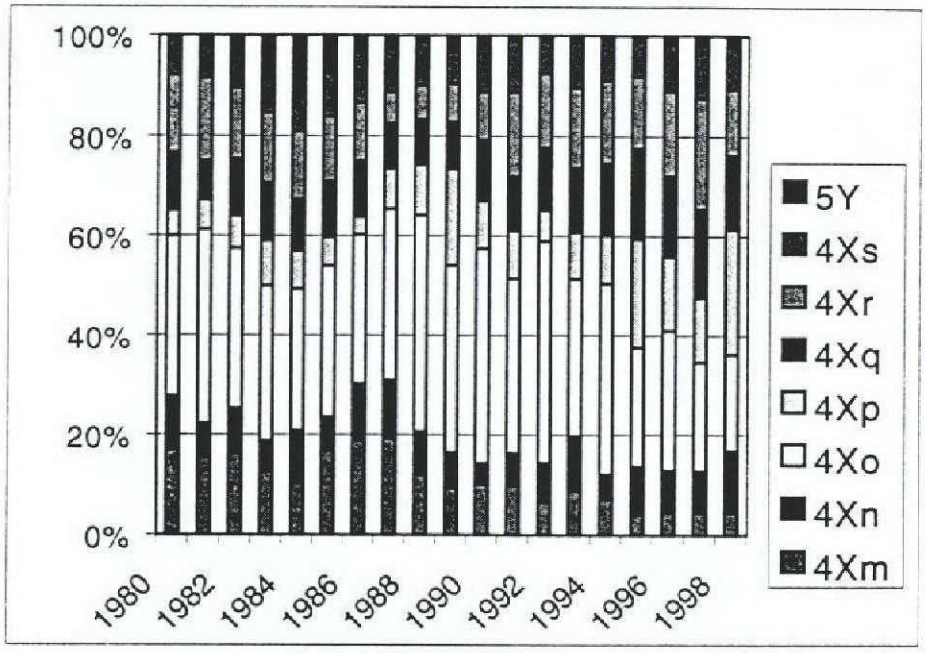

Fig AI.3. Proportional landings of 4X cod by unit area.

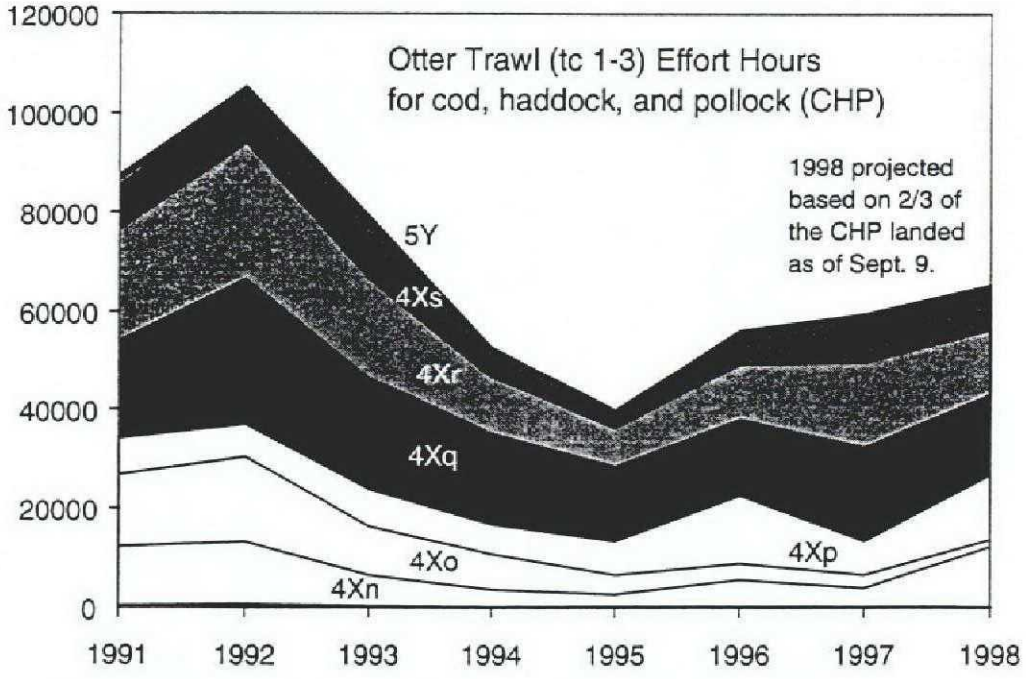

Fig. AI.4. Total fishing effort directed for cod, haddock, or pollock by tc 1-3 otter trawlers in Division 4X.

Appendix II.

Age Comparison Tests.

Routine age comparison testing was conducted for 4X cod. Intra-reader tests were conducted with otoliths from 1997 in order to evaluate whether there has been any shift in interpretation over time. The results showed acceptable levels of agreement , and did not give any indication of bias in interpretations. Otoliths deemed unreadable (cryst.) were not included in the analysis.

Bay of Fundy

	second												first
first	0	1	2	3	4	5	6	7	8	9	10	cryst.	total
0	5	0	0	0	0	0	0	0	0	0	0	0	5
1	0	14	1	0	0	0	0	0	0	0	0	0	15
2	0	0	6	0	0	0	0	0	0	0	0	0	6
3	0	0	1	24	0	0	0	0	0	0	0	0	25
4	0	0	0	2	18	1	0	0	0	0	0	0	21
5	0	0	0	0	0	40	1	0	0	0	0	0	41
6	0	0	0	0	0	1	4	0	0	0	0	0	5
7	0	0	0	0	0	0	0	4	0	0	0	0	4
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	1	0	1
cryst.	0	0	0	0	0	0	0	0	0	0	0	4	4
second total	5	14	8	26	18	42	5	4	0	0	1	4	127

Agreement= 94.5%

Scotian Shelf

	second												first
first	0	1	2	3	4	5	6	7	8	9	10	cryst.	total
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	6	0	0	0	0	0	0	0	0	0	0	6
2	0	0	27	1	0	0	0	0	0	0	0	0	28
3	0	0	0	40	2	0	0	0	0	0	0	0	42
4	0	0	0	4	46	2	0	0	0	0	0	1	53
5	0	0	0	0	1	63	0	0	0	0	0	0	64
6	0	0	0	0	0	0	8	0	0	0	0	0	8
7	0	0	0	0	0	0	0	7	0	0	0	0	7
8	0	0	0	0	0	0	0	0	4	0	0	0	4
9	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	2	0	2
cryst.	0	0	0	0	0	0	0	0	0	0	0	6	6
second total	0	6	27	45	49	65	8	7	4	0	2	7	220

Agreement= 95%