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Assessment of Cod in Division 4X in 1997

by

D. Clark
Department of Fisheries and Oceans
Biological Station
St. Andrew's, New Brunswick

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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, 3,800t of which was landed by the end of June. Landings in 1996 and the first half of 1997 were dominated by the 1992 year class. The summer survey indicates that abundance of 4X cod has declined since 1996, but continues to indicate that the 1992 year class is particularly strong. Abundance at ages greater than 6, however, remains low. The 1993 and 94 year-classes (ages 3 and 4) appear to be weak, and the initial indications are that the 1995 year-class is also below average.

The adaptive framework was used to calibrate the sequential population analysis with the research survey results. The analysis was conducted using catch at age data for quarter-year intervals, including the first half of 1997. Beginning of year biomass for ages 3 and older increased annually from the historic low recorded in 1994 up to 1997. Biomass is projected to decline slightly for the beginning of 1998. The 1992 year-class is estimated to be among the strongest during the period examined (1977-1994), however recruitment since then has been poor, and includes the two lowest estimates in the series. Fishing mortality in 1996 is the lowest in the time series, approaching $F_{0.1}$, however fishing mortality is expected to increase again for 1997.

The projected $F_{0.1}$ yield for 1998 is 8,500t. The beginning of year 1998 biomass for ages 3 and older is expected to decline slightly to 49,000t; about the middle of the range of 30,000t to 70,000t that has been observed since 1980. The fishery is now dependant to a great extent on 3 very weak year-classes. The strength of the 1992 year-class will help to maintain this fishery, however improved recruitment will be required in order for this stock to sustain the fishery at current levels.

Résumé

Les débarquements de morue en provenance de la division 4X ont fluctué entre 35 000 t, en 1948, et 8 800 t, en 1995. Le quota de 1997 a été porté à 13 000 t et les captures atteignaient déjà 3 800 t à la fin de juin. Les débarquements de 1996 et de la première moitié de 1997 étaient dominés par la classe d'âge de 1992. Le relevé d'été montre que l'abondance de la morue de 4X a diminué depuis 1996 mais que la classe de 1992 continue d'être particulièrement forte. Les classes d'âge supérieur à 6 demeurent cependant faibles. Les classes de 1993 et 1994 (âges 3 et 4) semblent faibles et, selon les premiers indices, la classe de 1995 est aussi inférieure à la moyenne.

Le cadre adaptatif a été utilisé pour étalonner l'analyse séquentielle de population fondée sur les résultats du relevé de recherche. L'analyse a été effectuée à partir des données des prises selon l'âge à intervalles trimestriels, y compris la première moitié de 1997. La biomasse de début d'année des âges 3 et plus, qui avait atteint sa valeur historique la plus faible en 1994, a augmenté à chaque année jusqu'en 1997. La biomasse devrait diminuer légèrement au début de 1998. La classe de 1992 semble compter parmi les plus fortes pour la période examinée (1977-1994), mais le recrutement a été peu important depuis lors et l'on y note les deux plus faibles estimations de la série. La mortalité par pêche de 1996 est la moins élevée de la série chronologique, s'approchant de la valeur du $F_{0,1}$, mais elle devrait augmenter de nouveau en 1997.

Le rendement prévu au niveau $F_{0,1}$ est 8 500 t pour 1998. La biomasse des âges 3 et plus au début de 1998 devrait diminuer légèrement jusqu'à 49 000 t, soit presque le milieu de la gamme des 30 000 t à 70 000 t notée depuis 1980. La pêche repose pratiquement sur trois classes d'âge très faibles. L'importance de la classe de 1992 favorisera le maintien de la pêche, mais le maintien des niveaux de capture actuels exigera un augmentation du recrutement.

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, hand-lining and long-lining 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. This increase occurred in conjunction with an 80% increase in the 4X haddock quota. 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 13,000t, 3,600t of which were landed by July 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 decine in the early 1980's, and has now all but disapeared. 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 Mannan 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. However, fish tagged on Browns Bank in spring disperse widely through the 4X area, with some also recaptured in 5Z.

DESCRIPTION OF FISHERY

The fishery in 4X takes place year round, with catches peaking in June and July (Table 1), and is prosecuted primarily by tonnage classes 2 and 3 otter trawlers, and by tonnage classes 1 and

2 long-liners and hand-liners (Table 2). The proportion of landings from the winter-spring fishery, prosecuted predominantly by the otter trawl fleet, has declined in recent years. Late starts in the fixed gear fishery in 1996 and 1997 led to a further reduction in landings early in the year. Poor weather in January and February of 1997 kept much of the fleet off the water, and was at least partly responsible for the very low landings in these months in 1997.

The distribution of landings has also shifted to the west in recent years, with landings from 4Xmno declining to a greater degree than in other areas (Table 3). There has been little change in the distribution of the hook and line fishery. 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. AI.1). 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 (Fig AI.2). Since 1993, this fishery has been conducted primarily in the Bay of Fundy throughout the year. Despite these changes, the overall proportion of 4X cod landings coming from the Bay of Fundy in recent years has not exceeded the levels seen in the mid-1980's. The high proportion of landings coming from the Bay of Fundy in the first half of 1997 is unusual (Fig AI.1); however, only 28% of the 1997 quota had been landed by mid-year, and the proportion of catch coming from the Bay will likely decline by the end of the year with the inclusion of the hook and line landings.

During meetings with industry representatives, dragger fishermen commented that declines in the winter-spring fishery reflect introduction of individual quota (cod quota is saved to use as bycatch when pursuing other fisheries through the year); traditionally, this was a period of high catch rates for the dragger fishery during which "steak" (large) cod were caught. Also, the duration of the seasonal closure in the Browns and Baccaro Banks area was extended in 1992.

Fishermen from around 4X are reporting mixed success in the cod fishery in 1997. Representatives from both the otter trawl and longline fleets have reported that fishing has been poor for cod east of Browns Bank. Similiarly, handline fishermen off Digby neck have reported poor fishing for cod this year, and longliners in the Saint John area had little success in their traditional spring fishery. However, both otter trawl and gill net fishermen in the Bay of Fundy have reported good catches, as have handliners around Cape Sable.

Recent changes in gear (increases in minimum hook and mesh sizes; change from diamond to square mesh) were expected to reduce the catch of small cod; however, in 1995 gear closures were enacted in two areas in the vicinity of La Have and Roseway Banks due to high proportions of undersized fish (<43 cm) in catches monitored at sea. Closures of Baccaro, La Have and Roseway banks to all fixed gear due to high proportions of undersized fish also occurred in 1996 and 1997.

Effort by the otter trawl (Fig AI.3) and the tonnage class (tc) 2 and 3 longline fleets (Fig AI.4) has declined since the early 1990's, although effort directed for cod increased slightly in 1996. Effort has also increased for most other gear sectors. Based on the effort expended in the first half of 1997 to land 28% of the cod quota, it appears likely that effort will also increase in 1997; however, in general effort remains substantially lower than seen in the early 1990's.

CATCH AND WEIGHT AT AGE

The 1996 catch at age was based on 39 samples which included otoliths, and 34 additional length frequency samples, while 21 samples with otoliths and 29 additional length frequencies are available for the first half of 1997 (Table 4). Of the 21 otolith samples in 1997, 8 were collected by National Sea Products. The number of otoliths (117) collected in the first quarter in the Bay of Fundy were not sufficient to provide a representative age length key, so samples from the first and second quarter were combined.

Intra-reader age comparison tests were conducted for both the Bay of Fundy and Scotian Shelf for samples from 1996 and 1990. An inter-reader comparison was also conducted using samples from 1986, prior to the transfer of duties to the current age reader. No problems were identified, and agreement ranged from 87% to 96% (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 in 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 1996, the 1992 year-class (age 4) dominated landings of all gear types in 4X (Table 5). Landings of cod over age 5 have declined in recent years (Table 6) and in 1996 the proportions of landed weight comprised by these ages were below their long term averages (Fig. 3). The proportions of 4 year-olds, which accounted for over 50% of the numbers landed, was high in comparison with the long term mean (Fig. 4). Landings for most ages were well predicted by the previous assessment (Fig. 5); however, landings of cod aged 5 and over were lower than predicted, as has been the case in recent assessments.

In the first half of 1997 landings were dominated by the strong 1992 year-class (age 5: Fig. 6). This year class accounts for 35% of the cod landings by number; a much greater proportion of the catch than usual (Fig. 7); however, it constitutes a lower proportion of the catch than predicted (Fig. 8), while the landings of ages 3 and 4 are almost double the predicted proportions. The lower than projected catches of older fish is consistent with the pattern observed in recent assessments.

Weights at age for commercial landings from both the Scotian Shelf and the Bay of Fundy are higher than average in recent years. For the Scotian Shelf, weight at age in a given quarter year interval is not higher than average in recent years (average for 1993-1997 compared to 1980-1992 mean), and increases in mean length at age for the year simply reflect a shift in the fishery to later in the year. In the Bay of Fundy, however, there does seem to be some increase in length at age in the third and fourth quarters.

Commercial catch at age data from 1980 to 1997 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 (Appendix III). Work is continuing in an attempt to reconstruct the population history prior to this.

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* (*A. N.*) 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 1997 survey showed a distribution of cod similar to that from the previous year (Fig. 9); however, catches were lower in most areas, particularly in the area between the Bay of Fundy and Browns Bank. Catch per tow decreased in both the Scotian Shelf and Bay of Fundy areas in 1997 (Fig. 10). Catches were below average in both areas, reversing the trend to increasing catches experienced in recent surveys.

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 biomass as estimated from VPA was high in the early 1980's, despite the low survey catches, and q adjusted indices (See Appendix III) for the *A T Cameron* (*A.T.C.*) and *Lady Hammond* (*L.H.*) are generally higher than the 1997 value (Fig. 10b).

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 and 5, and the second highest at age 3. The 1993 and '94 year classes, however (ages 3 and 4 in 1997) appear below average, and the initial indication given by this survey is that the 1995 year-class is also below average, with the second lowest survey index in the series.

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 third annual 4X ITQ groundfish survey was conducted in July, 1997 using commercial trawlers. The survey employs a fixed station design (although 35 fewer stations were occupied in 1995), 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 coordinates 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 (Browns and German Banks 1 (BG1) and Scotian Shelf 1 (SS1)) 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 (Fun1), however the skippers felt this was a minor change and should not effect the catch for these vessels. Calibration among vessels may be difficult, and the changes in gear and protocol for station selection could influence results, however, comparisons can be made among years for the 105 stations which were sampled by the same vessel in each year (172 stations for 1996 and 1997; Table 9).

The relative distribution of cod appears to have shifted in 1997, with almost all of the large catches coming from the Bay of Fundy (Fig. 11). Catches appear to have declined generally around Grand Manan and in the deep water outside of Browns Bank (Fig 12). In other areas increases and decreases in catch are well mixed.

The mean weight per tow has remained fairly consistent in the Bay of Fundy in each year (Fun1b; Table 9), although it is somewhat lower in 1997. Catch per tow declined from 1996 in eastern 4X (SS1), although the decline is of lower magnitude when the larger number of stations is examined. Catches were down by more than 50% from 1995 and 1996 in the Browns and German Bank areas.

The length frequency of the ITQ survey catch for 1997 on the Scotian Shelf (including only those sets made within Needler strata 470 - 481) peaks sharply at 45-52 cm, slightly higher than in the 1996 survey (Fig 13); this may indicate the progression of the 1993 year-class. These results contrast with the Needler survey, which marks the progression of the 1992 year-class (Fig. 14). The 1992 year-class has not been dominant on the Scotian Shelf in the ITQ survey in any year.

The 1996 ITQ survey results for the Bay of Fundy (including only those sets made within RV survey strata 484 - 495) has modes at lengths corresponding to 1, 2, 3 and 5 years of age. The survey in this area shows some inter-annual consistency, with modes progresing in successive years (Fig 13). In contrast, the length frequency in the RV survey peaked at 72 cm, continuing to indicate the strength of the 1992 year-class. In the inshore area, few cod of commercial size were caught.

This is similar to what was seen in 1995 and 1996, and suggests the region inshore of the RV survey area may contain predominantly pre-recruit cod.

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.

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 $t=1980, 1980.25, 1980.5, 1980.75, 1981,..., 1997.25$

$I_{a,t}$ = survey abundance index for ages $a=2, 3,..., 10$ observed during time $t=1983.5, 1984.5,..., 1997.5$ (excluding 1988.5 for ages 3 and 4).

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 1997 ($t = 1997.5$) as parameters was employed. Define the model parameters

$\phi_{a,1997.5}$ = ln population abundance for ages $a = 2, 3,..., 12,$ (age 1 abundance assumed equal to the geometric mean recruitment 1991-95), 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 = 1997.5, the population abundances are obtained directly from the parameter estimates,

$$N_{a,1997.5} = exp[\phi_{a,1997.5}].$$

For all other years, y = 1980 to 1997.25, 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 10) and used to construct the history of the stock status (Table 11). 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 12).

In the 1996 assessment, two options were given for the assessment: version 'a' used only data from the initial 1996 summer RV groundfish survey, while version 'b' included 3 stations which were resampled during the second leg of the survey, one of which was the highest catch of cod for any set in the RV time series (Clark and Brown, 1996). The mean squared residual was lower for version 'a', and the 1996 residuals showed no strong pattern. Version 'b' showed a strong trend towards positive residuals in 1996, suggesting the survey was anomalously high. This option benefitted from including all available survey information from 1996, but it was strongly influenced by a single set. Initial analysis in 1997 indicated that residuals were all strongly positive for the 1996 survey if version 'b' was used. Residuals were still generally positive for version 'a', but were smaller in magnitude. Version 'a' of the 1996 survey was therefore selected for use in all subsequent analyses.

Residuals were generally small in magnitude, with no consistent trend across years (Fig. 15). Residuals were generally positive for the 1996 survey, and negative for the 1997 survey. Close correspondence occurred between the survey indices, scaled by the calibration constants, and results from the sequential population analysis (Fig. 16). The results indicate that the 1992 year class is the third strongest in the time series, on parr 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 beginning of year population biomass for ages 3 and older (fishable biomass) increased for 1996, after declining rapidly from a peak in 1990 to the lowest levels in the time series in 1993 and 1994 (Table 12 and Fig. 18). For the beginning of 1997 it increased again to the highest level seen since 1985, primarily due to growth by the 1992 cohort.

The fishing mortality rate for ages 4 and older has fluctuated around 0.5 (Table 13 and Fig. 19). F increased rapidly after 1989, peaking above 1.0 in 1992, and has declined since then. The high F's in the early '90's exceeded thrice $F_{0.1}$ likely resulting in lost yield due to capture of fish before their growth potential had been realized. In the first half of 1997, 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.

A retrospective analysis was conducted for this stock and showed no strong pattern (Fig. 20). There is a tendancy for estimates of year class strength to increase with additional years of information, however the changes are generally small, and the pattern is not apparent for all year classes.

A pattern of decreasing F's at older ages can be seen in the fishing mortality estimates in recent years (Table 13), and is evident at ages 5 and over in the first half of 1997. Partial recruitment (PR) patterns were examined for temporal trends. Average F for all years (1980-1997.3) peaked at ages 5 and 6; hence, F for these ages was used for fully recruited F in calculating PR; thus, if F is not highest for these ages, PR can exceed 1.

A strong domed pattern can be discerned in PR in recent years (Fig. 21). Prior to 1992, there was some seasonal variability in the PR by age, but it was not strongly domed at any time of year. Since 1992, however, the dome is characteristic of PR in all seasons.

Members of the otter trawl fleet have indicated that in recent years they have avoided the concentrations of large cod which had traditionally made up the bulk of their spring fishery, in order to save their cod quota for later in the year, allowing them to continue fishing for other species. The targeting of older fish in the spring can be seen in the quarterly partial recruitment patterns; however, the domed pattern in partial recruitment in recent years is seen in all quarters of the year, not only the spring (Fig. 21).

Patterns in partial recruitment by area and gear type were examined to see if the dome was apparent in all parts of the fishery. Partial F's were derived for the gear/area/quarter combination, and partial recruitment calculated in relation to the fully recruited F for the full year. A dome in partial recruitment was typical of the Bay of Fundy (all gear combined) and of the otter trawl fleet on the Scotian Shelf in all periods.

For the otter trawl fleet on the Scotian Shelf, there is little change below age 9, while ages 9 and over appear poorly recruited to the fishery in recent years (Fig 22). When the periods before and after 1992 are compared on a quarterly basis, little temporal change is seen, except in the first quarter. The reduced PR seen for older fish here may reflect the redirection of effort noted for this fleet.

In the Bay of Fundy, where the fishery is predominantly prosecuted by otter trawlers, there has been only a slight change in the PR pattern with time. This appears to be the result of increases in the first quarter fishery which is targeted at young fish (ages 3 and 4; Fig. 23). Fish recruit to the fishery earlier in the Bay of Fundy, due to the higher growth rate, thus a high partial recruitment for young fish in this area is not unexpected. Also, RV surveys catch fewer old fish in the Bay of Fundy, as would be anticipated, since the higher fishing mortality experienced at younger ages leaves fewer old fish.

The changes seen in the longline fishery are the most pronounced (Fig. 24). Longliners prior to 1992 appeared to select for old fish, particularly in the first quarter. Since 1992, however, the PR peaks at age 5 in the second, third and fourth quarters, and at age 4 in the first quarter. It is not clear what has led to this change. There have been a number of changes in the hook and line fishery in recent years, however it is not clear whether these are responsible for the changes in partial recruitment patterns, or if the current distribution of cod in 4X is such that old fish are no longer present in the traditional hook and line fishing areas.

The low numbers of age 5+ cod in the landings suggests either that there has been a change in fishing patterns which targets younger fish, or that there are few old fish remaining, and the assessment is overestimating their numbers. The consistently high indices for the 1992 year-class, and the wide dispersal of these fish in the 1997 survey, suggest that the former is more likely. A similar lack of fit for projections in the pollock fishery in 1997 (Neilson and Perley, 1997) suggests there has been a change in fishery practices. In addition, the lack of any major change in fishing effort, or catch per unit effort are inconsistent with the level of fishing mortality which would be required to deplete the 1992 year class. This pattern, however, is a concern, particularly in respect to the hook and line fishery, and will be examined further in the coming year.

If the domed PR observed in recent years is used in a yield-per-recruit analysis, the $F_{0.1}$ fishing mortality level increases to 0.31 from the 0.19 obtained using a flat topped PR. A higher fishing mortality is required to maximize the yield from the stock since they are less available to the fishery after age 5. This, however, also results in a lower yield per recruit, since the fishery is focussed on younger fish. Thus, if the domed PR is a result of current fishing practices, it should be recognized that this stategy reduces the potential yield for the resource. Although it appears that partial recruitment in recent years has been domed, until the reasons for this are understood it would seem rash to suggest that the target F be increased, given the impact this has on yield and stock biomass.

There is a weak correlation between spawning stock (age 5+) and recruitment for 4X cod (Figure 25). A comparison assuming knife-edged recruitment to the spawning stock indicated that biomass at ages 5+ correlated most closely with year-class abundance (r= 0.29; years 1980-1994).

The correlation improves if the longer data series available for the Scotian Shelf alone is used (r=0.42, years 1971-1994), however recruitment is still highly variable for a given spawning biomass (Fig. 26). Although stock biomass is not 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.

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 14). 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 13,000t TAC for 1997 is landed (9,200t remain for the last half of 1997), the resulting fully recruited fishing mortality will be about 0.3 for the year. The projected yield for 1998 at $F_{0.1}$ is 8,500t. If an $F_{0.1}$ harvest strategy is followed, the beginning of year 1999 biomass for ages 4 and older will decline slightly to 44,000t. (Fig. 27). Landings in 1998 would have to drop below 8,000t to avoid a decline in stock biomass. If a domed PR is assumed for projections, $F_{0.1}$ is 0.31, and the yield is 11,400t. At this harvest level, the 4+ biomass is projected to decline by nearly 4,000t for the beginning of 1999 to 41,000t.

Though not all uncertainties and biases can be incorporated, the statistical precision of the abundance estimate was approximated, and used to evaluate the risk that specific catch levels in 1998 would exceed $F_{0.1}$, or result in a decline in age 4+ biomass from 1998 to 1999. At a yield of 8,500t, which corresponds to a 50% risk of exceeding $F_{0.1}$, there is a 57% chance that 4+ population biomass will decline for 1998; this probability falls to 50% at a yield of 7,900t (Fig. 28).

This fishery is strongly dependent on the 1992 year-class. Despite relatively low fishing mortality, stock biomass will not increase even at $F_{0.1}$ without improved recruitment. Based on the stock/recruit relationship, there would appear to be a high proobability that the 1996 year class will also be poor. The 5+ biomass in 1997 and projected for 1998 is in a range where better recruitment has been experienced in the past. Although maintaining spawning stock biomass in this range does not guarantee the consistently good recruitment that was seen in the 1970's (circled years in Fig. 26), higher 5+ biomass does correlate with a higher probability of successful recruitment. Without improvements over the recruitment seen in recent years no further building in this stock is possible (the maximum sustainable yield for an annual recruitment of 10 million fish is 11,000t).

Beginning of year biomass for ages 4 and older has fluctuated between about 19,000t and 60,000t since 1980. Biomass has increased from the record low seen in 1994, however, this growth has now leveled off. Given the weak recruitment in the past three years, further growth in this stock seems unlikely until recruitment improves. If the spawning biomass can be maintained at or near current levels, the probability of receiving average or better recruitment will be enhanced.

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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	1321							3609

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	1267	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*	44	819	1179	41	23	105	140	313	222	53	668	2	3609

* January 1 - June 30.

Table 3. Nominal catch of 4X 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*	70	287	509	472	846	829	221	311	64	1532	2077		3609

January 1 - June 30.

Table 4a. Construction of age length keys for 4X cod for 1996.

Area	Fundy (4Xqrs5Y)				Shelf (4Xmnop)			
Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
No. Samples	4	5	5	2	5	8	5	5
No. Aged	144	184	191	94	202	356	179	232
Landings (t)	652	1426	1701	737	627	1678	2302	1448

Table 4b. Construction of length frequencies for 4X cod for 1996, and age-length keys against which they are matched.

Gear	Quarter	Area	a	b	Number o samples	Number Measured	Landings (t)	ALK used
OT	1	Fundy	0.0081	3.0503	5	1166	641	Fundy Q1
LL					0	OT Q1 F#	12	
GN					0		0	
Ot	1	Shelf			3	719	414	Shelf Q1
LL					3	805	214	
GN					0		0	
OT	2	Fundy	0.0084	3.041	5	1099	857	Fundy Q2
LL					1	275	493	
GN					0	GN Q2 S#	76	
OT	2	Shelf			4	1050	248	Shelf Q2
LL					12	2397	1277	
GN					2	454	153	
OT	3	Fundy	0.0087	3.0233	5	1127	896	Fundy Q3
LL					1	216	404	
GN					3	581	401	
OT	3	Shelf			2	465	184	Shelf Q3
LL					12	2602	1819	
GN					1	210	298	
OT	4	Fundy	0.0063	3.1152	6	1406	639	Fundy Q4
LL					0	OT Q4 F#	61	
GN					0	GN Q3 F#	37	
OT	4	Shelf			4	931	339	Shelf Q4
LL					4	1133	1022	
GN					0	GN Q3 S#	87	

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 1997 (Jan. - July).

Area	Fundy (4Xqrs5Y)				Shelf (4Xmnop)			
Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
No. Samples	3	7			5	6		
No. Aged	117	347			213	248		
Landings (t)	487	1590			351	1181		

Table 4d. Construction of length frequencies for 4X cod for 1997 (Jan. - July), and age-length keys against which they are matched.

Gear	Quarter	Area	a	b	Number o samples	Number Measured	Landings (t)	ALK used
OT	1	Fundy	0.0081	3.0503	6	1490	474	Fundy Q1*+ Fundy Q2
LL					0	OT Q1 F[#]	13	
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	1086	Fundy Q2
LL					2	491	390	
GN					3	633	114	
OT	2	Shelf			8	1756	328	Shelf Q2
LL					8	1407	719	
GN					4	733	134	

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

* Fundy Q 1 was insufficient on its own; thus the first and second quarter ALK's were combined.

Table 5a. Landed numbers of 4X cod at age by gear type for 1996.

Age	1	2	3	4	5	6	7	8	9	10	11	12
LL+H	0	13	465	1298	212	104	13	5	2	2	1	0
OT	0	28	326	976	152	66	10	6	6	0	0	0
GN	0	7	39	182	37	24	2	1	0	0	0	0

Table 5b. Landed numbers of 4X cod at age by gear type for 1997 (Jan. - July).

Age	1	2	3	4	5	6	7	8	9	10	11	12
LL+H	0	0	133	259	165	19	9	1	0	1	0	0
OT	0	0	121	175	270	41	19	2	1	1	0	0
GN	0	0	1	7	32	8	4	0	0	0	0	0

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

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	0	255	441	467	68	32	4	1	1	1	1	1271	1271	1271	1016

* 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
	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	
	Mean	0.78	0.85	1.23	1.80	2.56	3.68	5.00	7.07	9.17	11.55	13.79	15.62
	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
	Mean	0.44	0.96	1.64	2.62	4.18	5.80	7.57	9.49	11.27	13.71	13.49	15.66

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

Age	2	3	4	5	6	7	8	9	10
1983	223	4226	2369	1480	946	389	0	77	37
1984	1385	3390	2362	1820	688	482	63	58	25
1985	1139	4331	1527	1451	766	483	267	165	13
1986	258	2920	1226	314	549	448	217	97	19
1987	1158	618	1180	528	260	245	304	75	40
1988	564			1776	496	210	244	91	38
1989	1073	3420	2549	420	489	108	27	82	37
1990	110	5523	2463	2321	240	414	80	42	0
1991	390	1131	3086	1094	751	128	116	19	21
1992	874	1569	681	1710	471	460	124	85	0
1993	350	2518	925	129	265	52	61	0	6
1994	711	2739	1605	449	36	195	88	70	0
1995	350	4779	1477	598	274	94	91	34	42
1996*	323	2048	5527	880	753	148	0	56	15
1997	211	1189	1444	2462	321	194	100	0	57

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

Table 9. ITQ survey cod catches at repeated stations compared for each area/vessel.

# of sets	Area/ Vessel	1995 weight	1995 number	1996 weight	1996 number	1997 weight	1997 number
35	SS1	10.7	12.3	15.1	14	9.3	7.8
32	BG1	28.8	21.9	24.1	17	9.8	8
39	Fun1	100.7	67.9	64	38.7	55	26.4
38	Fun1b*	52.7	33.3	54.1	33.1	51.4	24.8
58	SS1			11.9	11.7	9.4	7.9
57	BG1			19	12.8	7.8	6
58	Fun1			51.3	28.8	45	20.7
57	Fun1b*			44.5	24.9	42.5	19.5

*Block 31 excluded.

SS = Scotian Shelf; BG = Brown's and German Banks; Fun = Bay of Fundy.

Table 10. Statistical properties of estimates for population abundance and survey calibration constants for cod in Division 4X.

	Population abundance					July survey calibration constants				
Age	Par. est.	Std. err.	Rel. err.	Bias	Rel. bias	Par. est.	Std. err.	Rel. err.	Bias	Rel. bias
2	4659	2222	0.48	545	0.12	0.045	0.006	0.128	0	0.005
3	4525	1577	0.35	282	0.06	0.315	0.041	0.129	0.002	0.005
4	4140	1320	0.32	201	0.05	0.352	0.045	0.128	0.002	0.006
5	7177	2185	0.3	303	0.04	0.369	0.046	0.124	0.002	0.005
6	1322	414	0.31	58	0.04	0.385	0.048	0.126	0.002	0.005
7	778	239	0.31	33	0.04	0.484	0.063	0.131	0.003	0.007
8	258	76	0.29	11	0.04	0.446	0.063	0.142	0.004	0.008
9	45	28	0.61	5	0.12	0.454	0.064	0.141	0.004	0.009
10	135	37	0.28	5	0.04	0.268	0.041	0.153	0.003	0.011
11	45	15	0.32	2	0.05					
12	78	22	0.29	2	0.03					
Mean squared residuals = 0.22596										

Table 11. Estimated bias adjusted beginning of year population numbers ('000s) for 4X cod.

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	1+	2+	3+	4+
1980	23049	23967	23250	8608	4867	3049	1395	896	292	187	82	64	0	89706	66657	42690	19440
1981	25932	18871	18838	13511	4900	2409	1474	745	502	158	99	51	37	87527	61558	42687	23849
1982	14159	21231	14684	11887	7195	2327	1036	681	342	248	62	46	25	73923	59739	38508	23824
1983	13905	11592	16547	9409	5731	3123	1084	496	307	150	126	14	14	62498	48579	36987	20440
1984	17579	11376	8530	10165	5467	2791	1466	473	222	144	56	71	3	58343	40761	29385	20855
1985	9973	14361	8444	4795	5530	2738	1418	785	229	126	74	19	42	48534	38519	24158	15714
1986	27499	8165	11091	5372	2499	2415	1079	696	468	124	55	45	9	59517	32009	23844	12753
1987	18677	22514	6456	6544	2628	1143	1072	521	389	300	54	24	18	60340	41645	19131	12675
1988	27581	15291	17622	4454	3497	1182	468	423	219	193	187	15	12	71144	43551	28260	10638
1989	9175	22581	12148	11247	2115	1468	380	224	176	102	112	127	7	59862	50680	28099	15951
1990	14174	7495	17894	7656	5953	1177	708	170	114	91	66	83	96	55677	41407	33912	16018
1991	16180	11605	6003	12056	3725	2666	511	330	70	58	40	42	54	53340	37106	25501	19498
1992	12255	13245	9139	3518	5279	1440	951	221	128	28	33	7	20	46264	33989	20744	11605
1993	27530	10033	10136	4345	1162	1385	391	323	125	60	9	19	2	55520	27988	17955	7819
1994	10461	22540	7390	5147	1711	361	533	153	183	90	37	3	16	48625	38148	15608	8218
1995	7470	8565	18008	3983	2203	597	119	273	87	133	73	28	3	41542	34069	25504	7496
1996	5552	6116	6886	12778	2284	1282	371	73	187	61	104	59	23	35776	30201	24085	17199
1997	13262	4546	4961	4823	8094	1470	858	278	45	146	48	84	48		25353	20807	15846
1997.5	12000	4113	4243	3939	6874	1264	745	248	40	130	43	75	0		21714	17601	13358

Table 12. Estimated population biomass (000 t) at the beginning of the year for cod in Division 4X.

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	1+	2+	3+	4+
1980	10603	17017	25808	14548	11437	10184	6431	5501	2558	2194	1112	1005	0	108396	97794	80777	54970
1981	11929	13398	20910	22834	11515	8046	6795	4574	4398	1853	1342	801	611	109006	97078	83679	62769
1982	6513	15074	16299	20089	16908	7772	4776	4181	2996	2909	841	723	413	99494	92981	77907	61608
1983	6396	8230	18367	15901	13468	10431	4997	3045	2689	1760	1709	220	231	87445	81048	72818	54451
1984	8086	8077	9468	17179	12847	9322	6758	2904	1945	1689	759	1115	50	80200	72114	64037	54569
1985	4588	10196	9373	8104	12996	9145	6537	4820	2006	1478	1003	298	693	71237	66649	56453	47080
1986	12650	5797	12311	9079	5873	8066	4974	4273	4100	1455	746	707	149	70178	57529	51732	39421
1987	8591	15985	7166	11059	6176	3818	4942	3199	3408	3519	732	377	297	69269	60678	44693	37527
1988	12687	10857	19560	7527	8218	3948	2157	2597	1918	2264	2536	236	198	74704	62017	51160	31599
1989	4221	16033	13484	19007	4970	4903	1752	1375	1542	1196	1519	1995	116	72113	67892	51860	38376
1990	6520	5321	19862	12939	13990	3931	3264	1044	999	1067	895	1304	1584	72720	66200	60878	41016
1991	4530	8240	6663	20375	8754	8904	2356	2026	613	680	542	660	891	65235	60704	52465	45802
1992	3431	9621	10273	6356	14212	5295	4382	1464	1042	346	485	110	330	57344	53913	44292	34019
1993	12664	7123	11251	7343	2731	4626	1803	1983	1095	704	122	298	33	51776	39112	31989	20738
1994	2929	16373	8307	9299	4606	1327	2456	1013	1489	1111	543	47	272	49773	46843	30471	22164
1995	2092	6221	20242	7196	5931	2195	548	1808	708	1642	1072	440	51	50145	48054	41832	21591
1996	1555	4443	7740	23085	6149	4714	1709	483	1522	753	1527	927	391	54998	53444	49001	41261
1997	3713	3302	5576	8713	21790	5405	3953	1841	366	1802	705	1320	816	59303	55590	52288	46712
1997.5	4560	3661	5898	8154	21241	5309	4157	1848	421	1638	670	1238	600	59392	54832	51172	45274

Table 13. Estimated bias adjusted fishing mortality for 4X cod

Age	1	2	3	4	5	6	7	8	9	10	11	12	4+
1980	0.00	0.04	0.34	0.36	0.50	0.53	0.43	0.38	0.41	0.44	0.28	0.35	0.428209
1981	0.00	0.05	0.26	0.43	0.54	0.64	0.57	0.58	0.51	0.73	0.56	0.51	0.489959
1982	0.00	0.05	0.25	0.53	0.63	0.56	0.54	0.60	0.63	0.48	1.28	0.97	0.568051
1983	0.00	0.11	0.29	0.34	0.52	0.56	0.63	0.60	0.56	0.79	0.37	1.44	0.4475
1984	0.00	0.10	0.38	0.41	0.49	0.48	0.42	0.53	0.37	0.46	0.86	0.33	0.443679
1985	0.00	0.06	0.25	0.45	0.63	0.73	0.51	0.32	0.41	0.63	0.31	0.53	0.554433
1986	0.00	0.03	0.33	0.52	0.58	0.61	0.53	0.38	0.25	0.62	0.62	0.70	0.528874
1987	0.00	0.05	0.17	0.43	0.60	0.69	0.73	0.67	0.50	0.27	1.09	0.51	0.515771
1988	0.00	0.03	0.25	0.54	0.67	0.93	0.54	0.68	0.56	0.35	0.19	0.51	0.614608
1989	0.00	0.03	0.26	0.44	0.39	0.53	0.60	0.47	0.46	0.23	0.10	0.09	0.43783
1990	0.00	0.02	0.20	0.52	0.60	0.63	0.56	0.70	0.48	0.62	0.26	0.23	0.561378
1991	0.00	0.04	0.33	0.63	0.75	0.83	0.64	0.75	0.71	0.36	1.53	0.52	0.677898
1992	0.00	0.07	0.54	0.91	1.14	1.10	0.88	0.37	0.55	0.90	0.34	0.97	1.005526
1993	0.00	0.11	0.48	0.73	0.97	0.75	0.74	0.37	0.13	0.29	0.88	0.00	0.73212
1994	0.00	0.02	0.42	0.65	0.85	0.91	0.47	0.37	0.12	0.01	0.06	0.00	0.649491
1995	0.00	0.02	0.14	0.36	0.34	0.28	0.29	0.18	0.15	0.05	0.01	0.00	0.324261
1996	0.00	0.01	0.16	0.26	0.24	0.20	0.09	0.27	0.05	0.04	0.01	0.01	0.241431
1997.5	0.00	0.00	0.11	0.21	0.13	0.10	0.08	0.03	0.06	0.03	0.02	0.03	0.157618

Table 14. Projections for cod in Division 4X.

Age	Beg. yr. wt.		Mid-yr. wt.		catch 1997.5			catch 1998			beg. yr popn '98		beg. yr popn '99	
	1998	1998	1998	1998	num.	biom.	F	F	num.	biom	num	biom	num	biom
1	0.38	0.28	0.48	0.38	0	0	0	0	0	0	12000	3360	12000	3360
2	0.89	0.73	0.91	0.89	86	78	0.044	0.01	98	88	10858	7926	9825	7172
3	1.39	1.12	1.45	1.39	425	617	0.222	0.084	266	370	3640	4077	8801	9858
4	2.07	1.81	2.21	2.07	646	1428	0.378	0.152	440	911	3435	6218	2740	4960
5	3.09	2.69	3.17	3.09	1306	4134	0.444	0.2	486	1503	2951	7938	2416	6499
6	4.2	3.68	4.31	4.2	240	1035	0.444	0.2	821	3448	4980	18328	1978	7279
7	5.58	4.61	5.87	5.58	142	831	0.444	0.2	151	842	916	4221	3338	15390
8	7.45	6.62	7.46	7.45	47	351	0.444	0.2	89	663	540	3573	614	4063
9	10.52	8.14	9.91	10.52	8	75	0.444	0.2	30	311	179	1460	362	2945
10	12.6	12.34	11.95	12.6	25	295	0.444	0.2	5	60	29	357	120	1484
11	15.58	14.69	14.09	15.58	8	115	0.444	0.2	16	242	94	1383	19	285
12	16.5	15.71	16.76	16.5	14	240	0.444	0.2	5	85	31	491	63	992
13	17.5	17									55	929	21	356
1+					2947	9200			2407	8523	39708	60261	42297	64643
2+					2947	9200			2407	8523	27708	56901	30297	61283
3+					2861	9122			2309	8435	16850	48975	20472	54111
4+					2436	8504			2043	8065	13210	44898	11671	44253

*1997.5 refers to the half year period beginning July 1, 1997.

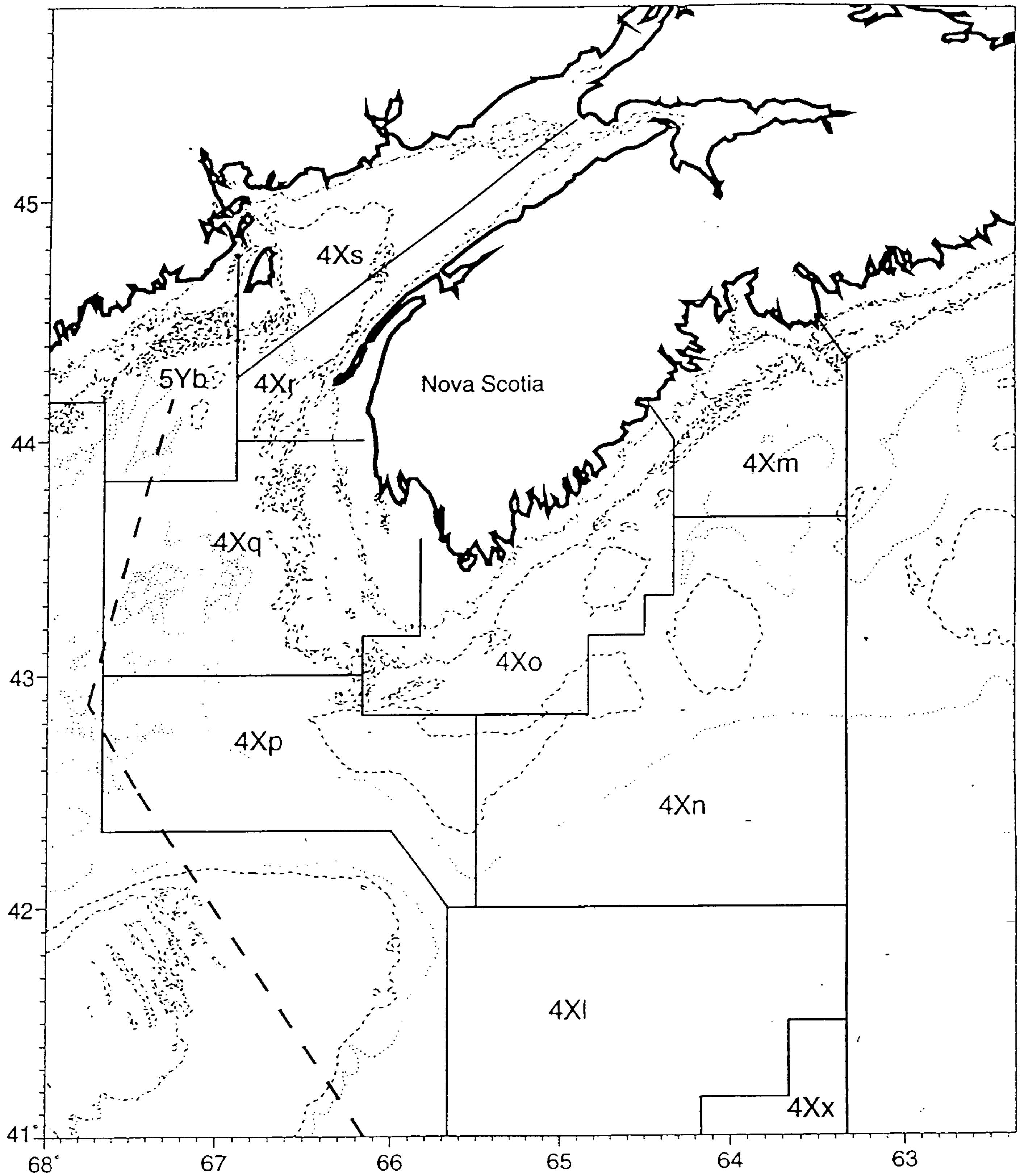


Fig. 1. Canadian fisheries statistical unit areas in NAFO Division 4X.

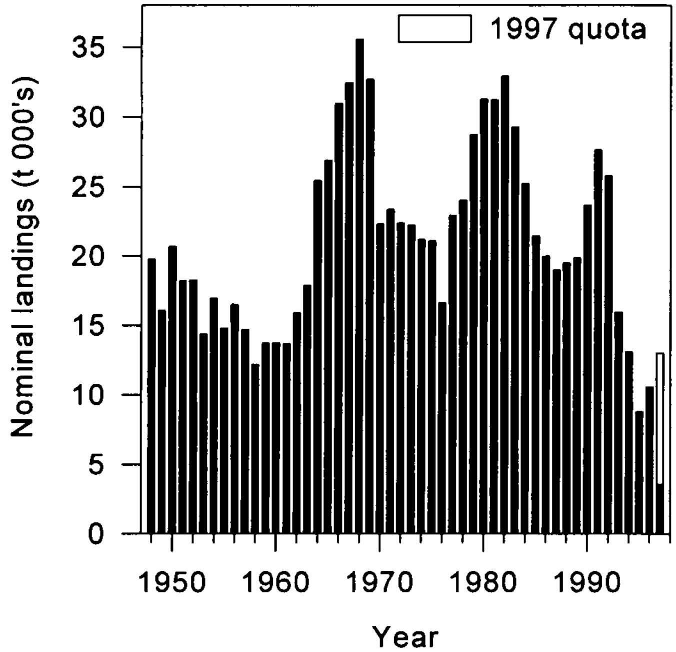


Fig. 2. Nominal landings of cod in Division 4X including catches by Canada in Division 5Y. For 1997, quota and mid-year landings shown.

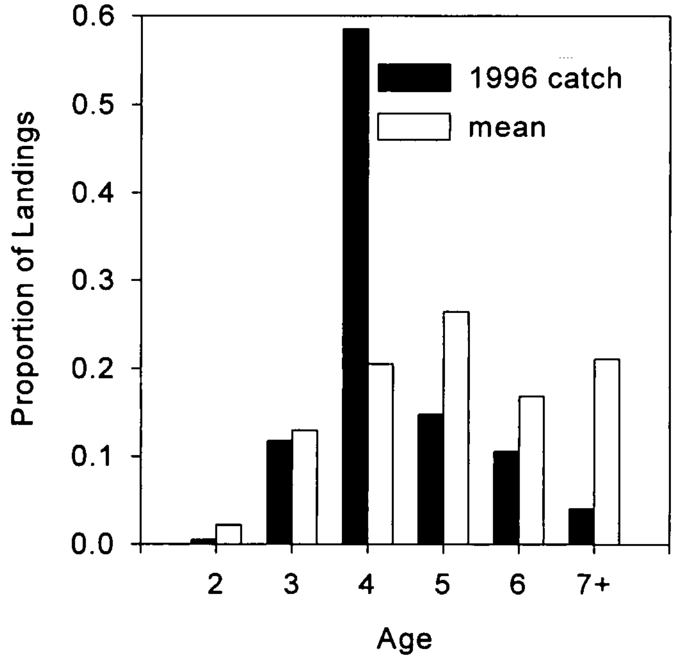


Fig. 3. Division 4X cod catch (t) at age for 1996 compared to the 1980-95 mean.

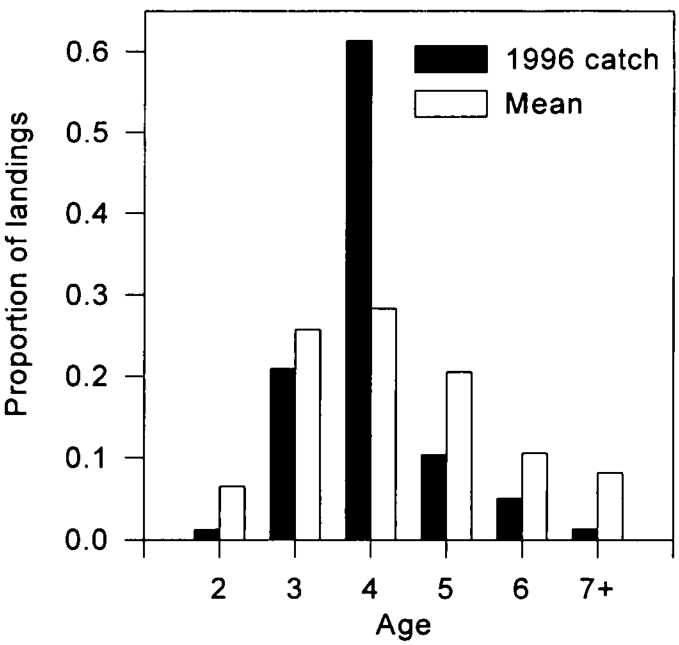


Fig. 4. 4X cod catch at age (in numbers) for 1996 compared to the mean for 1980-95.

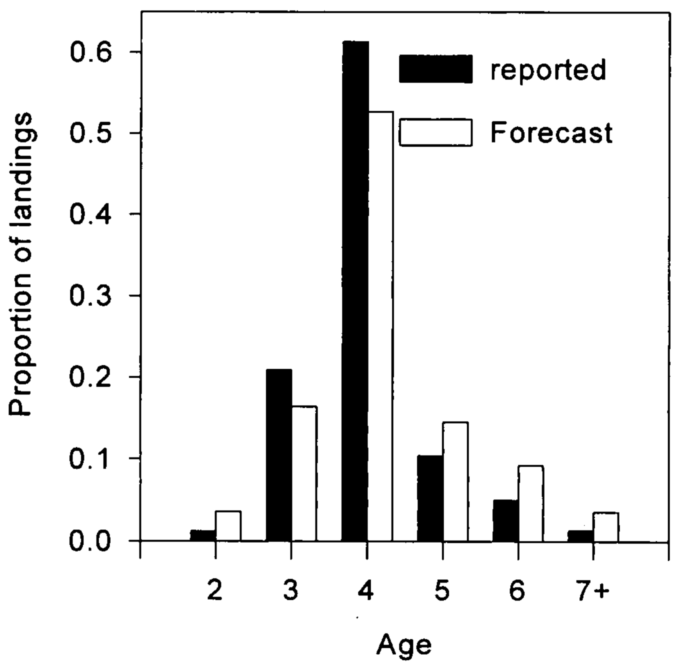


Fig. 5. Reported and forecast landings of cod in Division 4X for 1996 proportioned by age.

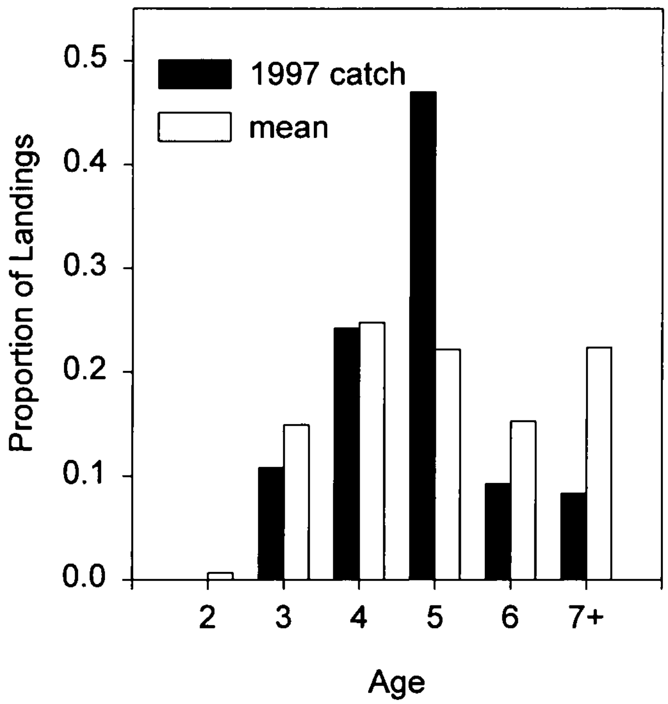


Fig. 6. Division 4X cod catch (t) at age for 1997 compared to the 1980-96 mean (Jan.-July).

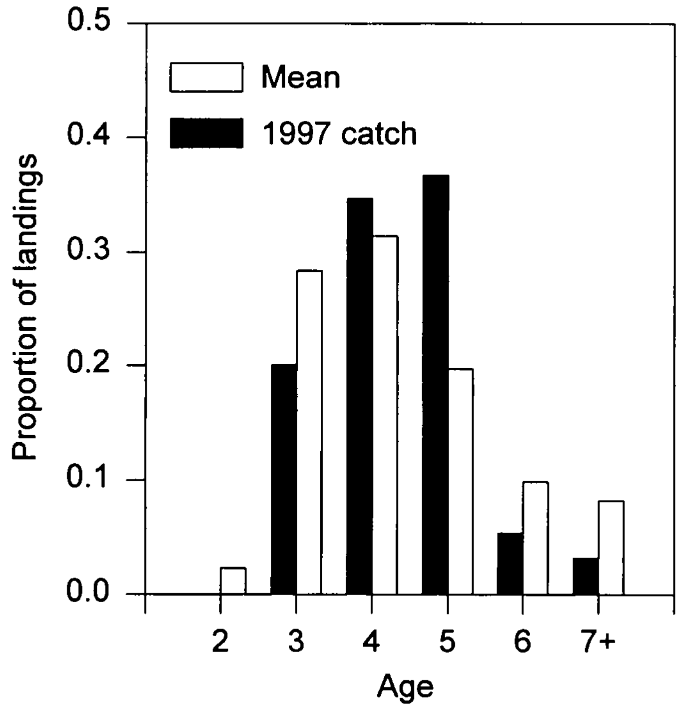


Fig. 7. 4X cod catch at age (in numbers) for 1996 compared to the mean for 1990 -1995 (January - July).

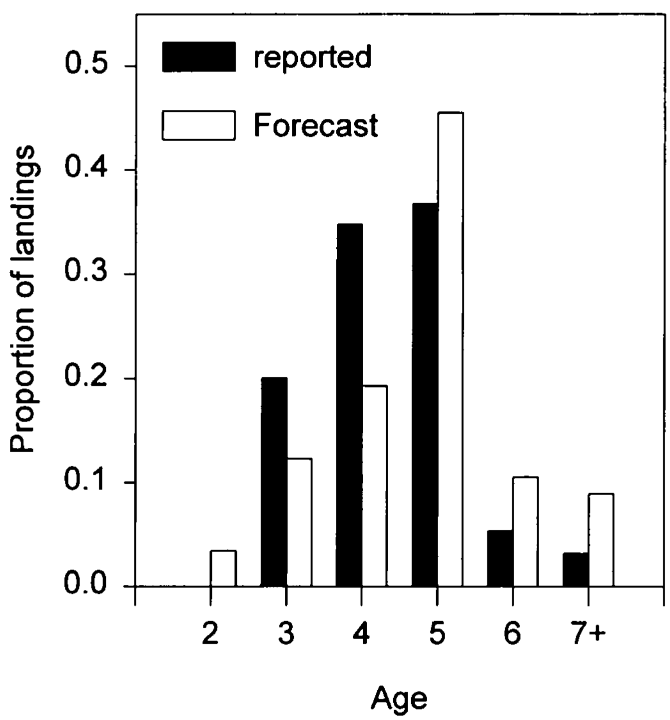


Fig. 8. Reported and forecast landings at age of cod in Division 4X for 1997 (Jan. - July)

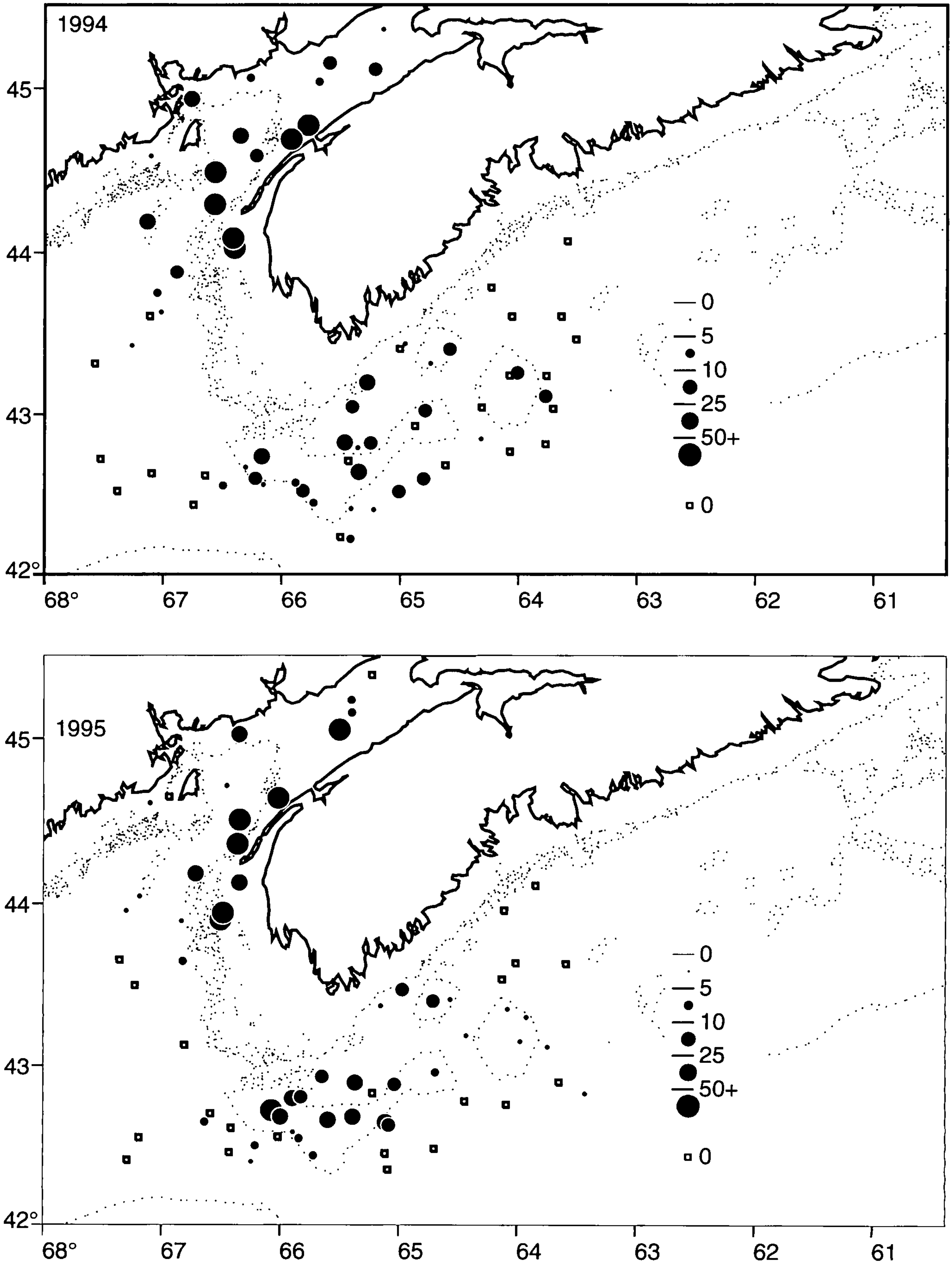
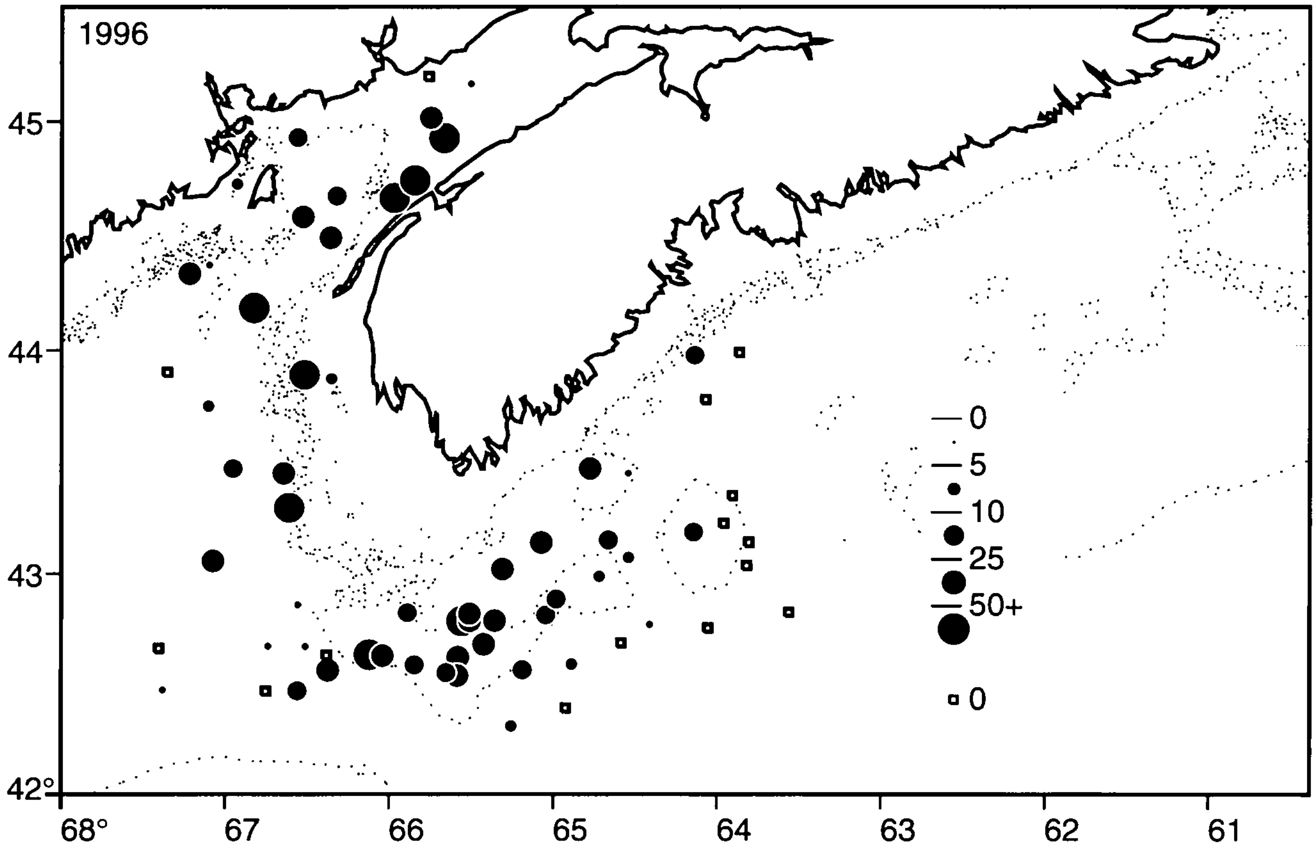


Fig. 9. Summer R.V. groundfish survey 4X cod catches (Kg/tow).



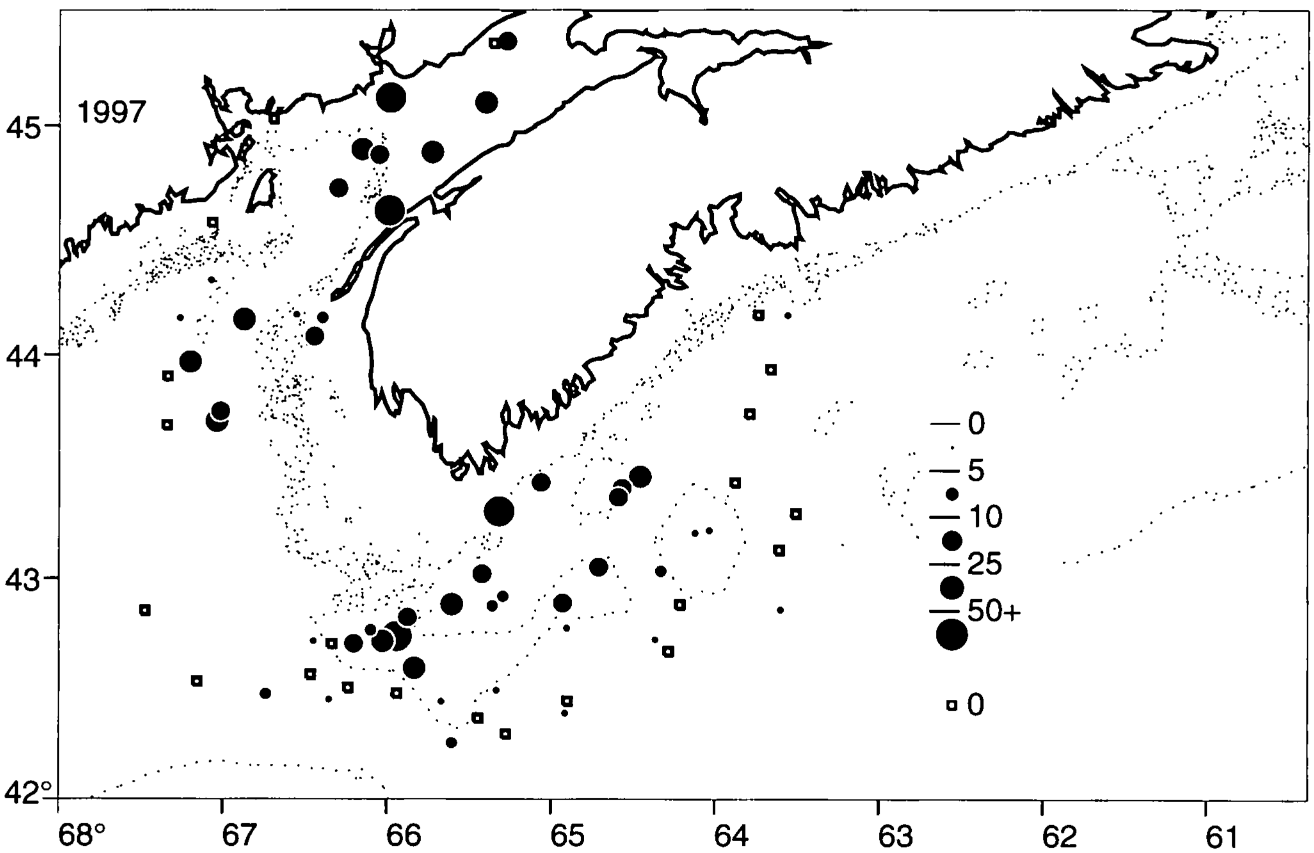


Fig. 9 (cont.). R.V. 4X Groundfish Survey cod catches (Kg/tow).

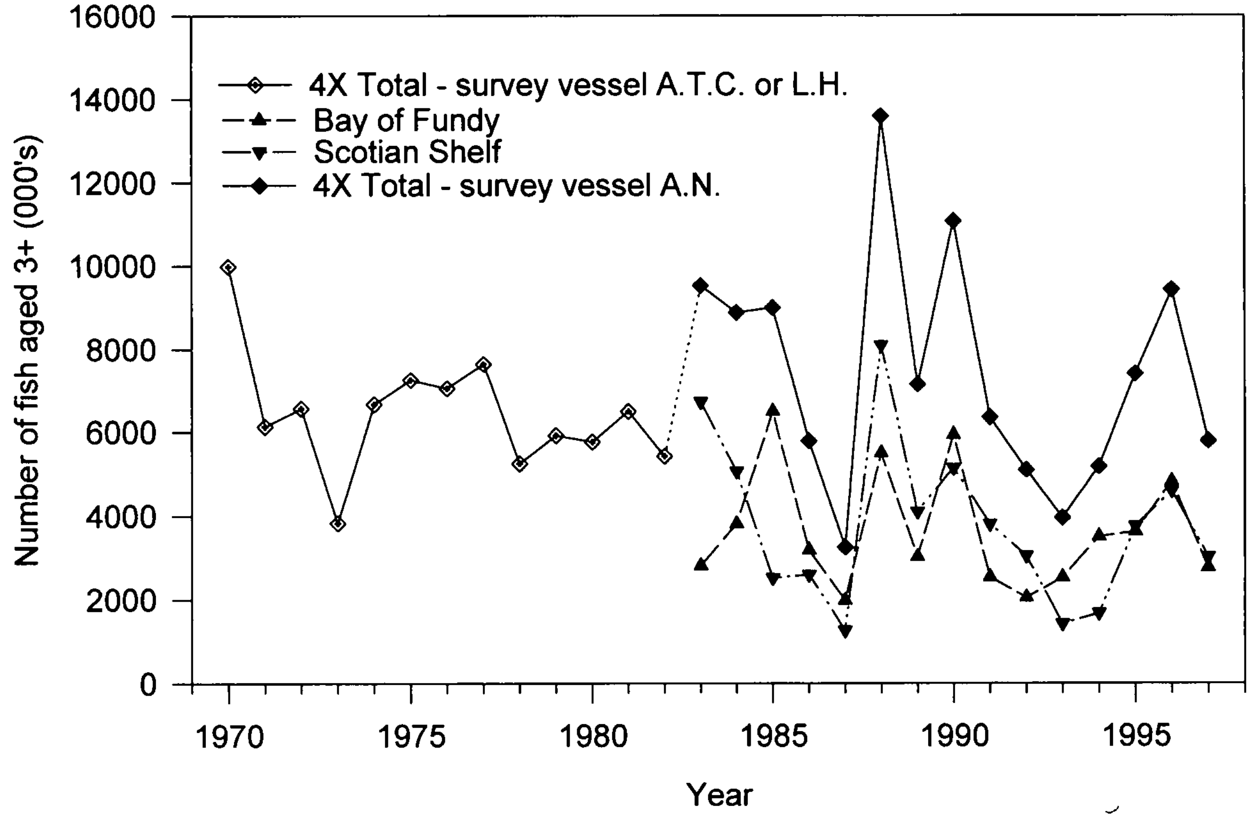


Fig 10. Summer groundfish survey indices for 4X cod by region.

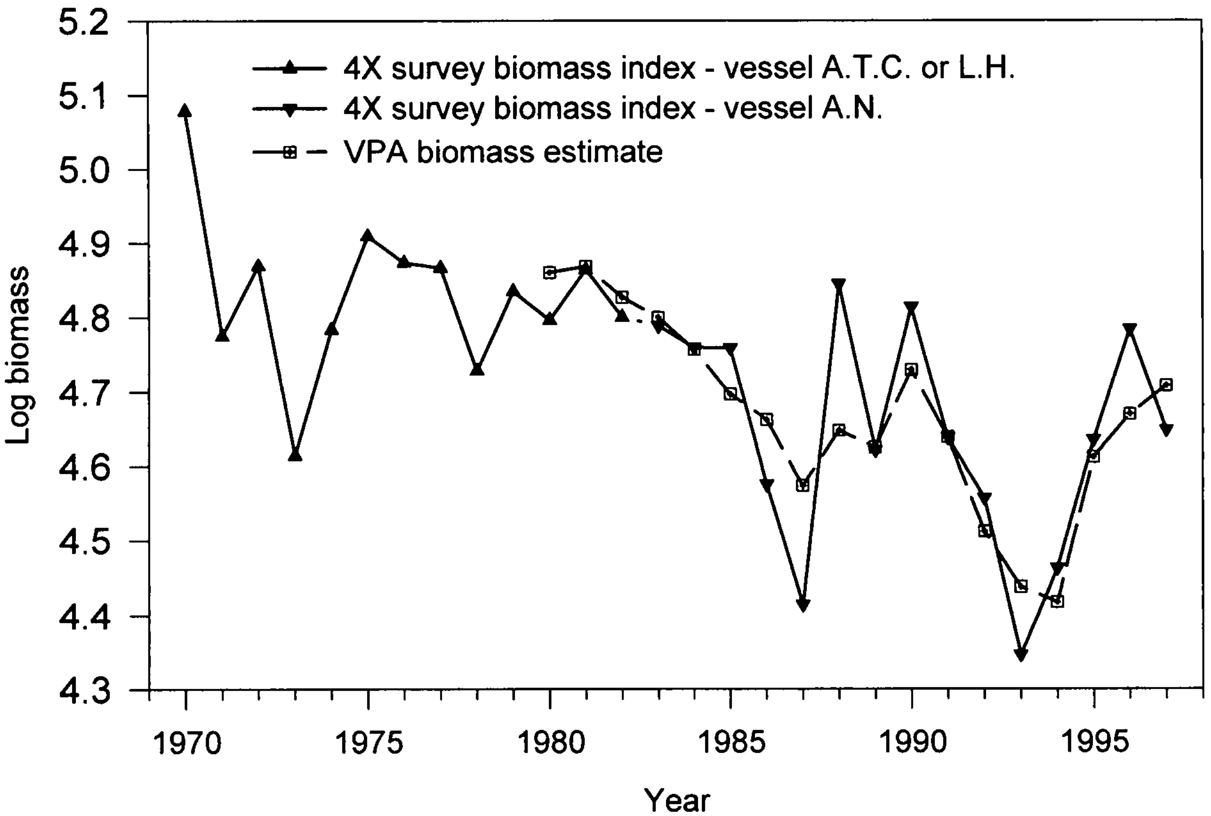
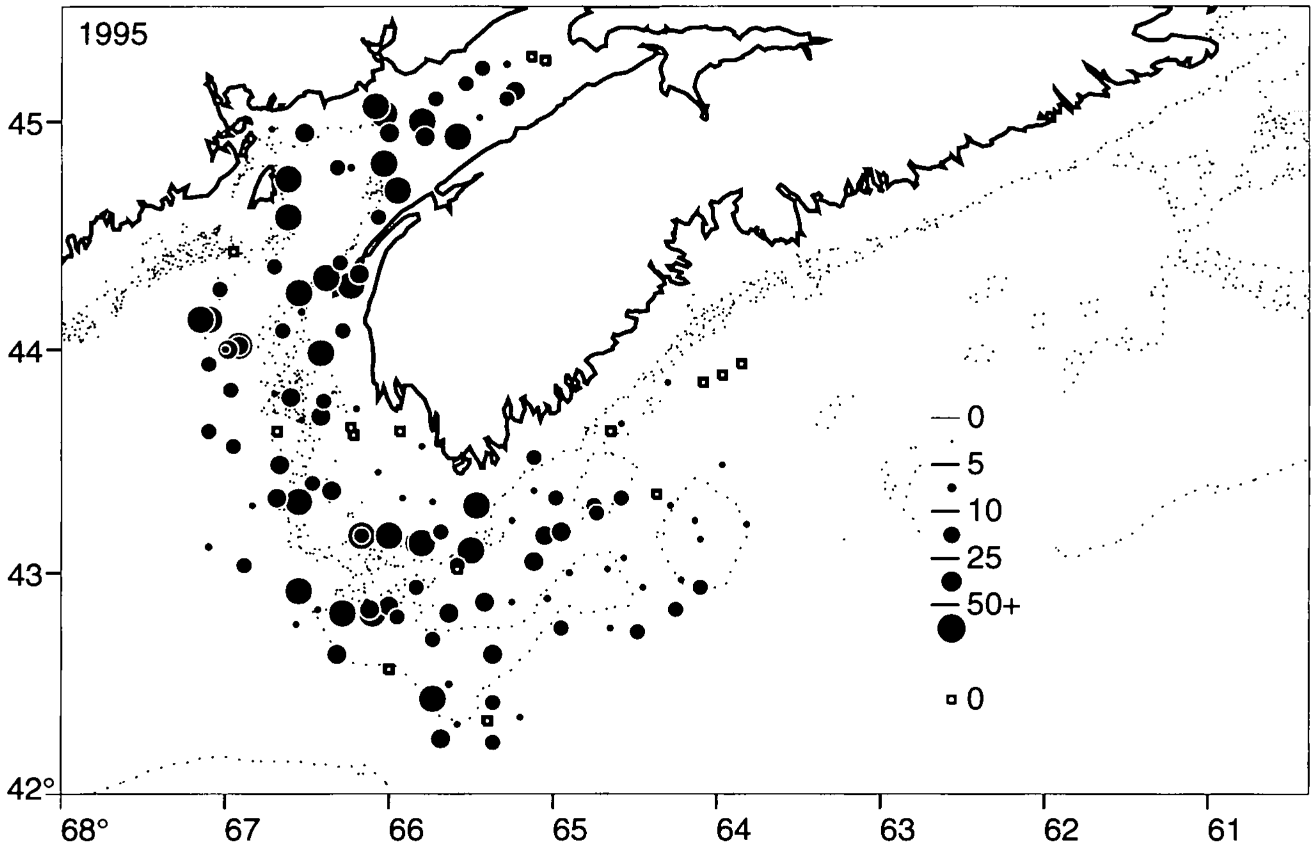


Fig. 10b. Comparison of q-adjusted survey biomass indices and VPA biomass estimate.



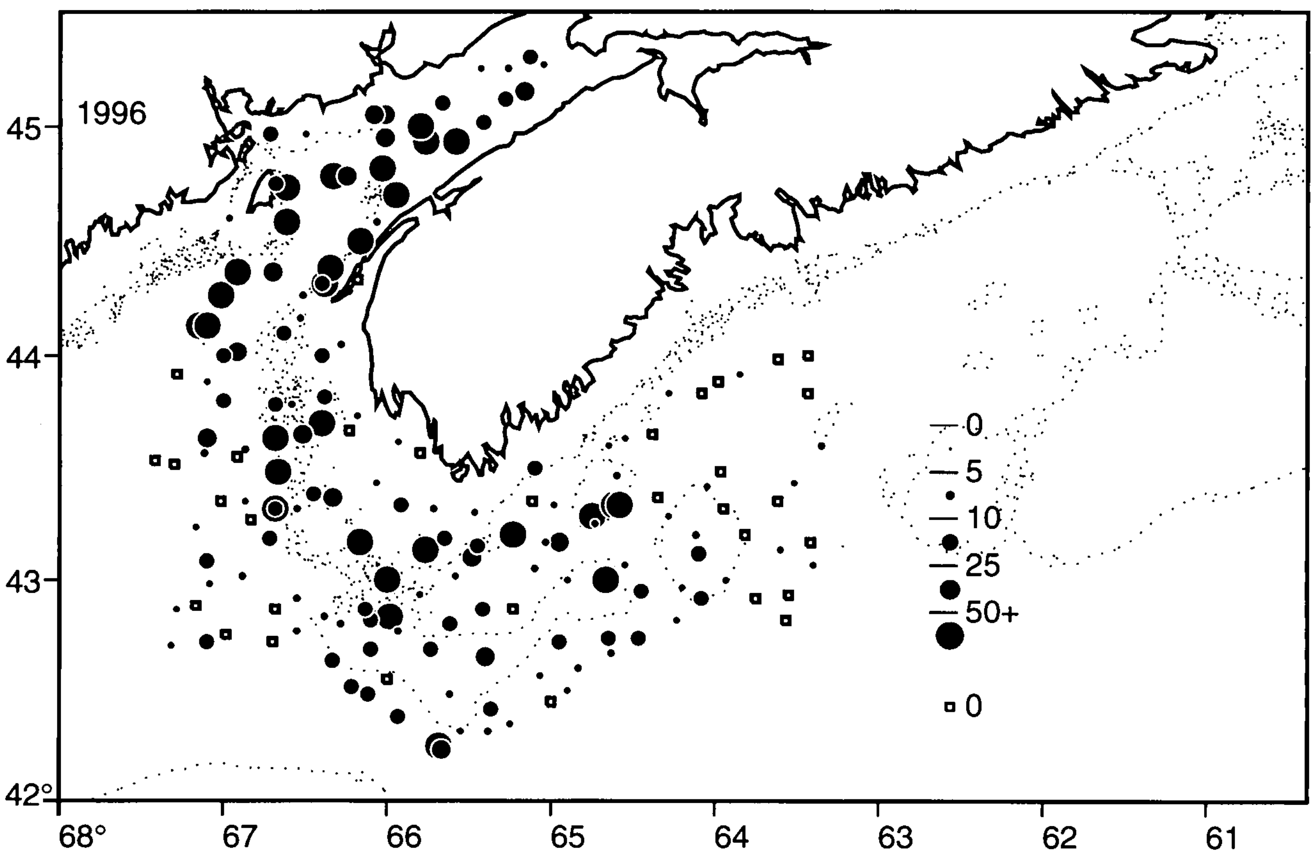


Fig. 11. Summer I.T.Q. groundfish survey 4X cod catches (Kg/tow).

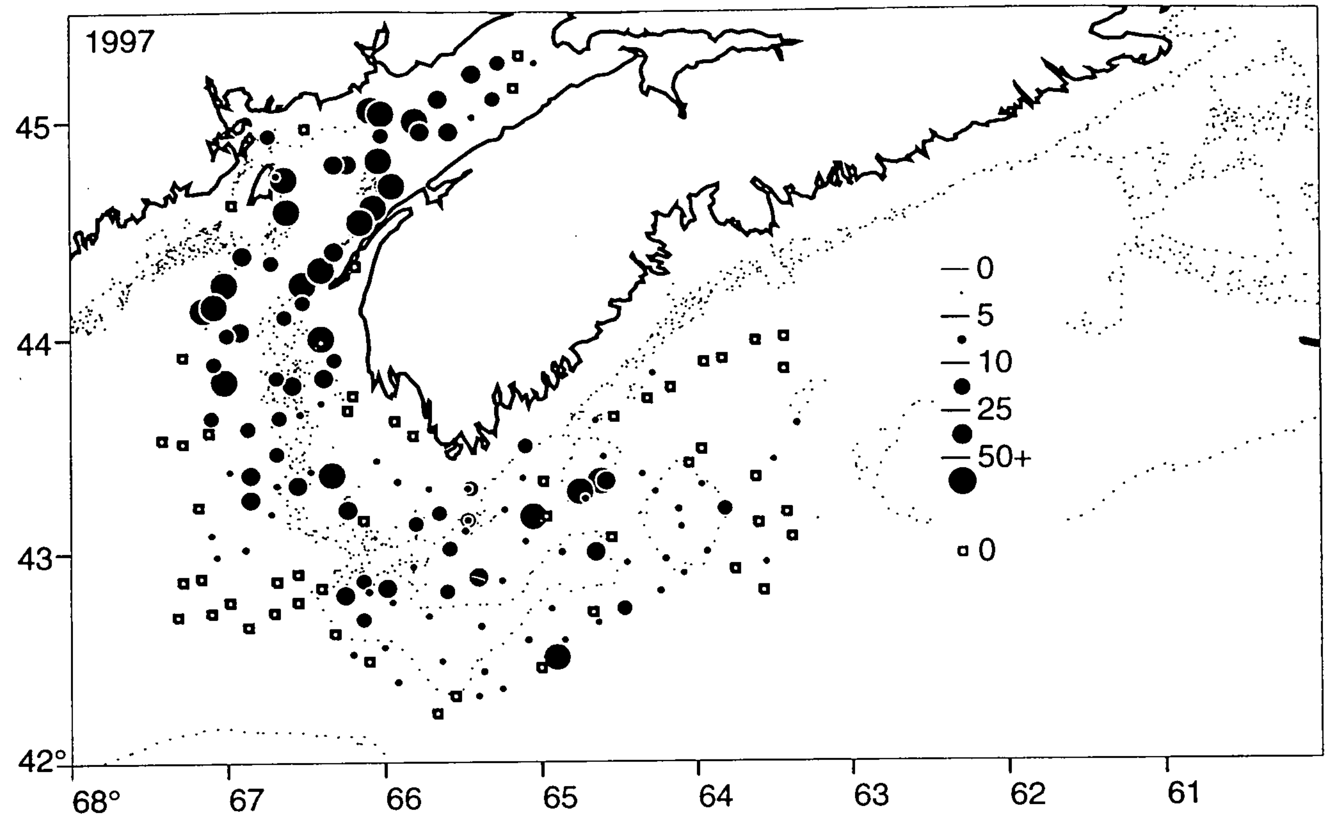


Fig. 11 (cont.). Summer I.T.Q. groundfish survey 4X cod catches (Kg/tow).

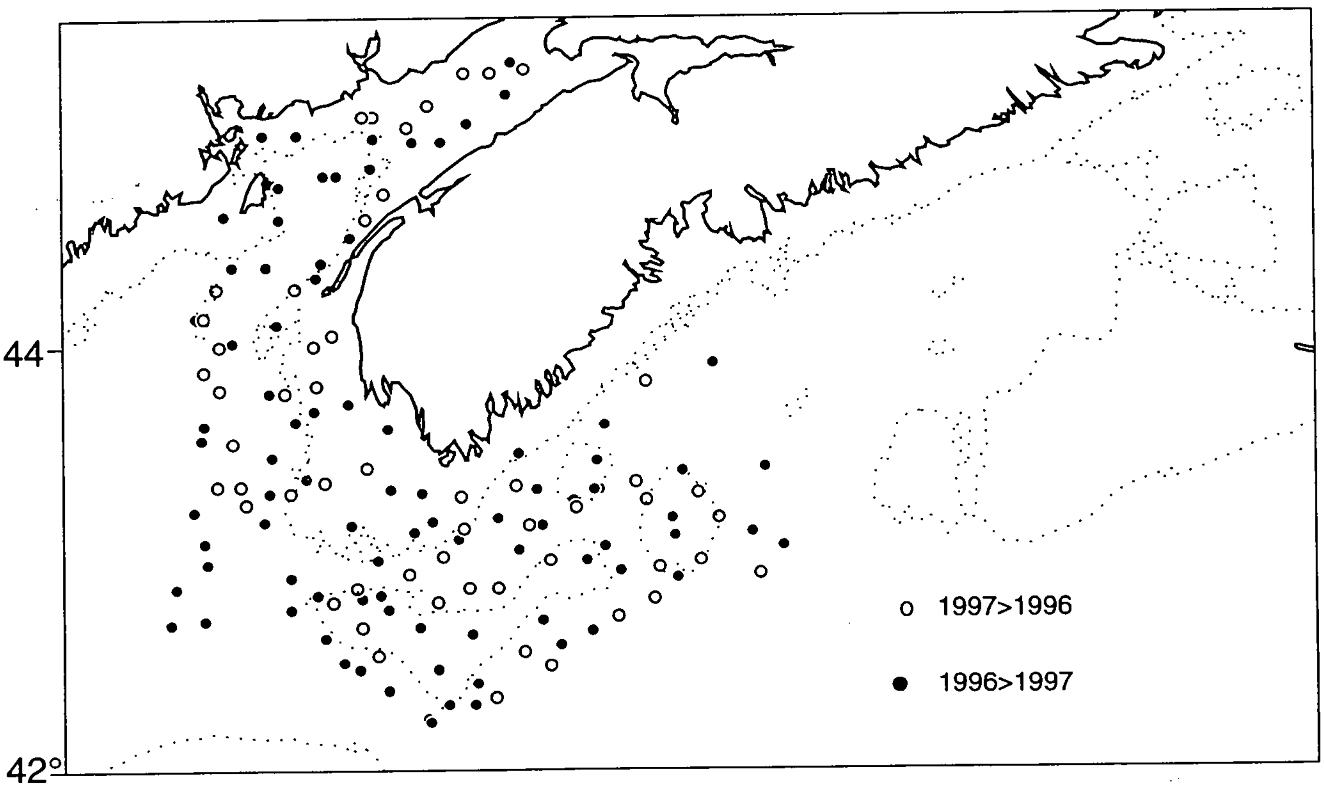


Fig. 12. Comparison of ITQ survey cod catches at repeated stations for 1996 and 1997

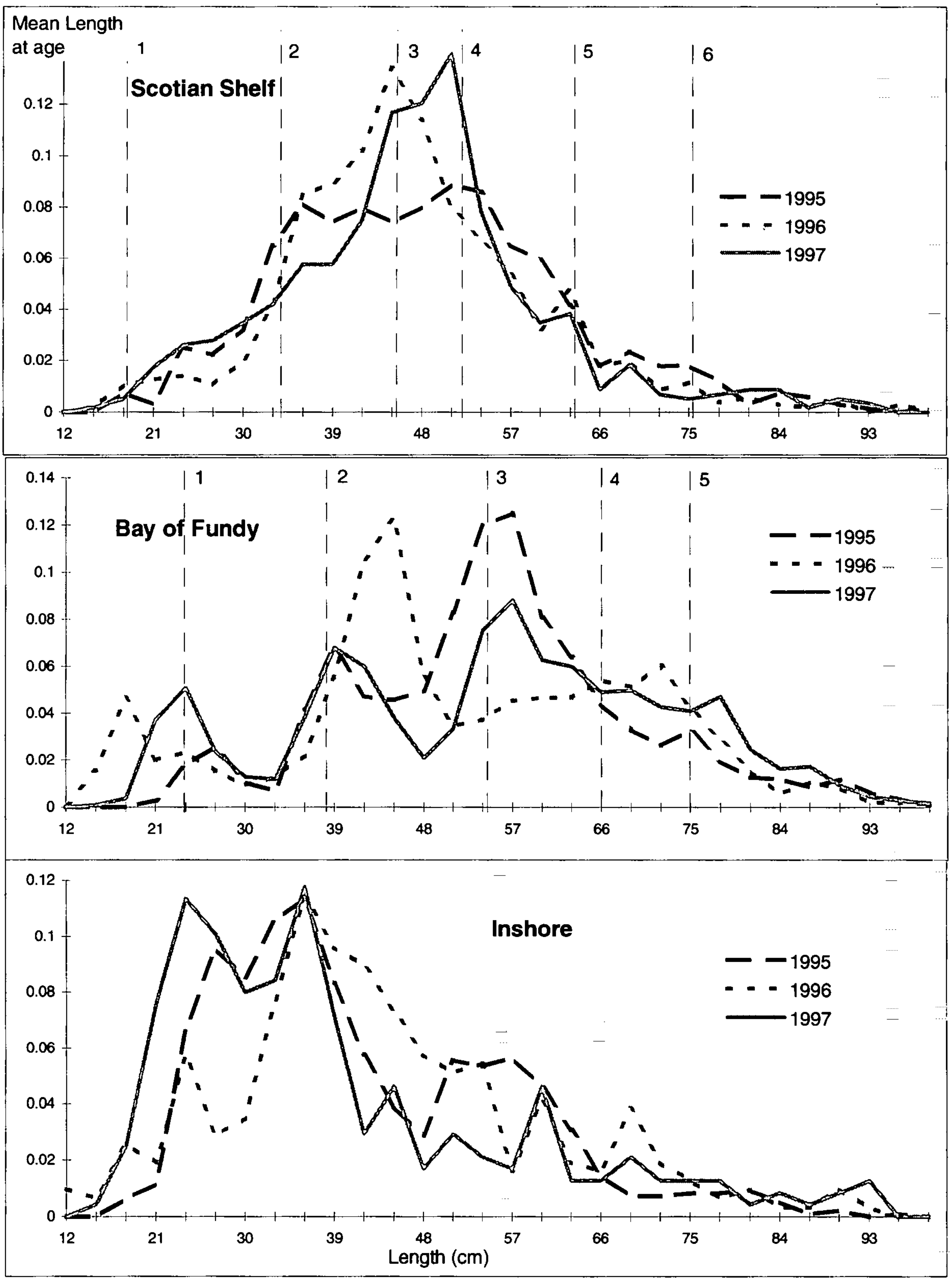
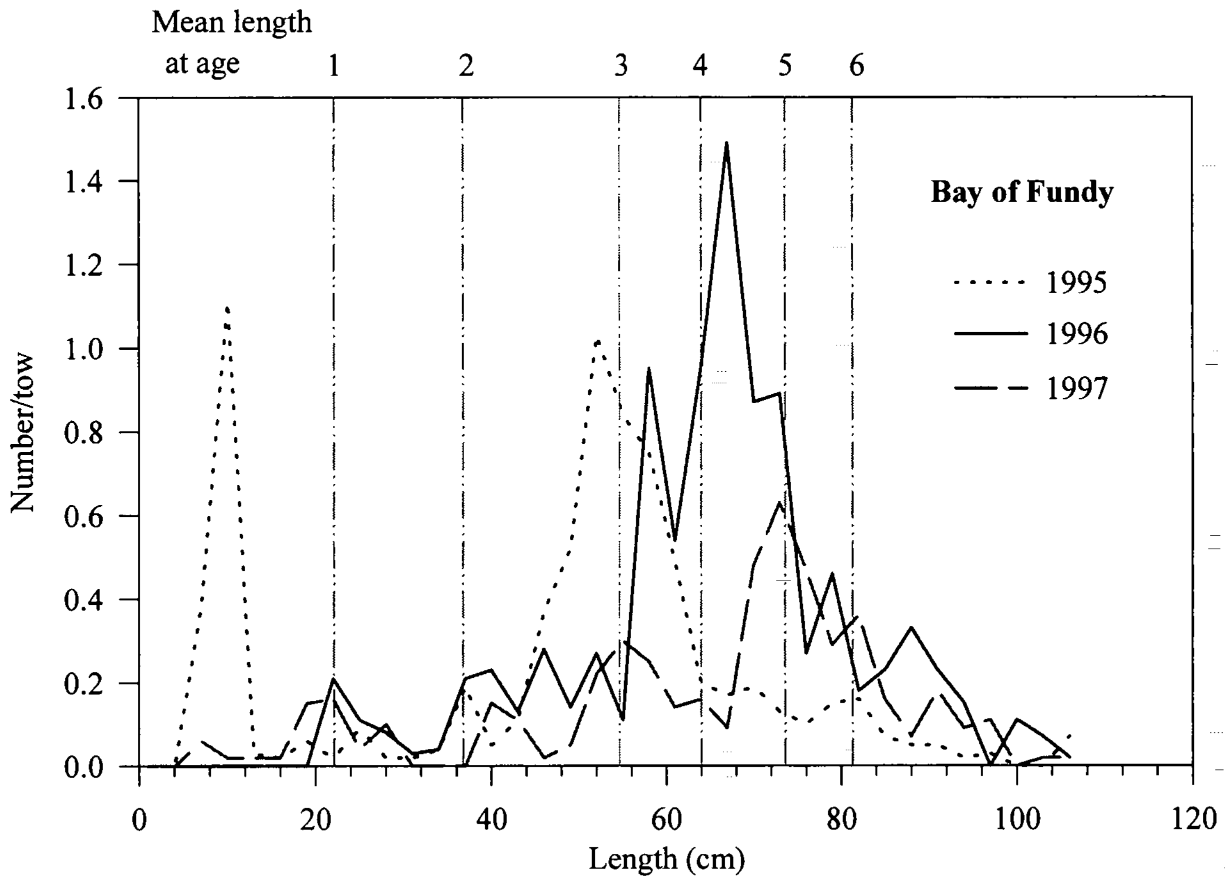


Fig. 13. Length frequencies for cod from ITQ surveys in Division 4X.



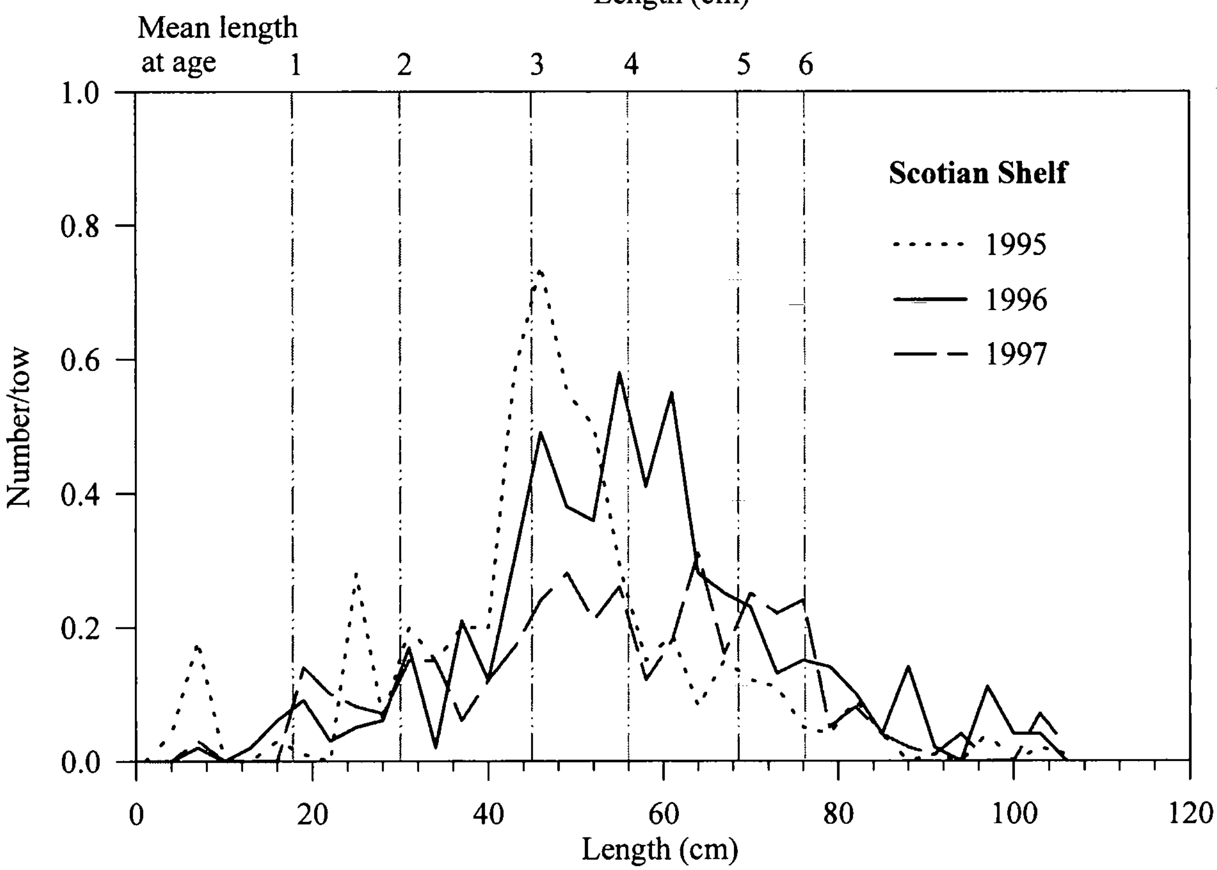


Fig 14. Length frequencies from summer RV groundfish surveys in Division 4X.

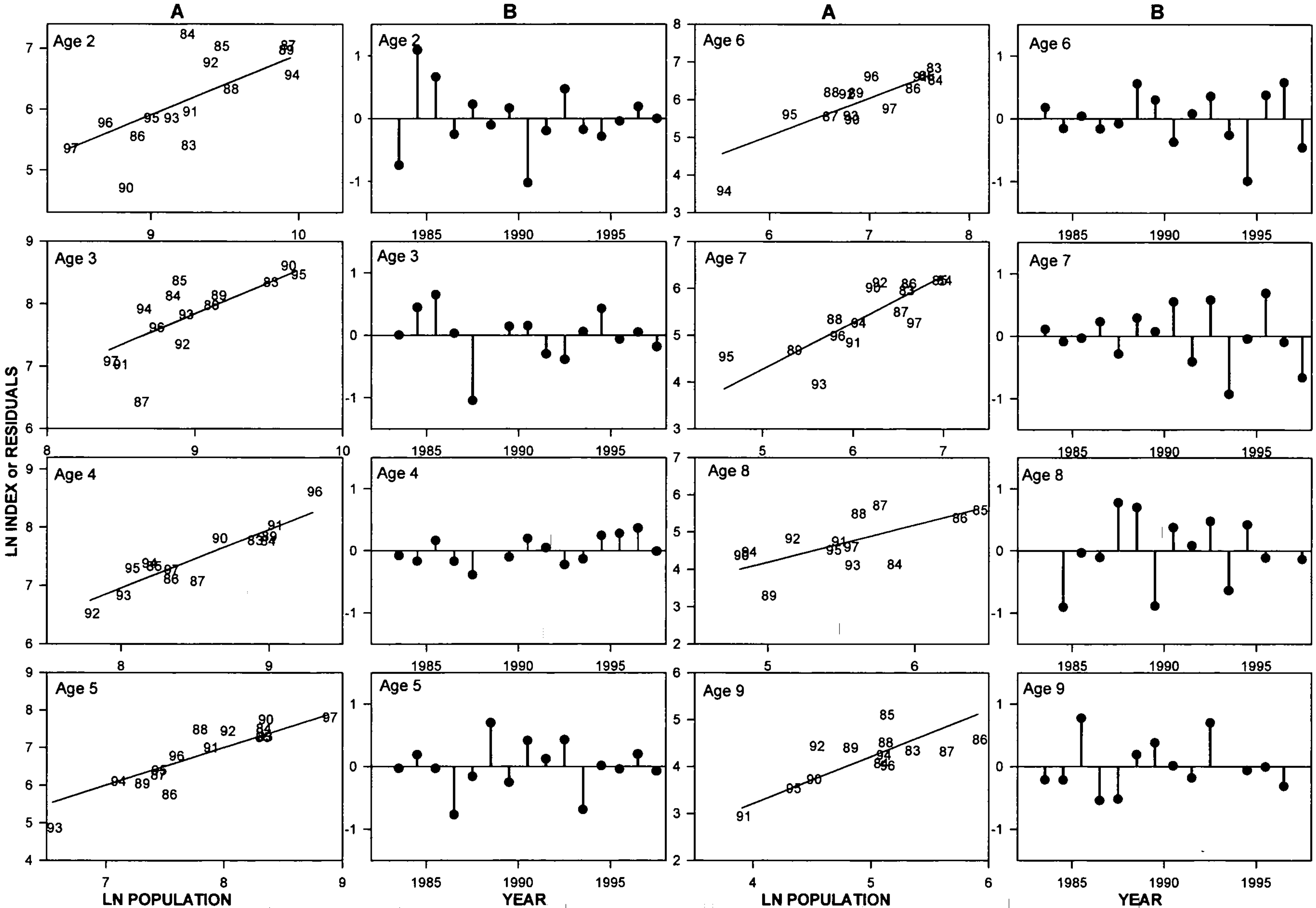


Fig. 15. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for cod in Division 4X and the Canadian portion of 5Y.

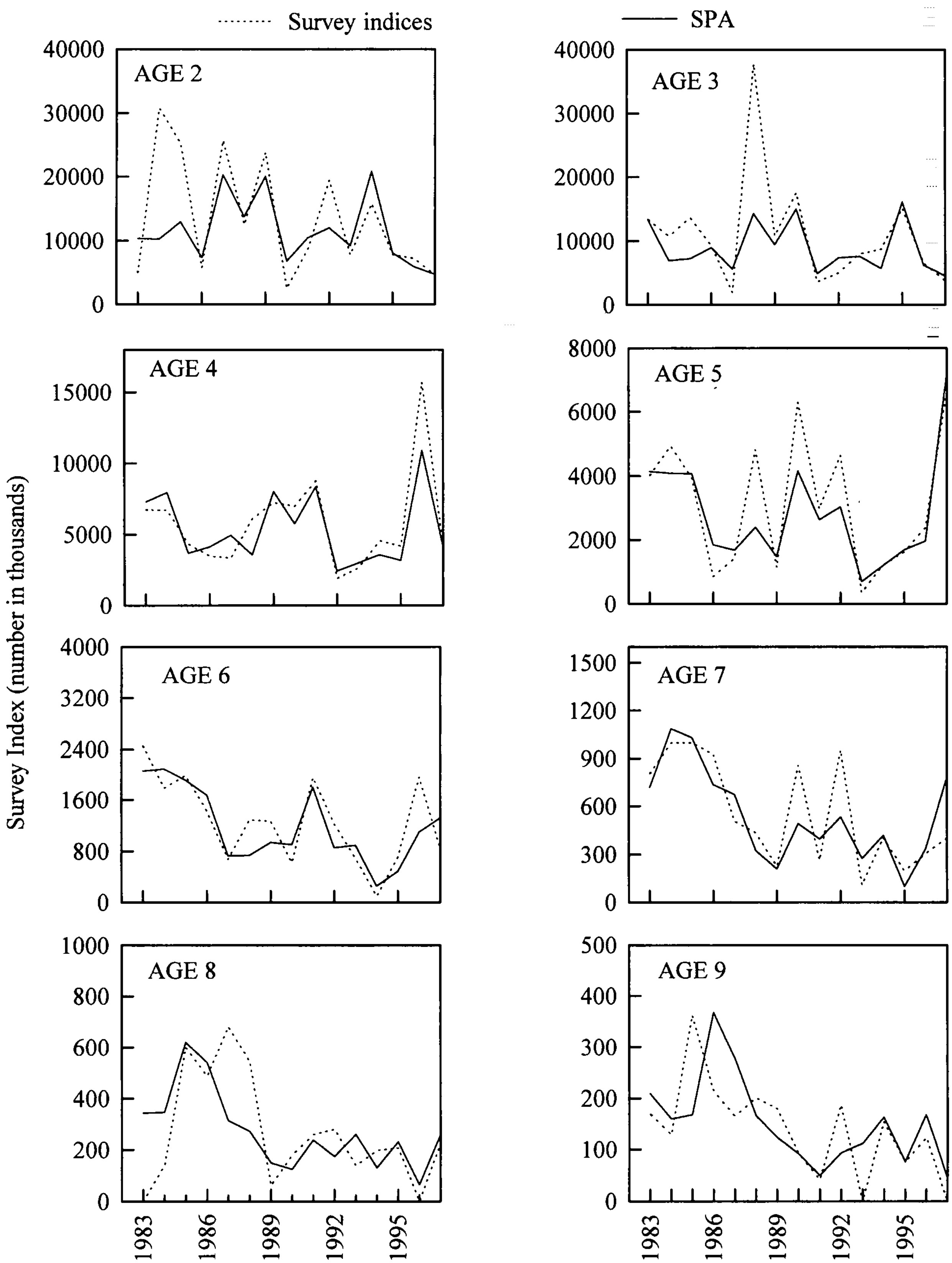


Figure 16. Mid-year population numbers from sequential population analysis (SPA) and research survey indices (adjusted by calibration constants) for 4X cod.

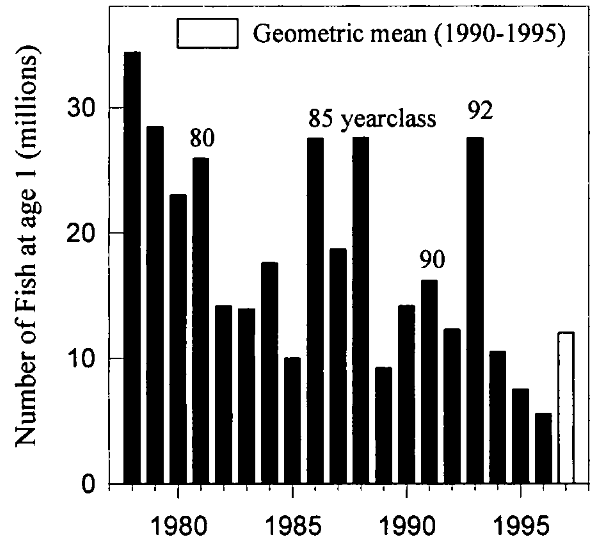


Fig. 17. Recruitment (age 1) for cod in Division 4X.

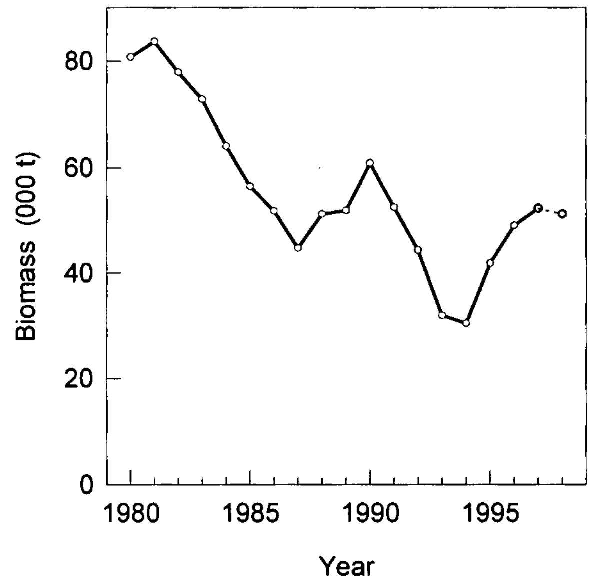


Fig. 18. Beginning of year biomass (3+) for cod in Division 4X.

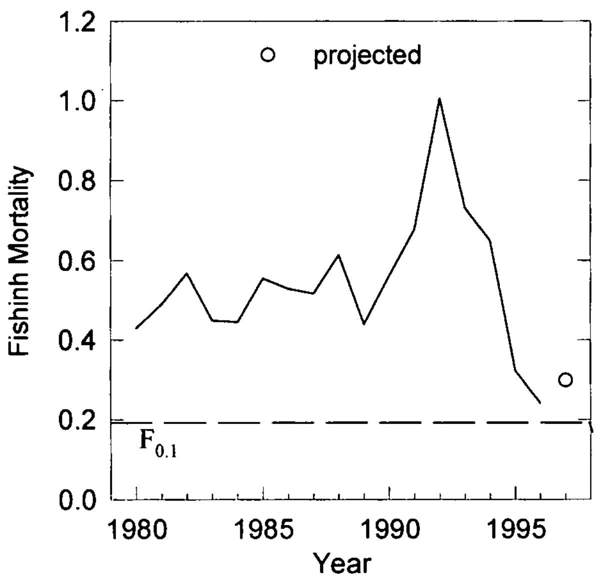


Fig. 19. Fully recruited fishing mortality for 4X cod.

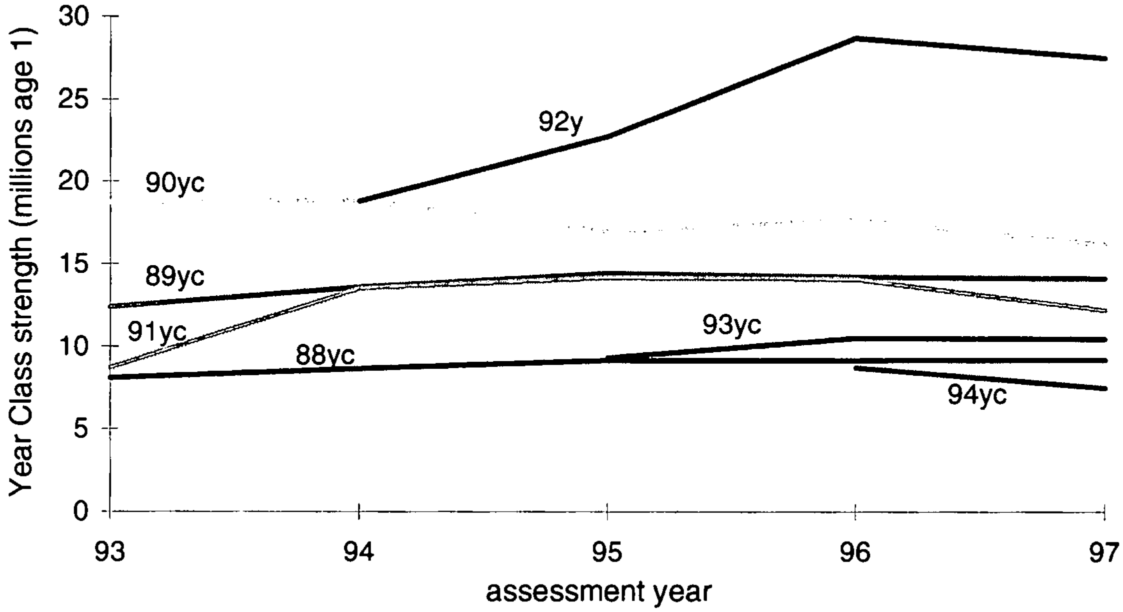


Figure 20. Interannual variability in estimates of year-class strength for the 4X cod assessment.

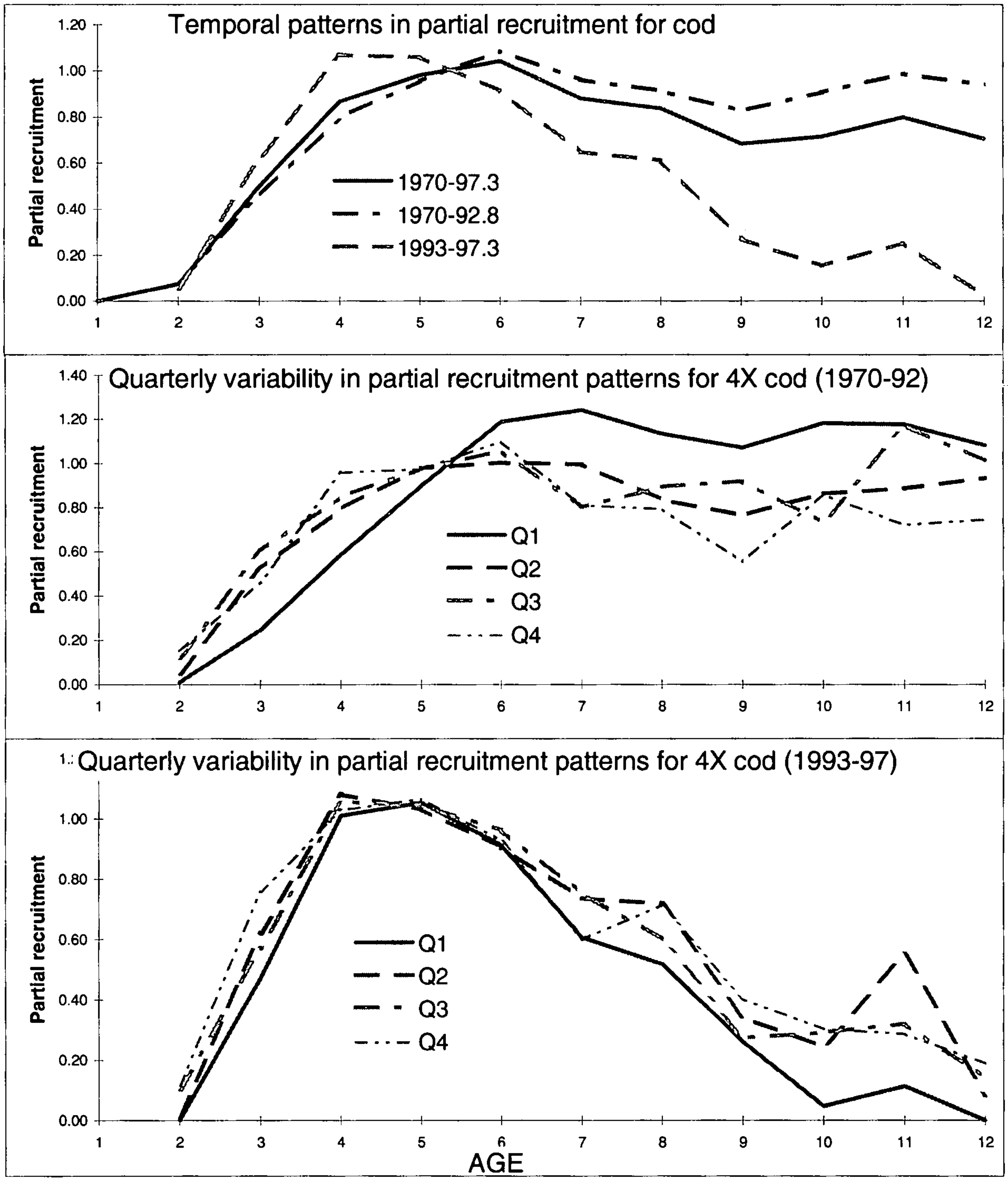


Fig. 21. Patterns in partial recruitment of 4X cod to the commercial fishery.

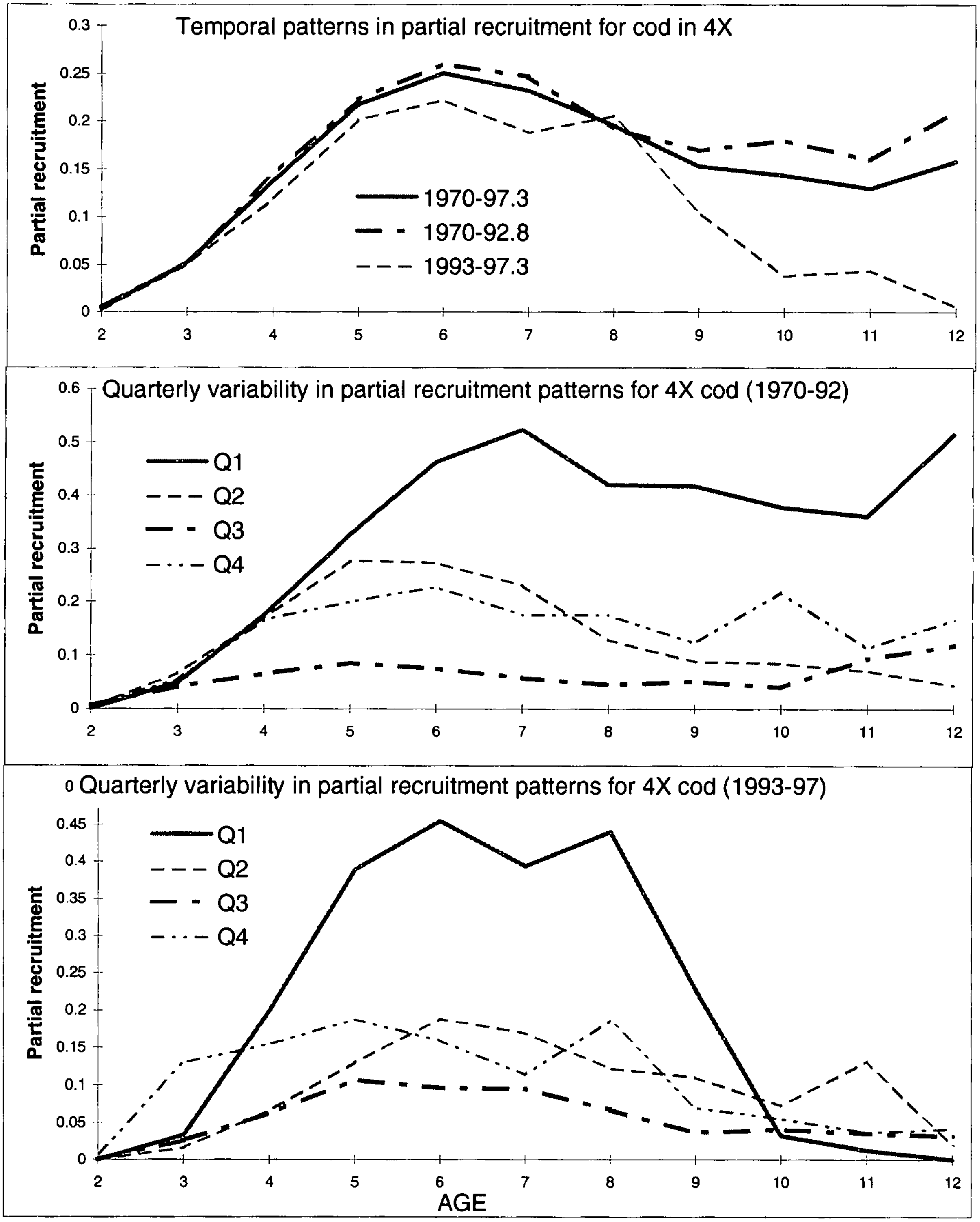


Fig. 22. Partial recruitment patterns for 4X cod to otter trawl gear on the Scotian Shelf.

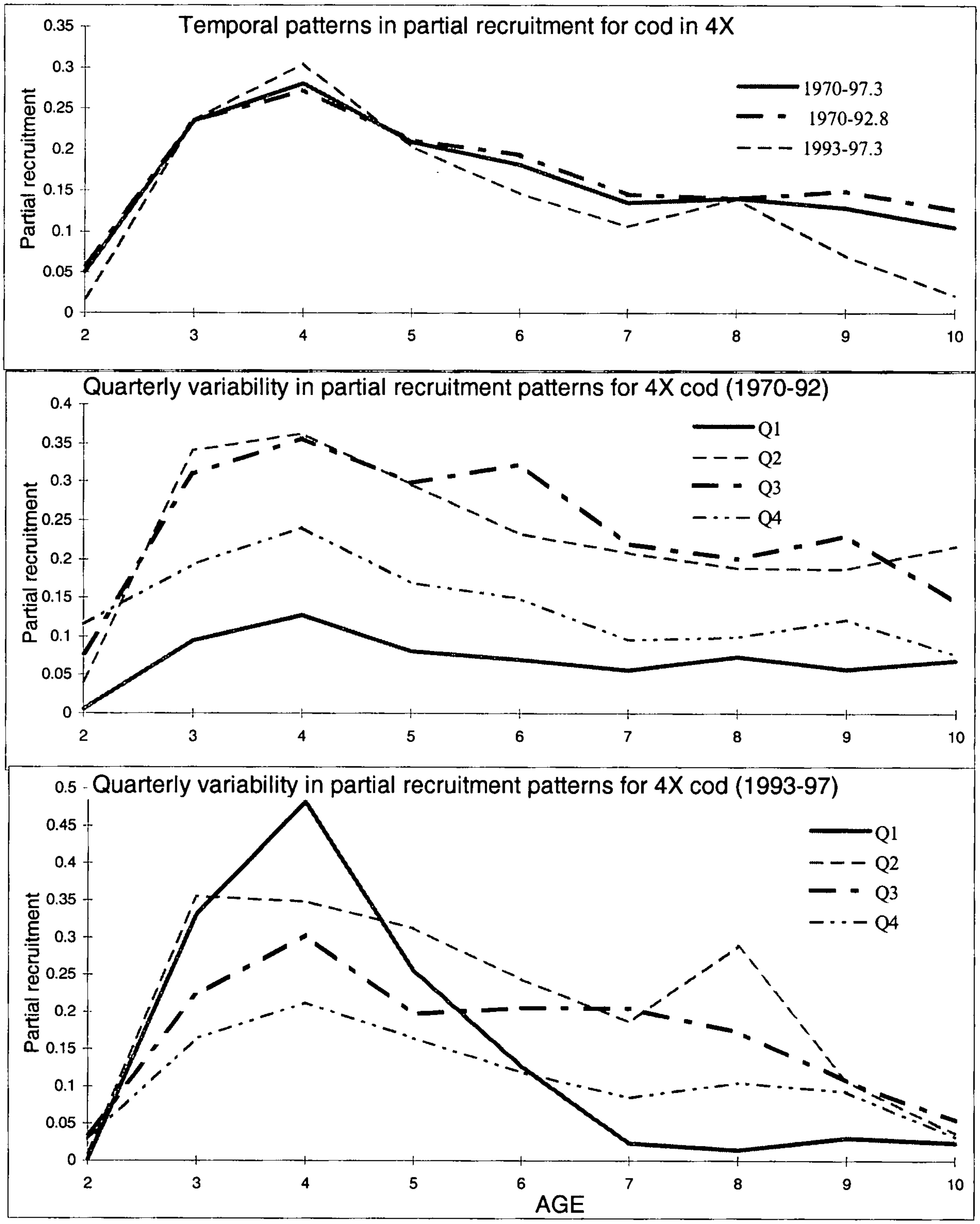


Fig. 23. Partial recruitment patterns for cod in the Bay of Fundy to all gear types.

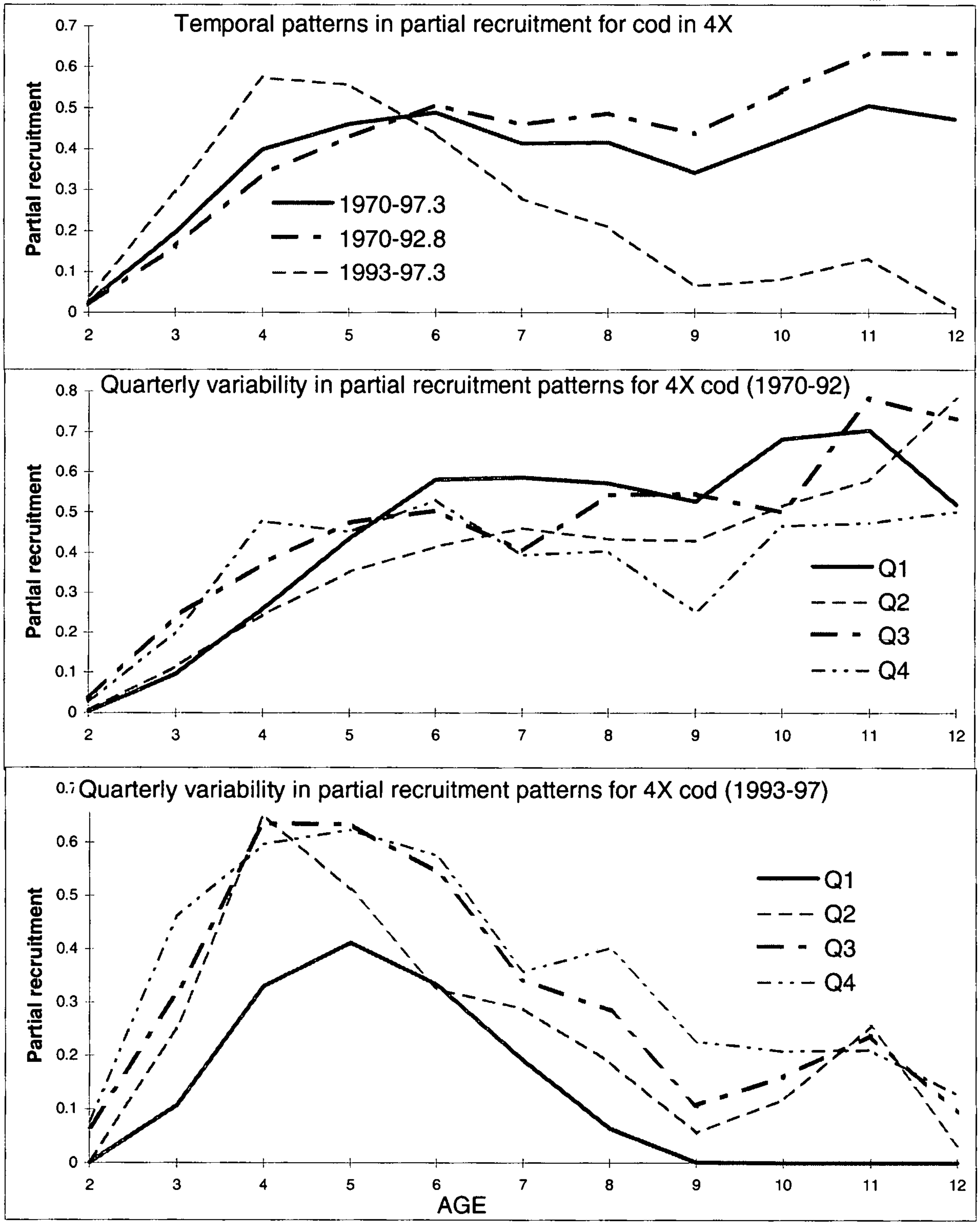


Fig.24. Partial recruitment patterns for 4X cod to long-line gear on the Scotian Shelf.

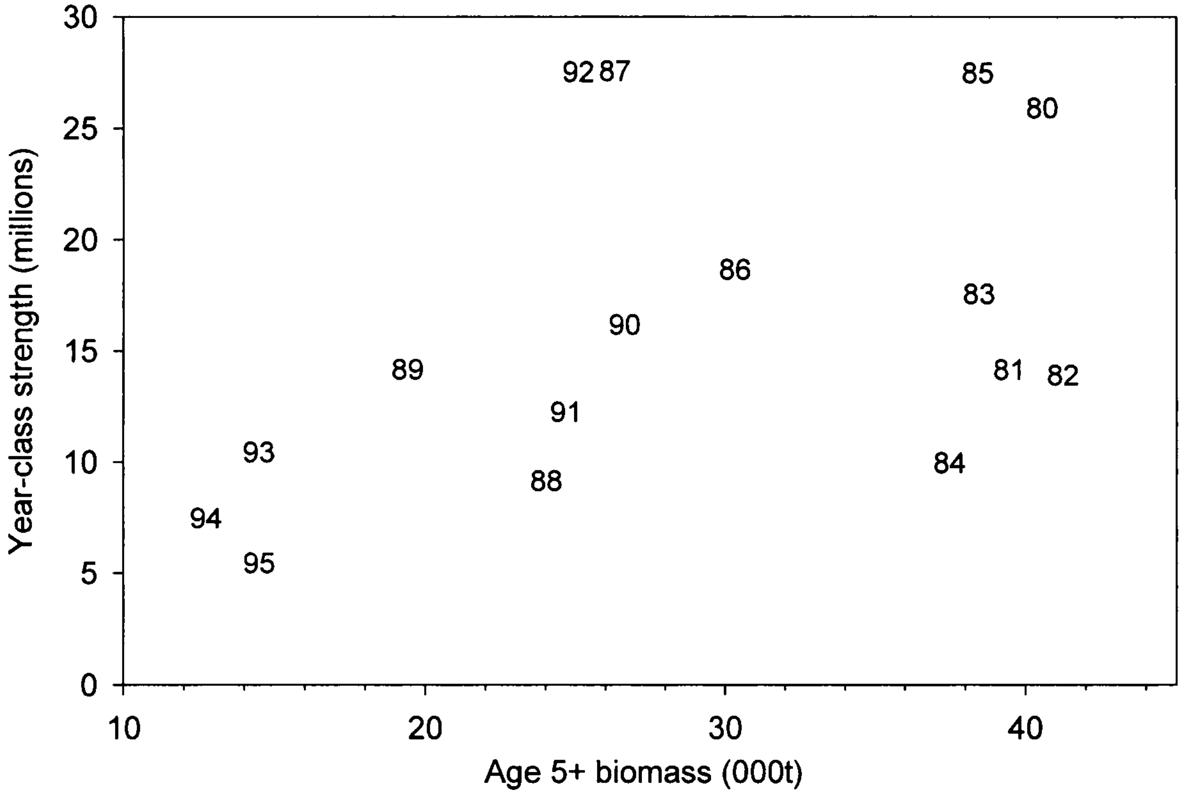


Fig. 25. Stock recruitment relationship for 4X cod.

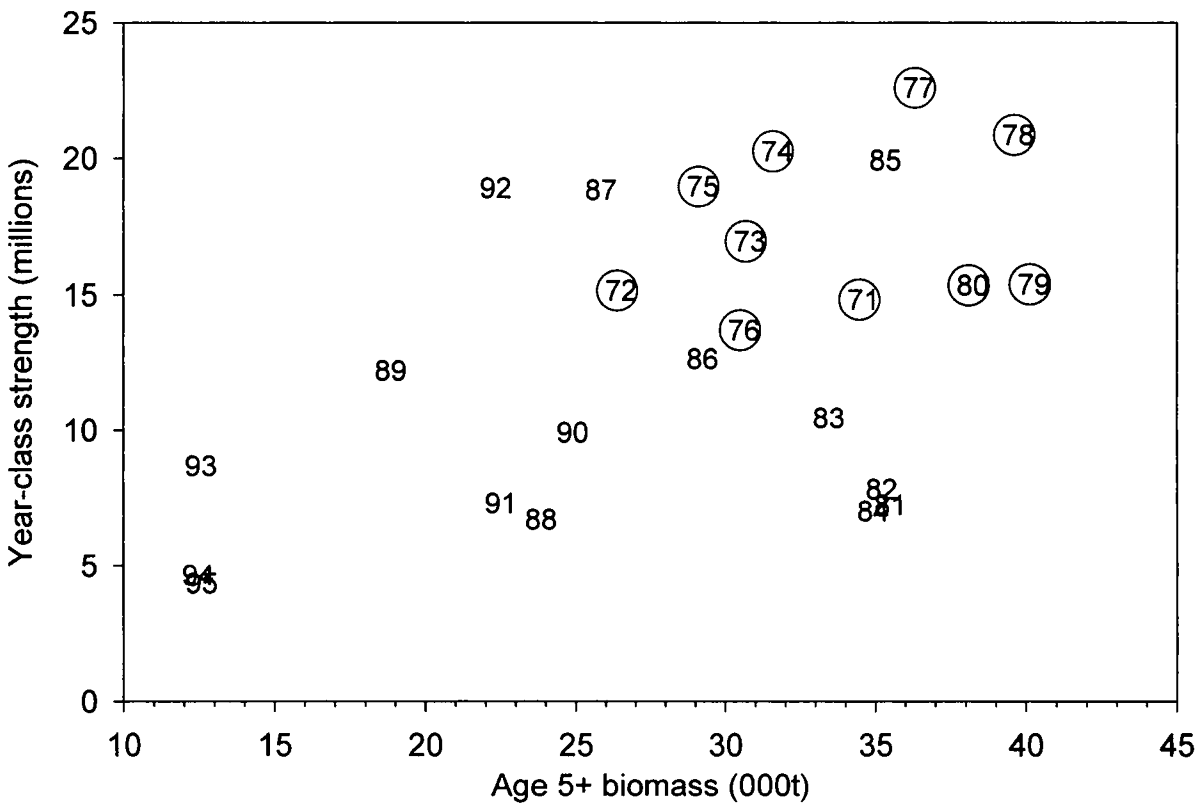


Fig. 26. Stock recruitment relationship for 4X cod on the Scotian Shelf. Circled values highlight the consistently good recruitment prior to 1981.

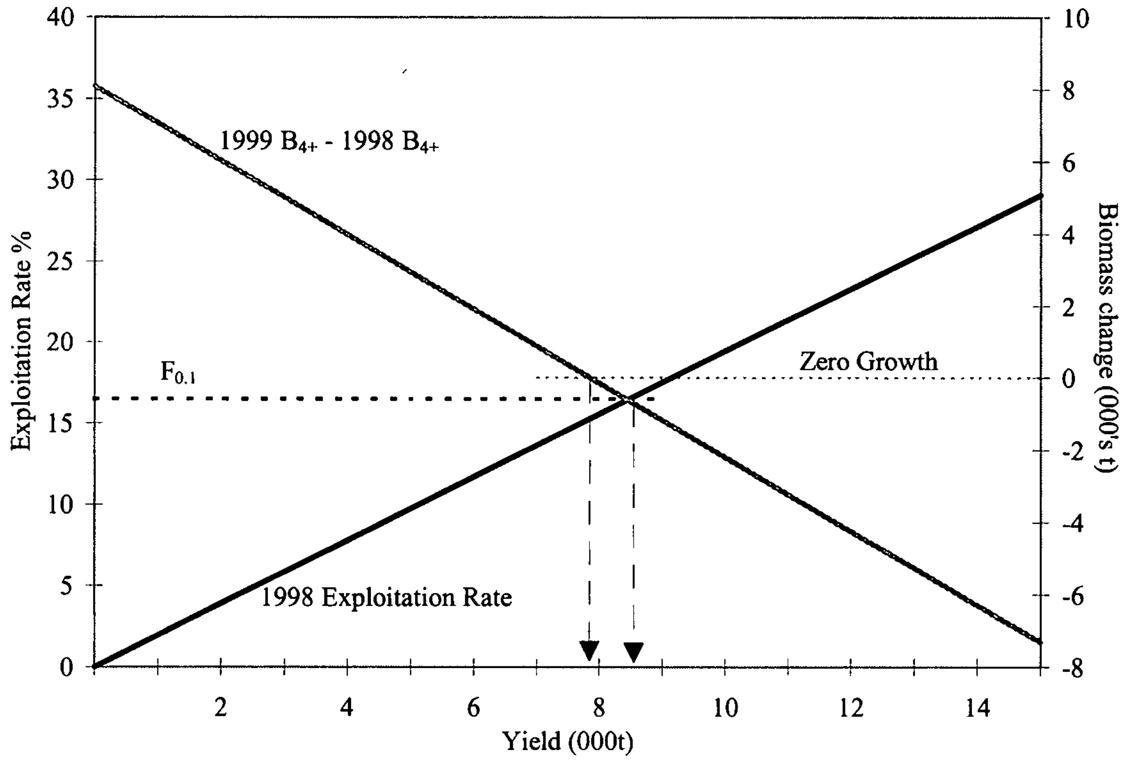


Fig. 27. Yield and resultant exploitation rate for 4X cod in 1998, and its impact on age 4+ biomass.

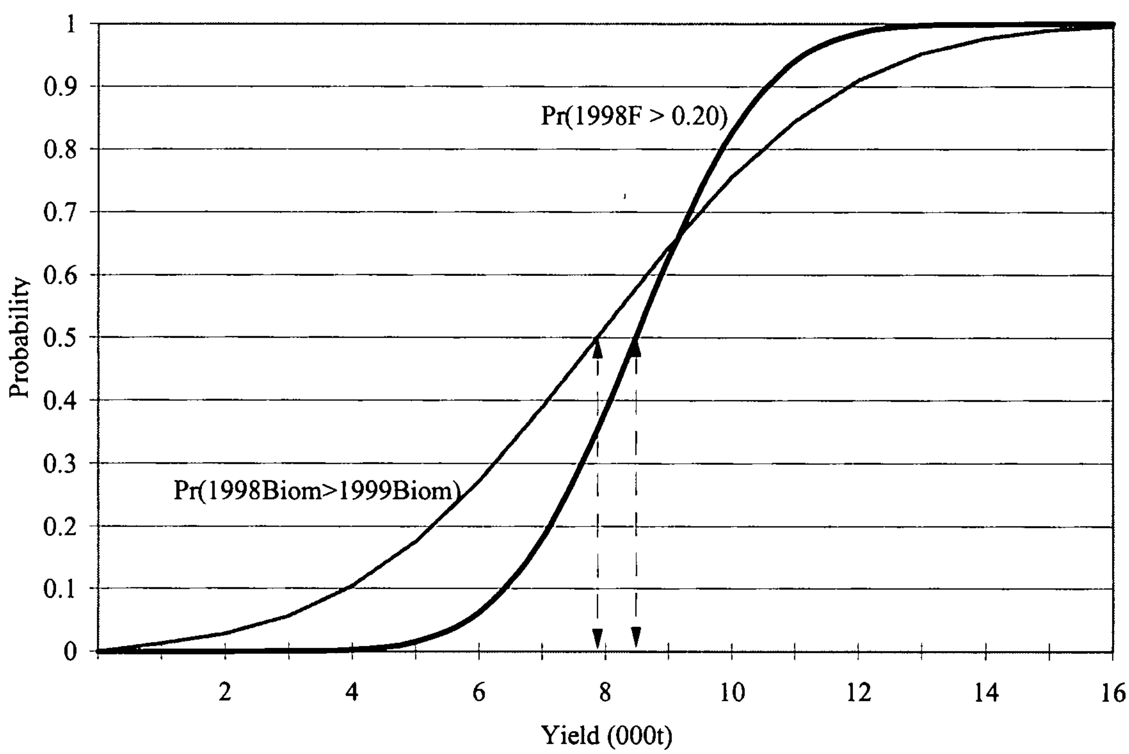


Fig. 28. Influence of yield for 4X cod in 1998 on the probability of exceeding F0.1 and of age 4+ biomass decreasing.

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

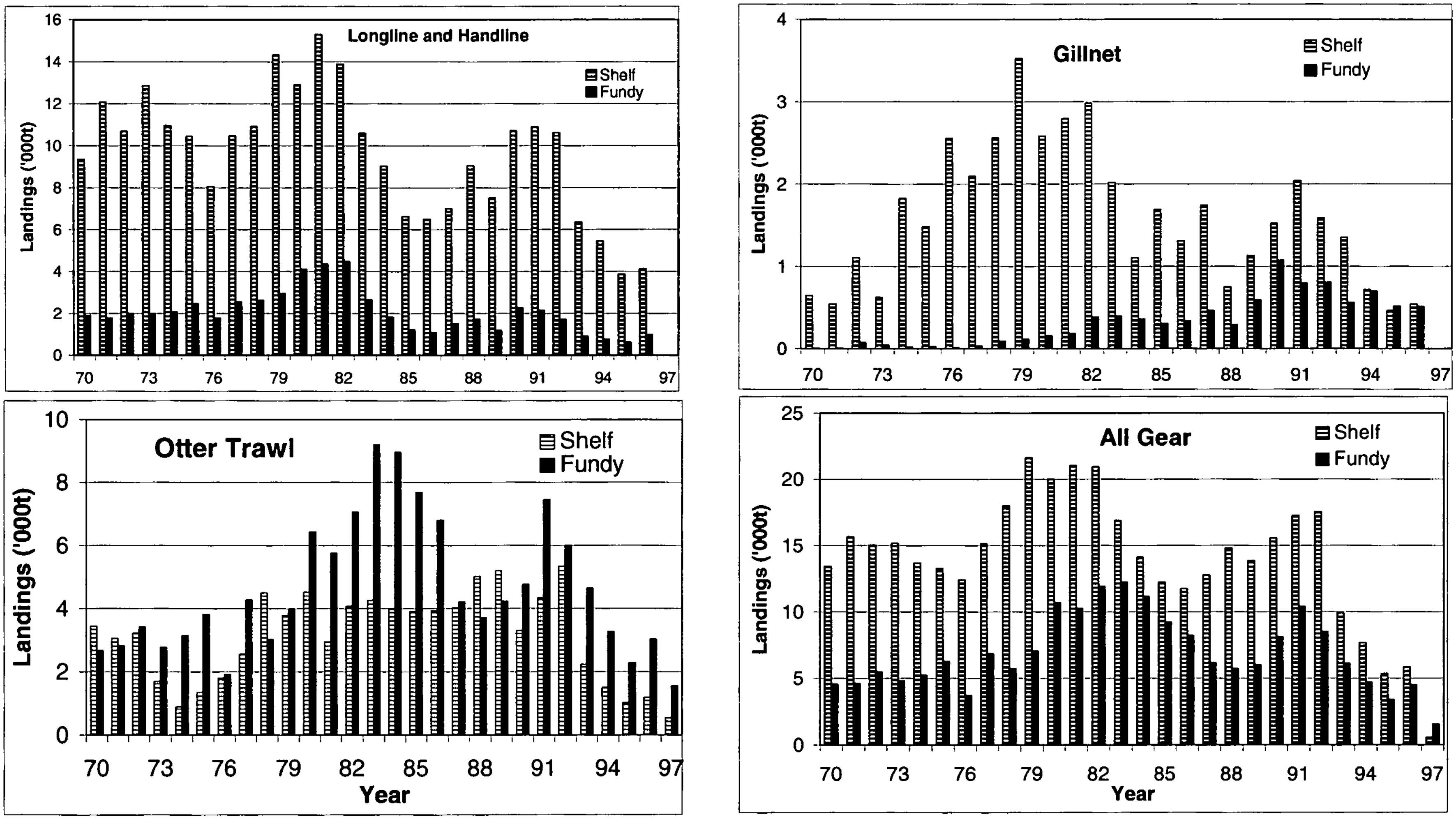
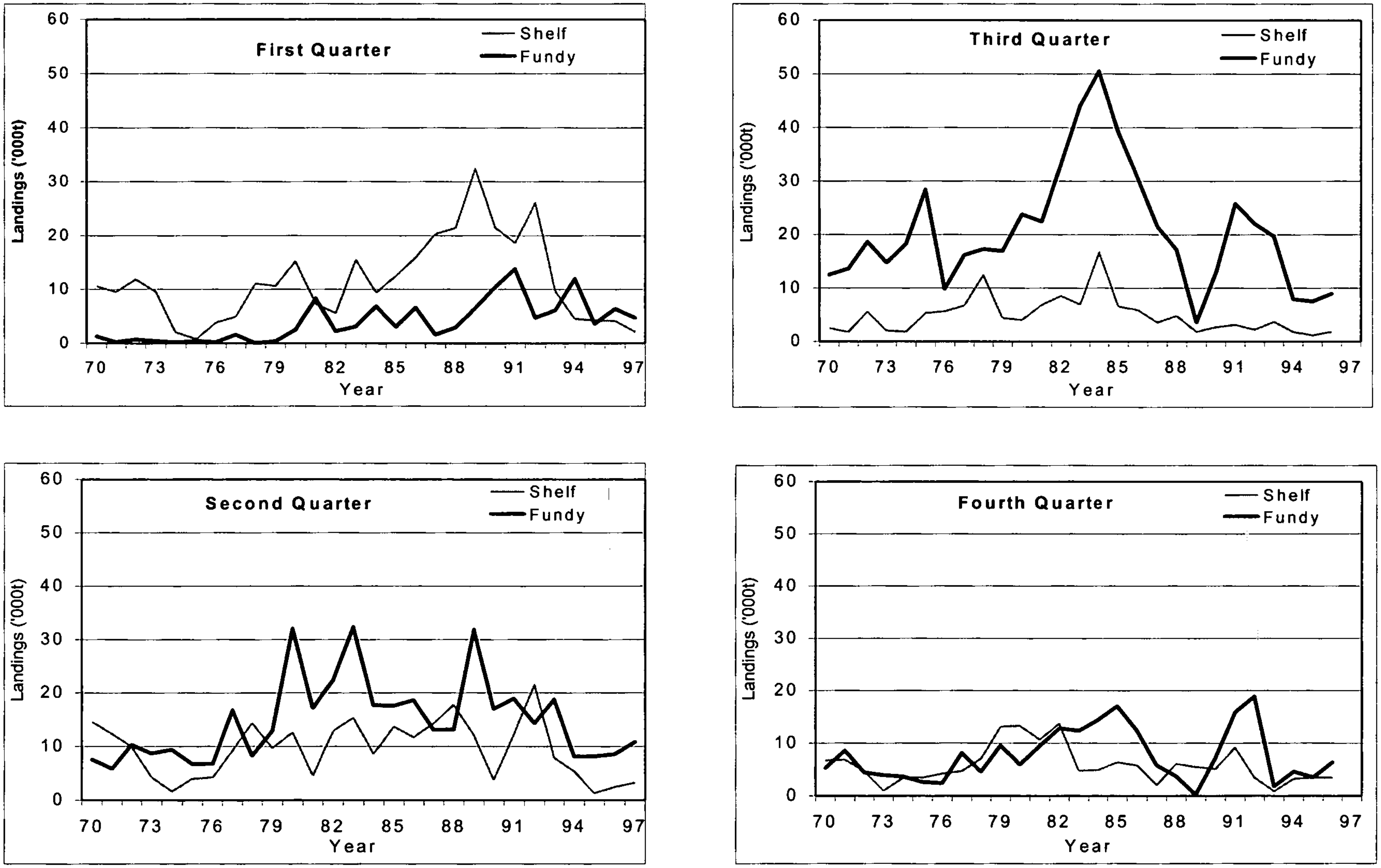
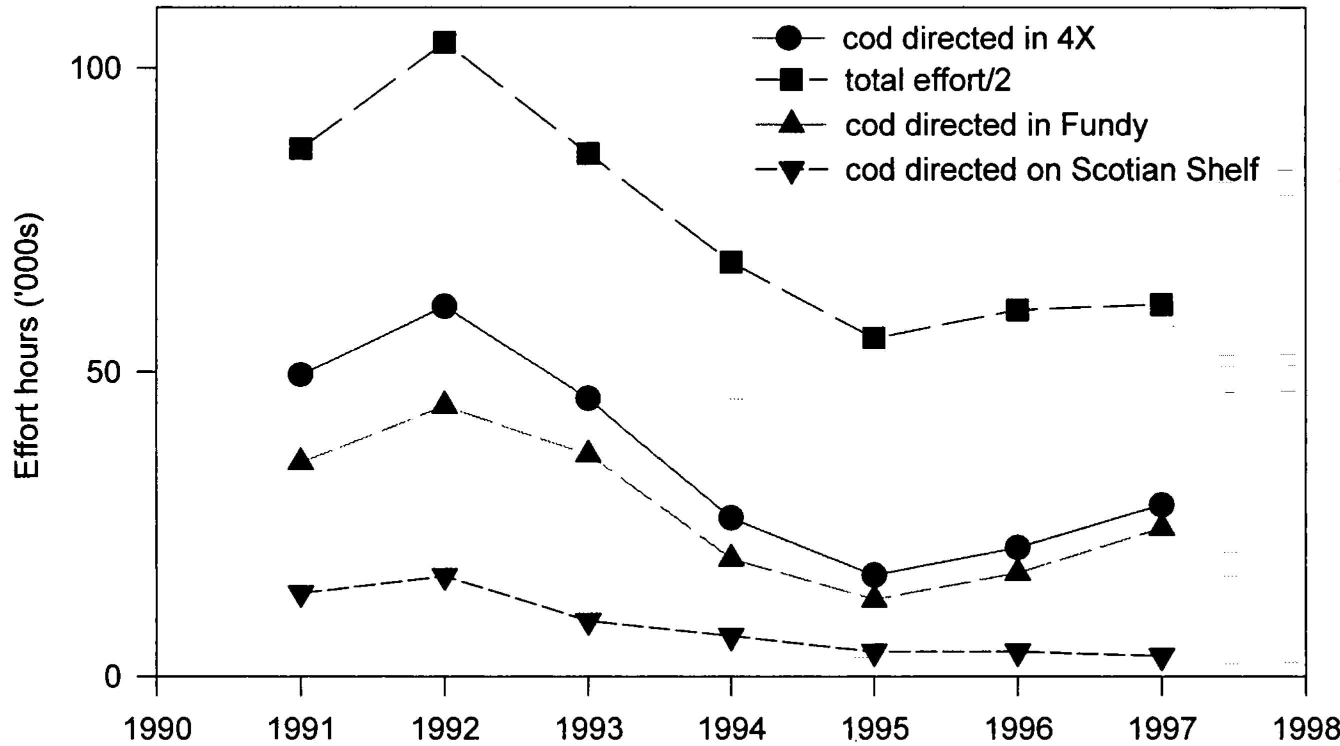


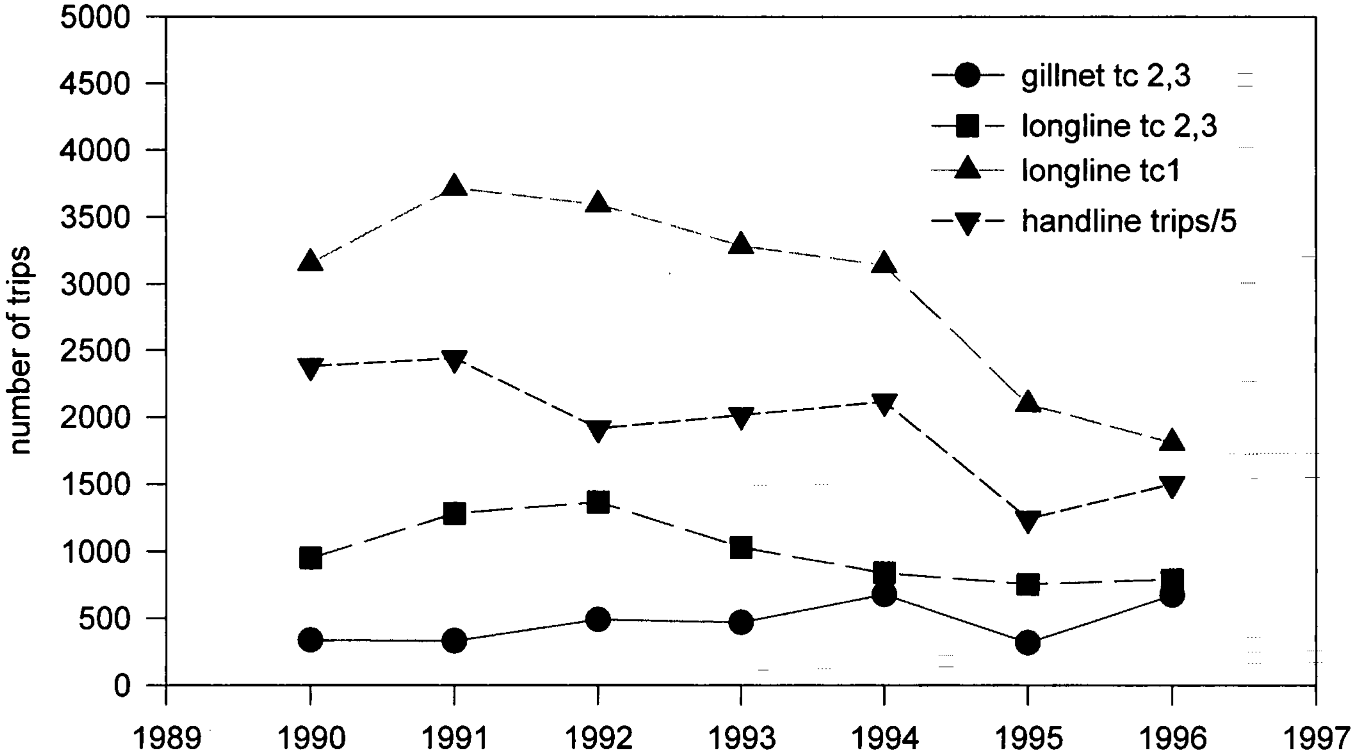
Fig AI.1 Annual landings of 4X cod by gear type and area.



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



AI.3. Total and cod directed fishing effort by tc 1-3 otter trawlers in Division 4X.



AI.4. Number of trips directed for 4X cod by gear type and tonnage class for fixed gear.

Appendix II. Age Comparison tests.

Routine age comparison testing was conducted for 4X cod. Intra-reader tests were conducted with otoliths from 1996, and also with otoliths from 1990 to evaluate whether there has been any shift in interpretation over time. Inter-reader historical testing was also conducted using otoliths from 1986, which were originally aged by the previous primary age-reader for this stock. In all cases testing was done separately for Bay of Fundy and Scotian Shelf samples. The results showed acceptable levels of agreement in all cases, and did not give any indication of bias in interpretations. Otoliths deemed unreadable (cryst.) in either reading were not included in the analysis.

Intra-reader comparison for Bay of Fundy cod otoliths (1996)

	second										
first	2	3	4	5	6	7	8	9	10	cryst	Grand Total
2	***1***	0	0	0	0	0	0	0	0	0	1
3	0	***10***	2	0	0	0	0	0	0	0	12
4	0	0	***42***	1	0	0	0	0	0	0	43
5	0	0	0	***14***	1	0	0	0	0	0	15
6	0	0	0	0	***21***	0	0	0	0	1	22
7	0	0	0	0	0	***3***	0	0	0	0	3
8	0	0	0	0	0	0	***2***	0	1	0	3
9	0	0	0	0	0	0	0	***1***	0	0	1
cryst.	0	0	0	0	0	0	0	0	0	***2***	2
Grand Total	1	10	44	15	22	3	2	1	1	3	102

Agreement = 95%.

Intra-reader comparison for Scotian Shelf cod otoliths (1996)

	second										
first	2	3	4	5	6	7	8	9	10	cryst	Grand Total
2	***2***	0	0	0	0	0	0	0	0	0	2
3	0	***12***	2	0	0	0	0	0	0	1	15
4	0	1	***69***	0	0	1	0	0	0	0	71
5	0	0	2	***13***	0	0	0	0	0	0	15
6	0	0	0	1	***22***	2	0	0	0	0	25
7	0	0	1	0	0	***6***	0	0	0	0	7
8	0	0	0	0	0	0	***6***	1	1	0	8
9	0	0	0	0	0	0	0	***6***	1	0	7
10	0	0	0	0	0	0	0	0	***2***	0	2
cryst.	0	0	1	0	0	0	0	0	0	***3***	4
Grand Total	2	13	75	14	22	9	6	7	4	4	156

Agreement = 92%.

Appendix II (cont.).

Intra-reader comparison for Bay of Fundy cod otoliths (1990)

	second										
first	3	4	5	6	7	8	9	10	11	12	cryst	Grand Total
3	***12***	1	0	0	0	0	0	0	0	0	0	13
4	0	***18***	1	0	0	0	0	0	0	0	0	19
5	0	0	***41***	0	0	0	0	0	0	0	0	41
6	0	0	0	***3***	1	0	0	0	0	0	0	4
7	0	0	0	0	***19***	1	0	0	0	0	0	20
8	0	0	0	0	0	***2***	1	0	0	0	0	3
9	0	0	0	0	0	0	***3***	0	0	0	0	3
10	0	0	0	0	0	0	0	***4***	0	0	1	5
11	0	0	0	0	0	0	0	0	***1***	0	0	1
12	0	0	0	0	0	0	0	0	0	***1***	0	1
cryst.	0	0	0	0	0	0	0	0	0	0	***2***	2
Grand Total	12	19	42	3	20	3	4	4	1	1	3	112

Agreement = 96%.

Intra-reader comparison for Scotian Shelf cod otoliths (1990)

	second														
first	2	3	4	5	6	7	8	9	10	11	12	13	15	cryst	Total
2	***3***	1	0	0	0	0	0	0	0	0	0	0	0	0	4
3	0	***15***	0	1	0	0	0	0	0	0	0	0	0	0	16
4	0	2	***23***	0	0	0	0	0	0	0	0	0	0	0	25
5	0	0	3	***17***	0	0	0	0	0	0	0	0	0	0	20
6	0	0	0	2	***21***	0	0	0	0	0	0	0	0	1	24
7	0	0	0	0	0	***14***	1	0	0	0	0	0	0	0	15
8	0	0	0	0	0	1	***6***	2	1	0	0	0	0	2	12
9	0	0	0	0	0	0	1	***5***	0	0	0	0	0	1	7
10	0	0	0	0	0	0	0	0	***8***	1	0	0	0	0	9
11	0	0	0	0	0	0	0	0	0	***1***	0	0	0	1	2
12	0	0	0	0	0	0	0	0	0	0	***2***	1	0	0	3
13	0	0	0	0	0	0	0	0	0	0	0	***0***	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	***1***	0	1
cryst.	0	0	0	0	1	0	0	0	0	0	0	0	0	***3***	4
Total	3	18	26	20	22	15	8	7	9	2	2	1	1	8	142

Agreement = 87%.

Appendix II (cont.).

Inter-reader comparison for Bay of Fundy cod otoliths (1986)

	current											
former	2	3	4	5	6	7	8	9	10	11	12	cryst	Total
2	***5***	2	0	0	0	0	0	0	0	0	0	0	7
3	0	***46***	2	0	0	0	0	0	0	0	0	0	48
4	0	2	***36***	0	0	0	0	0	0	0	0	0	38
5	0	0	4	***19***	0	0	0	0	0	0	0	0	23
6	0	0	0	2	***25***	2	0	0	0	0	0	0	29
7	0	0	0	0	1	***2***	0	0	0	0	0	0	3
8	0	0	0	0	0	1	***4***	0	0	0	0	0	5
9	0	0	0	0	0	1	0	***2***	0	0	0	1	4
10	0	0	0	0	0	0	0	0	***1***	0	0	0	1
11	0	0	0	0	0	0	0	0	0	***0***	0	1	1
12	0	0	0	0	0	0	0	0	0	0	***1***	1	2
cryst	0	3	4	3	1	0	0	0	0	0	0	***5***	16
Total	5	53	46	24	27	6	4	2	1		1	8	177

Agreement = 90%.

Inter-reader comparison for Scotian Shelf cod otoliths (1986)

	current													
former	3	4	5	6	7	8	9	10	11	12	13	14	15	cryst	Total
3	***5***	1	0	0	0	0	0	0	0	0	0	0	0	0	6
4	0	***18***	0	0	0	0	0	0	0	0	0	0	0	0	18
5	0	0	***15***	0	0	0	0	0	0	0	0	0	0	0	15
6	0	0	1	***35***	2	0	0	0	0	0	0	0	0	0	38
7	0	0	1	5	***22***	0	0	0	0	0	0	0	0	1	29
8	0	0	0	0	1	***14***	0	0	0	0	0	0	0	0	15
9	0	0	0	0	0	1	***20***	1	0	0	0	0	0	1	23
10	0	0	0	0	0	0	0	***8***	0	0	0	0	0	1	9
11	0	0	0	0	0	0	0	0	***4***	0	0	0	0	4	8
12	0	0	0	0	0	0	0	0	0	***6***	1	0	0	2	9
13	0	0	0	0	0	0	0	0	0	2	***3***	1	0	0	6
14	0	0	0	0	0	0	0	0	0	0	0	***1***	0	0	1
15	0	0	0	0	0	0	0	0	0	0	0	0	***4***	0	4
cryst.	4	1	3	2	1	2	1	0	1	0	0	0	0	***10***	25
Total	9	20	20	42	26	17	21	9	5	8	4	2	4	19	206

Agreement = 93%.

Appendix III. VPA for cod on the Scotian Shelf in 4X.

Due to the paucity of commercial sampling from the Bay of Fundy prior to 1980, it is not feasible to reliably reconstruct the catch at age for cod in this area for many years. Since catch at age, and length at age differ between the Scotian Shelf and the Bay of Fundy, catch at age for the Scotian Shelf cannot be used to represent the proportional catch at age for the Bay of Fundy. Thus, the catch at age for 4X cod cannot be reliably reconstructed. However, sampling on the Scotian Shelf, although much reduced in comparison with recent years, was sufficient in most years during the 1970's to provide a reasonable reconstruction of catch at age for this area.

The consistent differences in length at age between cod in the Bay of Fundy and those on the Scotian Shelf in 4X suggest there is little mixing of fish from these areas. Tagging studies indicate that fish tagged in the Bay of Fundy and those tagged inshore on the Scotian Shelf generally remain within these broad geographic areas. However, fish tagged on Browns Bank during the spring spawning period are recaptured throughout the 4X area, suggesting that there is some degree of mixing among fish from the two regions.

Length at age of fish taken from commercial samples in 4Xp generally show that fish caught on Browns Bank are similar in growth to the Scotian Shelf, while those taken in deep water to the west of Browns Bank are similar to Bay of Fundy cod in growth. Age length keys for individual samples tended to resemble those for either the Bay of Fundy or the Scotian Shelf, rather than a blend of the two. Although it does appear that there is some mixing of cod between the Bay of Fundy and the Scotian Shelf, there is clearly some rationale for assuming they are generally separate. On this basis, preliminary population analyses have been conducted separately for these two areas.

Diagnostics and partial results of a VPA for cod on the Scotian Shelf in 4X are presented here to provide a longer perspective on the stock/recruitment relationship for cod in this area.

Catch at age was input for full year from 1971-1979, and by quarter year from 1980.0 to 1997.25. Catches from the Scotian Shelf only (4Xmnop) were included. Two separate indices were used: survey indices for RV Alfred Needler from 1983 to 1997, and for the A T Cameron and Lady Hammond from 1971 to 1982. The LH was used as the survey vessel in1982, and was grouped with the ATC because comparative survey studies showed no difference between these vessels, but indicated the need for a conversion factor between the LH and the AN.

Using these as separate indices obviated the need for deriving a vessel conversion factor. Aside from these differences, the model formulation was the same as that used for the 4X cod assessment.

Appendix III (cont.).

Statistical properties of estimates for population abundance and survey calibration constants for cod on the Scotian Shelf in Division 4X.

Survey calibration constants.

	Age	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
Needler	2	0.097	0.019	0.194	0.001	0.01
	3	0.198	0.036	0.18	0.002	0.008
	4	0.23	0.041	0.179	0.002	0.008
	5	0.243	0.044	0.181	0.002	0.008
	6	0.259	0.048	0.186	0.002	0.007
	7	0.29	0.058	0.199	0.004	0.012
	8	0.242	0.064	0.264	0.007	0.028
	9	0.233	0.06	0.259	0.008	0.033
Cameron and Hammond	2	0.057	0.011	0.192	0.001	0.018
	3	0.134	0.026	0.192	0.002	0.018
	4	0.168	0.032	0.192	0.003	0.018
	5	0.25	0.048	0.192	0.005	0.018
	6	0.253	0.049	0.192	0.005	0.018
	7	0.201	0.039	0.192	0.004	0.018
	8	0.181	0.036	0.2	0.004	0.02
	9	0.267	0.063	0.235	0.007	0.027

Terminal year class abundance

Age	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
1	8000	0	0	0	0
2	4103	2841	0.69	1019	0.25
3	2945	1463	0.5	383	0.13
4	3761	1671	0.44	372	0.1
5	5194	2244	0.43	459	0.09
6	717	340	0.47	74	0.1
7	560	247	0.44	52	0.09
8	406	164	0.4	34	0.08
9	39	34	0.86	10	0.25
10	68	36	0.53	8	0.12
11	78	40	0.52	9	0.12
12	123	61	0.5	12	0.1

Note that catchability is generally higher for the Needler than for the Cameron/Hammond. This is the reverse of what was determined through analysis of comparative survey results (Fanning, 1985). The proportional difference between the two also varies with age; highest at younger ages, and dropping to a minimum for ages 5 and 6. This suggests that a single conversion factor for all ages may be inappropriate.

The residual plots for the Needler survey present no anomalous patterns, and indicate residuals are generally small in magnitude (Fig. III.1). For the

Cameron/Hammond surveys, residuals are more variable and larger in magnitude and contain some strong patterns (Fig. III.2). The 1969 year-class (age 2 in 1971) is characterized by a large positive residual at all ages. Also, there appears to be a time trend in the residuals for younger ages. These patterns, and the influence they exert on the VPA results, warrant further investigation.

Recruitment patterns for the Scotian Shelf are generally similar to those for 4X as a whole, however, there are years where recruitment to 4X increased while a decrease was seen for the Scotian Shelf (Fig III.3). Also, recruitment to the Scotian Shelf varies in proportion to 4X as a whole; in some years Scotian Shelf recruitment is only slightly lower than recruitment in 4X, while in other years it is roughly half of the 4X level.

Trends in the q-adjusted indices from the Needler surveys are generally similar to the population trends estimated from the VPA (Fig. III.4). The same cannot, however, be said for the Cameron/Hammond indices. The survey shows a generally declining trend through the 70's, while the estimated population size increased. It has been suggested in past assessments for this stock that misreporting of landings to 4X from adjacent NAFO Divisions may have been a problem in the late 1970's and early 1980's, before a quota was established for this region. Thus, it is possible that the trend indicated in the surveys may be more representative of population trends than the VPA results. Further investigations of alternative indices may help to resolve this discrepancy.

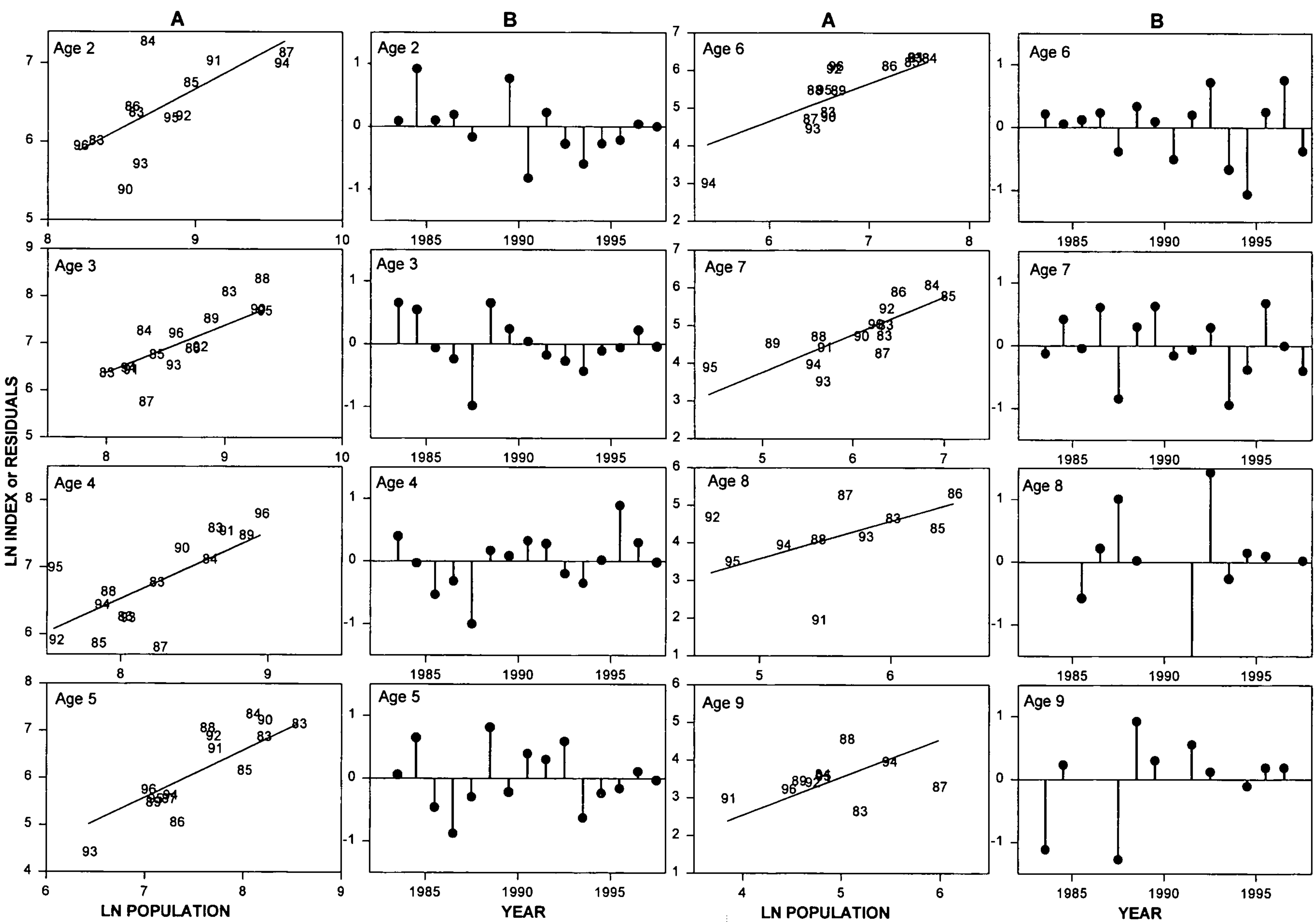


Fig. III.1. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for cod on the Scotian Shelf in Division 4X; R.V Alfred Needler.

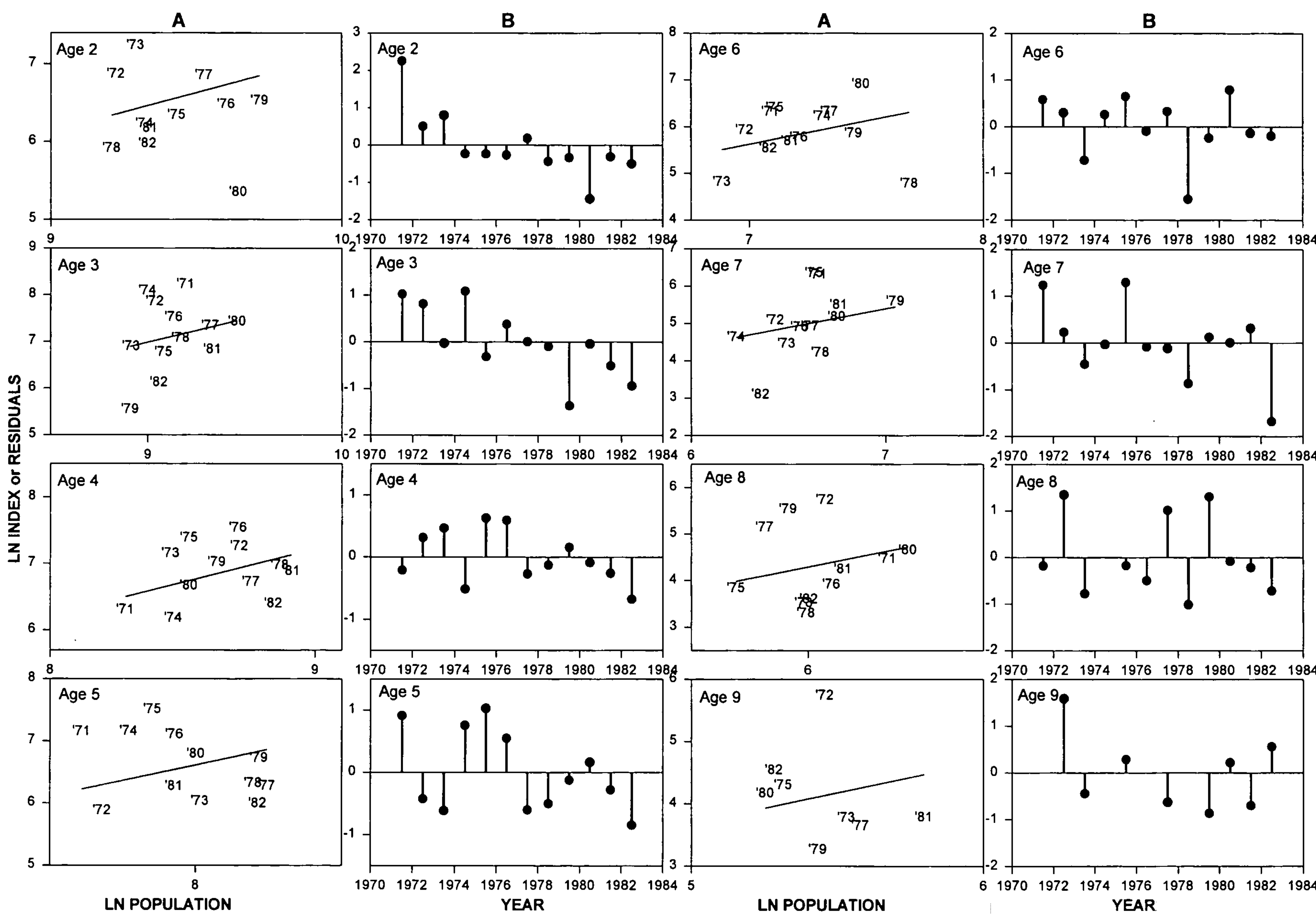


Fig. III.2. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for cod on the Scotian Shelf in Division 4X; R.V A. T. Cameron and Lady Hammond.

Appendix III (cont.)

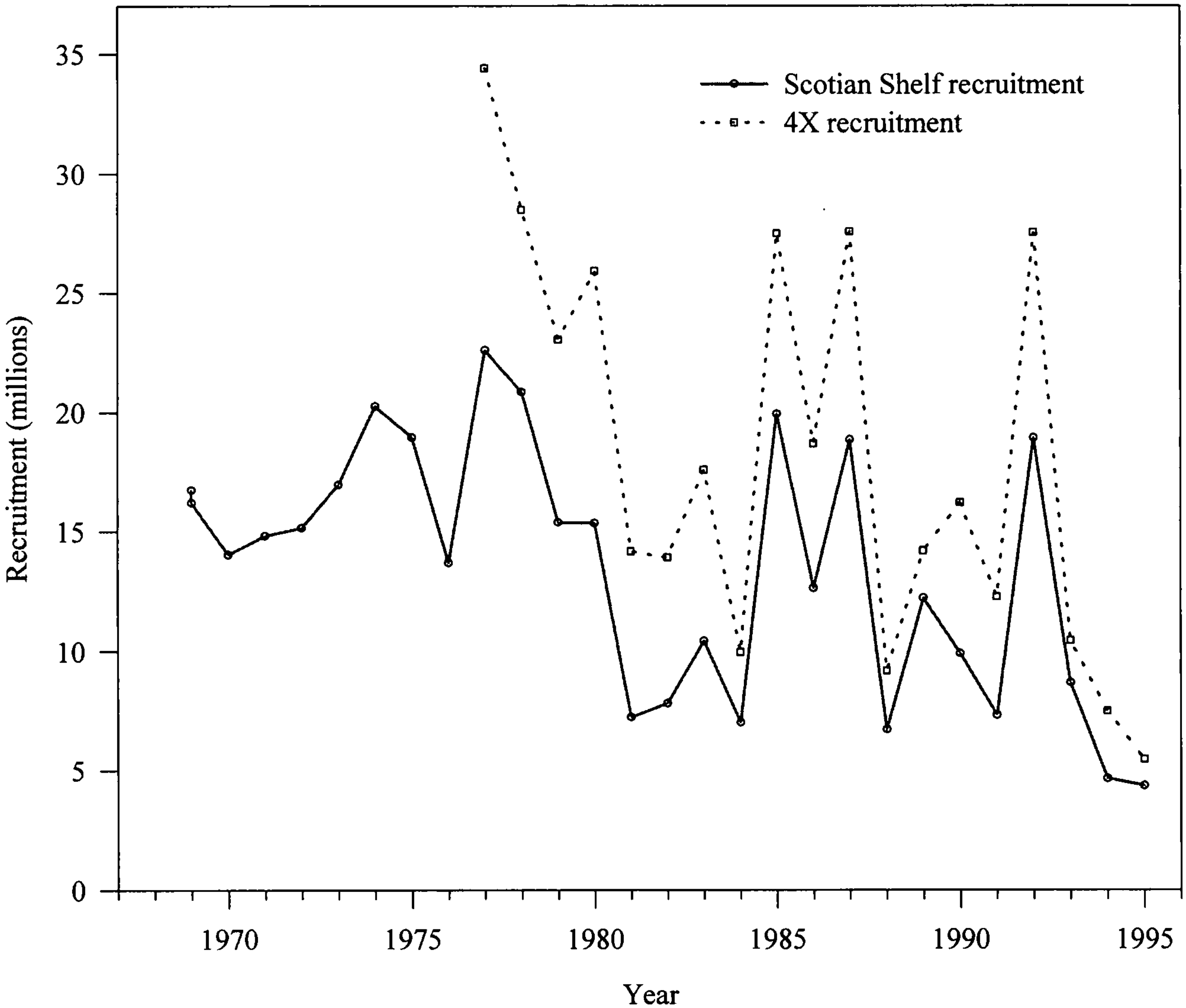


Fig. III.3. Recruitment series for cod in 4X and on the Scotian Shelf (4Xmnop).

Appendix III (cont.).

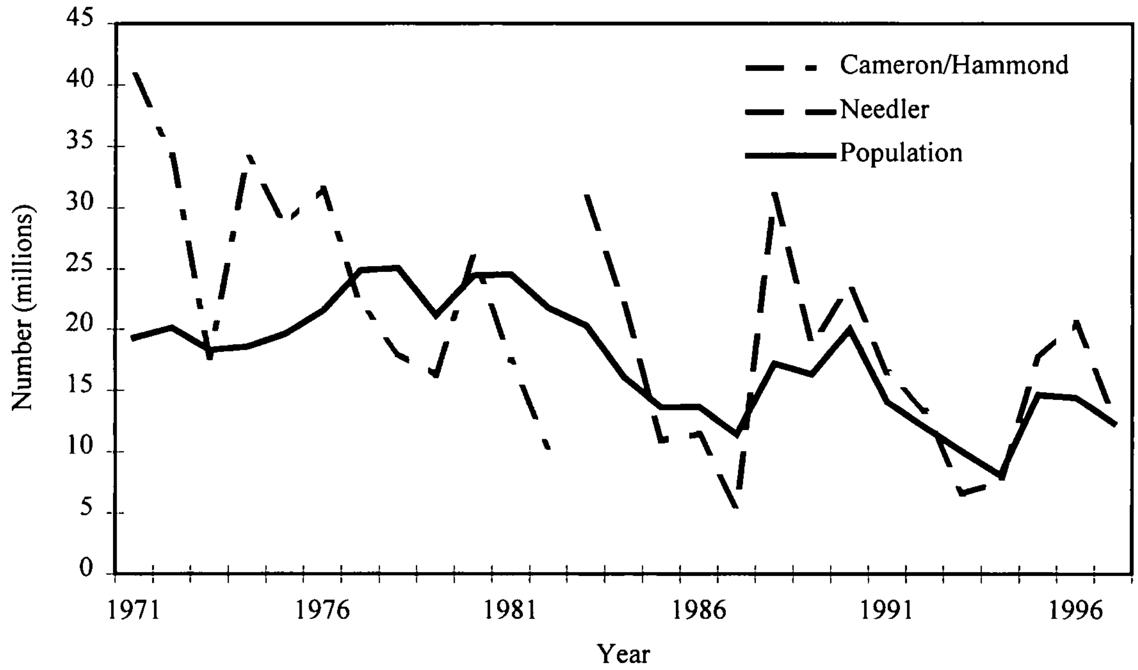


Fig. III.4. Comparison of q-adjusted survey indices and mid-year population (ages 3-10) for 4X cod on the Scotian Shelf.