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# Update of the Status of 4Vn Cod: 1996

by

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## ABSTRACT

The 4Vn cod fishery has been closed since September 1993. Nevertheless the stock shows little sign of recovery, largely due to lack of recruitment. About 46 tonnes of cod were taken commercially as bycatch in redfish and flatfish fisheries. The stock is monitored by annual DFO groundfish trawl surveys in July and for 1994-95 in September by an extension into 4Vn of the regular 4T groundfish survey. In addition, a "sentinel survey" employing commercial longliners, inaugurated in September 1994, conducted two more surveys in 1995 and again in 1996. All of these surveys gave a similar picture of the stock status. Until there is substantial recruitment, there are no prospects for a reopening this fishery.



## RÉSUMÉ

La pêche de la morue est interdite dans 4Vn depuis septembre 1993. Malgré cela, le stock montre peu de signe de rétablissement, en grande partie à cause d'une absence de recrutement. Environ 46 t de prises accessoires ont été capturées dans le cadre de la pêche commerciale du sébaste et du poisson plat. Le MPO contrôle le stock en menant chaque année, en juillet, un relevé du poisson de fond au chalut qui, en 1994-1995, a eu lieu en septembre dans le cadre du relevé régulier du poisson de fond de 4T, qui a été étendu à 4Vn. En outre, des palangriers commerciaux ont effectué, dans le cadre des pêches sentinelles mises en oeuvre en septembre 1994, deux autres relevés, l'un en 1995 et l'autre en 1996. Tous les relevés brossent le même tableau de l'état du stock. On ne prévoit pas rouvrir la pêche de la morue de 4Vn tant qu'il n'y aura pas d'augmentation importante du recrutement.

## INTRODUCTION

Cod landings in NAFO Subdivision 4Vn have declined since 1985 until the closure in 1993 (see Figure 1). Throughout most of the 80's, catch quotas restrained the fishery, but after 1990 the catch was substantially less than the TAC. In September 1993 the cod fishery was closed and this moratorium is still in effect. In the few years prior to the closure, vessels using mobile gear generally managed to maintain a catch close to their allocation, whereas the longline fleet fared less well. Mixing of Gulf of St. Lawrence (4T) cod with the resident stock and the inability to accurately apportion landings according to stock has complicated the assessment and management of 4Vn cod.

4T cod overwinter along the shelf edge from Sydney Bight as far as Banquereau Bank region, migrating out of the Gulf in the late autumn and returning in the spring. During this period the catch of cod in 4Vn comprised both Gulf and resident cod, although the 4T cod made up the bulk, being a much larger stock. Thus, unknown quantities of 4Vn cod were being caught during the overwintering period. Furthermore, the dragger fleet which had traditionally caught most of its catch between May and October began to transfer its activities toward the latter part of the year to exploit migrant cod. The effect was to maintain the overall catch for 4Vn even as the abundance of resident fish fell. Information on the overwintering migration of Gulf of St. Lawrence (4T) cod into the Sydney Bight area was reviewed in the spring of 1994 (Campana et al. 1995). From patterns of commercial fleet movements and results of tagging studies it was clear that many 4T cod had departed the Gulf by mid November and probably all by December. Therefore it was decided that effective 1994 that the 4Vn management unit definition be shortened from May to December to May to October, inclusive.

With the closure of the fishery, information on the status of the stock is now largely limited to two sources; the DFO July groundfish survey and a "Sentinel" survey operated by commercial longliners in July and September. Additional data are to be found from port sampling of commercial bycatch and a limited DFO inshore survey of the western half of Sydney Bight.

We present an analytical assessment for the first time since the late 1980s. While the degree of separation the of 4Vn cod from its neighbours to the northeast (4T) and to the south (4VsW) is still a topic of research, the analysis was performed for two reasons. The first is the conservation principle, if to some degree 4Vn is a self-sustaining population, it is more precautionary to treat it as a separate entity and not merge it with larger neighbouring stocks. The second is scientific, the analysis of the cod stocks from say 4W to eastern 4T as a complex will require preliminary population analysis of the constituent, interacting units. In an effort to focus more closely on the resident stock, the catch at age matrix has been recalculated to May-October period for 1982 - 1994. This action assumes that the migration timing has not changed significantly over the period of analysis.

## DATA

### *COMMERCIAL CATCH*

For the last three years, on the order of 50 tonnes of cod were taken annually as bycatch in 4Vn between May 1 and October 31 (Table 1 landings by gear type back to 1970, Figure 1) The bulk of this bycatch was caught along with redfish and flatfish.

The catch at age data for 1982 - 1993 inclusive were recompiled using a May- October data window. The standard software and historic age-length keys were applied to catch data from the shortened window. The recompiled catch data have been broken into $10^{th}$, $25^{th}$, $50^{th}$ (median), $75^{th}$ and $90^{th}$ percentiles in terms of age and weight in Figures 2 and 3. The age distributions show a compression to fewer ages in the early 1990s, consistent with a lack of any strong recruitment recently. The weight distributions (Figure 3) show a decrease in all the percentiles, and especially the largest fish (90th percentile), from 1982 to the early 1990s reflecting. A step is seen in 1993 in all weight classes which corresponds with the closure of the fishery in 1993.

### *JULY GROUNDFISH SURVEY*

The July survey for 4Vn is more variable than other stocks due to low numbers of sets and also no doubt due to high natural variability. Although the greatest mixing of stocks in 4Vn occurs in the winter, there appears to be a degree of mixing of cod stocks in this area during all months of the year. Although the index was slightly higher in 1995 and 1996 than in 1994, it is still at a very low level, less than 40 per tow, Figure 4 and Table 2. Although at a low level, more 1 and 2 year old fish were seen in 1996 than in recent years. Less than 1 cod per tow was taken in the deepest stratum (>183 m); about 74 per tow in the mid-depth stratum (91 to 183 m) and about 19 per tow in the shallow stratum (<91 m). Most of the catch was taken in two sets, 156 and 161 fish.. The 1991, 1992 and 1993 year classes made up the bulk of the catch with 4 year-olds being slightly more abundant than adjacent year-classes. This stock continues to suffer from low levels of recruitment; the last good year-class seen in this survey is 1987.

Figure 5a, b presents the survey indices plotted as proportions within a year. This normalisation was done to remove the year effect from the survey data. The diagonal nature of Figure 5a shows the cohort tracking. For comparison, the survey data for 4VsW cod is shown in Figure 5b. Furthermore, a correlation analysis of the survey data was performed to investigate cohort coherence. The survey index at age was regressed against the next older age in the same year (Lag 0 in the following table), lagged by one year (along cohorts) and lagged two years. Summer research survey data were used from 4Vn, 4T and 4VsW cod. The data are both unnormalised (Raw) and normalised(Norm.) to proportions within a year

| | 4Vn | | 4VsW | | .4T | |
|---|---|---|---|---|---|---|
| | Raw | Norm. | Raw | Norm | Raw | Norm |
| Lag 0 | .521 | .237 | .495 | .220 | .537 | .203 |
| Lag 1 | .095 | .243 | .375 | .203 | .586 | .541 |
| Lag 2 | .004 | .029 | .203 | .023 | .280 | .173 |

This analysis shows that there is very little cohort (lag 1) information in the raw 4Vn data compared to 4VsW or 4T. However, after removing year effects by normalising the cohorts are about a clear in 4Vn as 4VsW but less so than in 4T.

Total mortalities (Z) were also estimated directly from the July survey. The logs of the ratios of adjacent ages down a year class were smoothed after zeros were removed. The smoothing is a three year running average (Figure 6). The results show an increase in Z since the late 70s, which appears to continue even after the closure of the fishery in 1993. Again 4VsW cod results are shown for comparison.

Figures 7 and 8 are condition factors (weight at fixed length) from the summer RV series. The condition is based on all aged fish in the 30-34 and 60-64 cm size categories. In Figure 8 the condition factors are normalised to the long term mean which emphasises the similarity in the trends although the smaller fish are not of legal size and should not have been influenced by fishing mortality.

*INSHORE SURVEY*

A two-part inshore survey was begun in Sydney Bight in 1991; an ichthyoplankton component was abandoned early in 1992 due to reduction of funding but a bottom trawl program has continued at a reduced level until present. The trawl survey has consistently found 0-group and 1 year-old cod in the Bird Island area. These fish are present in the area from at least May to October after which time they disappear and presumably move to deeper water to overwinter. The 4Vn inshore survey is an important adjunct to the July groundfish survey as it provides additional information on smaller fish. The latter does not provide good evidence of the presence of young cod because it does not sample the shallow water area favoured by these juveniles. After a slight rise in 1993 and 1994, the numbers of one year-old cod (average length 12 cm) increased dramatically in 1996. One year-old cod were abundant from the Bird Islands region at least as far north as Cape Smokey at which point the survey was terminated due to boat engine problems. The relative abundance of year-classes as seen by the inshore survey agrees reasonably well with their subsequent relative abundance as seen in the July RV survey as 2 and 3 year-olds (Figure 9). It will be interesting to compare how well this apparently good 1995 year-class is seen by subsequent July surveys.

*SENTINEL SURVEY*

Recently, the sentinel surveys form an adjunct to DFO groundfish surveys that have been carried out in this area during the past two decades. The 4Vn sentinel survey is conducted during the summer and again in the autumn by commercial longliners following a random design, stratified by depth, similar to that used by the July groundfish survey. Five surveys have now been completed; September 1994, and July and September of 1995 and 1996. The area surveyed by the sentinel survey was the same as the DFO survey with the exception of there being no sets deeper than 100 fathoms and the stratification schemes being slightly different. The July survey uses three strata: <50 fath., 50 - 100 fath., and >100 fath. The sentinel survey also employs three strata; however, the deep stratum was dropped, the mid-depth was retained and the shallow stratum was divided in two. Hence the sentinel strata are; <30 fath., 30 to 50 fath. and 51 to 100 fath. The geographic distribution of cod caught in fall 1996 was similar to that seen previously by earlier surveys (Figure 10). The highest concentrations were found in deeper water in the 'Gutter' and western slope of Smokey Bank. As was seen in 1995, a strong seasonal effect on catch rates was evident in 1996, July catches being roughly 1/5 those of September (Figure 11). Longline fishermen report that July catch rates historically have been lower than in other times of the year. Nevertheless, catch rates of both July and September surveys indicate a decreasing trend. The September catch rate has fallen about 30% from 110.22 kg per 1,000 hooks in 1994 to 76.25 kg per 1,000 hooks in 1996. The areal coverage of the sentinel survey is much greater than that of the RV survey so it is not possible to make a good comparison of surveys; however, in July 1996 in areas where sampling coincided, the relative abundance of cod were comparable. Length frequencies in the July sentinel survey (Figure 12) were significantly larger than those in the July RV; this is probably due to gear selectivity. The research trawl is fitted with a small mesh liner so is capable of capturing very small cod; whereas, the size of hook used in the commercial longline fishery take few small fish. Fishermen indicate that cod <35 cm (14 in) are rarely taken with #12 hooks which are used for the survey.

Figure 13 shows the maturity ogive for 4Vn cod. The data are from all years (1994-96) of the Sentinel Survey and represents a sample size of more than 5,000 fish.

Although cod dominates the catch in July and September, dogfish, plaice and skate are also prevalent in both months. Dogfish were very abundant in July being second only to cod, with plaice and thorny skate ranking third and fourth, respectively. The numbers of dogfish drop markedly by September, whereas plaice and thorny skate increase. This pattern was very similar to that of 1995.

**ANALYSIS**

A standard age-based population analysis (SPA) was used to estimate the current status of the stock. This analysis assumes that the stock is closed. As 4Vn is a known area of stock mixing, the degree to which the 4Vn contains fish from other stocks will bias the results. To minimise this effect, the catch at age was reconstructed to the May to October period for the years 1982 - 1996 (Table 3).

*Estimation of parameters*

The age-based sequential population analysis was performed for this stock using ACON software to fit the model which is described as:

Parameters:

Terminal F estimates -- $F_{i,1996}$, i=5 to 9

Calibration coefficients -- $q_i$, i=4 to 10 for July RV survey

Structure Imposed:

Error in catch assumed negligible
Partial recruitment fixed for ages 1-4 and 9+ in year 96.
F on oldest age (15) set to 76% of the average F ages 5-9
No intercept was fitted
M=0.2 for all ages

Input:

$C_{i,t}$, i=1 to 15; t=1982 to 1996 - May-Oct catch at age
$J_{i,t}$, i=4 to 10; t=1982 to 1996 - July RV index

Objective function:

Minimise: $\Sigma\,\Sigma\,\{\ln J_{i,t} - \ln (q_i N_{i,t})\}^2$

Summary:

Number of observations: 98 from July RV
Number of parameters: 13, F's estimated by NLLS, q's algebraically

**RESULTS**

*SPA*

The diagnostic statistics from the SPA are given in Table 4. The coefficient of variation on the terminal F ranges from 44 to 65% with the youngest age having the largest CV. The bias estimates for $F_{1996}$ are small and range from -4 to 1.5% . The q's have small (<3%) biases Because the biases are small, and the stock status is clear, the estimates of stock status were not bias corrected. The residuals from the NLLS (Table 4b) instead of being random show a tendency to have columns all of one sign which is consistent with a 'year effect' in the RV data. There is also a tendency for the early years to have negative residuals which suggests there may be a retrospective problem. Because of the short data series a retrospective analysis was not performed.

The SPA results are given in (Tables 5-7, (Figures 6,14,15). Figure 14 shows the biomass from SPA (line) and q-scaled RV estimates (dots). All three ranges of biomass (, 1+, 5+ and fishable) are extremely low, near the level at which the fishery was closed. Figure 6 indicates that the average F(solid line) has increased until the fishery was closed and was well above $F_{0.1}$ (= 0.2) or at times even twice $F_{0.1}$. The 1987 yearclass is the strongest in recent years, but other recent yearclasses are well below the geometric mean (3.9 million since 1982 or 2.1 million since 1987).

The stock recruit relationship (Figure 15) displays a trend towards the origin. An arbitrary line is shown at a biomass of 10,000 t to demark a region beneath which good recruitment has not been seen. The 5+ biomass estimates for are shown on the x-axis of Figure 15.

*Applying SPA to tagging studies.*

Many tagging studies have been conducted on the cod stocks in Atlantic Canada (W. Stobo MFD/DFO, pers. comm.). If the sizes of the 4T, 4Vn, and 4Vs populations were known, the density of tags could be estimated. Then in turn, weights could be determined to scale the returns so that they would be proportional to their respective populations. The analysis was constrained to tags returns since 1975 and to those fish at large for more than 30 days. This represents 1628 returns the last of which was in 1988. As the 4Vn assessment starts in 1982 this defined a data window of 1982-88. A preliminary attempt at this weighting is shown in the following table. The number of releases is from the tagging data base. The population sizes are numbers of 1+ in 4Vn and 4Vs and 3+ for 4T from the reported SPAs (Fanning et al. 1996, Sinclair et al. 1996). The 4VsW cod resource was partitioned into a 4Vs component by finding proportion therein from the average research survey abundance for the period 1982-88; 55%. The tag density in 4Vn is seen to be about twice as great as 4Vs and 5 times as great as 4T

| | 4Vs | 4T | 4Vn |
|---|---|---|---|
| Releases | 8750 | 12427 | 5775 |
| Ave. Pop. size 1982-88 ($10^6$) | 127 | 434 | 41.9 |
| tag/pop | .0684 | .0287 | .138 |
| Weighting factor | 2.02 | 4.81 | 1 |
| Returns (Nov. - Apr.) | 296 | 393 | 178 |
| Weighted returns (%) in 4Vn | 1.4 | 91.1 | 7.5 |

From this preliminary analysis it is seen that the winter fishery is dominated by 4T fish. Figure 16 shows the weighted returns for both the 'summer' (May - Oct.) and 'winter' (Nov. - Apr.) periods for 4Vn and 4Vs.

*Illustration of Risk Analysis*

Figure 17 shows the history of the SPA estimated population in terms of 5+ biomass and fishing mortality. One hunkered bootstrap replicates were performed on the residuals of the assessment SPA. The location of the mean for each point is marked by the year. In more recent years an ellipse is shown whose axes are a single standard deviation of the F and the biomass to approximate the uncertainty in the estimation. Although the axes are shown orthogonally, it is known that the F and biomass covary and that the axes should be tilted. The figure shows the results of 1,000 bootstrap stock projections for 1997 and 1999 as irregular shapes. These shapes are the edge of area inside which 75% of the projections fell. The projections assume a recruitment of 2 million cod per year and annual removals of 500 t. The 500 t harvest level is for illustration only and does not indicate any endorsement or scientific basis for such a harvest.

Figure 18 focuses on the 1,000 bootstrap stock projections to 1997 and 1999 which are re-plotted from Figure 17 but at higher resolution. Standard cumulative distributions of biomass and F for risk analysis are presented on the margins of the phase plot of the distribution.

## CONCLUSIONS

The future of this stock remains bleak; only the inshore survey index (age 1 )shows any indication of an improvement. The potential contribution of these small, less than 15 cm, fish to future recruitment has not been established. Although the fishery has been closed since September, 1993, mortality rates estimated from the research survey are still quite high. Until there is substantial recruitment to the reproductive stock there is no biological basis for reopening the fishery. Because 4Vn is an area of stock mixing, recovery may be influenced by migration to or from neighbouring stocks.

## REFERENCES

Campana, S. (editor), P. Fanning, M. Fowler., K. Frank, R. Halliday, T. Lambert, R. Mohn, S. Wilson and W. Stobo. Report of the 4Vn cod Working Group on the scientific value of a 4Vn cod (May-Oct) stock assessment. DFO Atl. Fish. Res. Doc. 95/16. 110p.

Fanning, L. P., R. K. Mohn and W. J. MacEachern. 1996. Assessment of 4VsW cod in 1995 with consideration of ecological indicators of stock status. DFO Atl. Fish. Res. Doc. 96/27. 34p.

Sinclair, A., G. Chouinard and L. Currie. 1996. Assessment of southern Gulf of St. Lawrence cod stock, March 1996. DFO Atl. Fish. Res. Doc. 96/52. 75p

Table 1. Nominal landings for 4Vn cod (May-November)

| Year | OT | Seine | Longline | Handline | MIsc. | Total | TAC |
|---|---|---|---|---|---|---|---|
| 1970 | 4859 | 83 | 3229 | 495 | 1222 | 9888 | |
| 1971 | 5308 | 109 | 3728 | 696 | 790 | 10631 | |
| 1972 | 4418 | 121 | 3185 | 286 | 1094 | 9104 | |
| 1973 | 2099 | 143 | 1982 | 404 | 1120 | 5748 | |
| 1974 | 2842 | 138 | 1469 | 568 | 967 | 5984 | 10000 |
| 1975 | 1851 | 100 | 875 | 360 | 812 | 3998 | 10000 |
| 1976 | 4375 | 83 | 620 | 310 | 569 | 5957 | 10000 |
| 1977 | 4613 | 554 | 1805 | 595 | 354 | 7921 | 3500 |
| 1978 | 1600 | 326 | 3035 | 466 | 122 | 5549 | 3500 |
| 1979 | 624 | 278 | 4483 | 640 | 349 | 6374 | 3400 |
| 1980 | 1150 | 561 | 6440 | 1820 | 219 | 10190 | 5000 |
| 1981 | 1488 | 557 | 9801 | 741 | 61 | 12648 | 10000 |
| 1982 | 2785 | 724 | 7287 | 1360 | 177 | 12333 | 14000 |
| 1983 | 2448 | 863 | 5101 | 924 | 26 | 9362 | 14000 |
| 1984 | 3344 | 1112 | 4831 | 1112 | 45 | 10444 | 14000 |
| 1985 | 5081 | 1162 | 4823 | 1408 | 20 | 12494 | 12000 |
| 1986 | 3552 | 1258 | 5764 | 1182 | 15 | 11771 | 12000 |
| 1987 | 2034 | 1285 | 6369 | 848 | 16 | 10552 | 9000 |
| 1988 | 1377 | 1109 | 5858 | 626 | 31 | 9001 | 7500 |
| 1989 | 2129 | 851 | 3610 | 718 | 157 | 7465 | 7500 |
| 1990 | 2029 | 593 | 1889 | 591 | 8 | 5110 | 7500 |
| 1991 | 2213 | 694 | 1249 | 389 | 49 | 4602 | 10000 |
| 1992 | 2629 | 468 | 1043 | 232 | 88 | 4461 | 10000 |
| 1993 | 138** | 60 | 406 | 77 | 21 | 702 | 1800 |
| 1994* | 26** | 16 | 4 | 8 | <1 | 54 | |
| 1995* | 15** | 16 | 8 | <1 | <1 | 40 | |
| 1996* | 20** | 16 | 8 | <1 | <1 | 46 | |

*Redefinition of assessment period: Summed over six months (May to October)
**Preliminary statistics.

Table 2. Research survey numbers (thousands) per standard tow and total over ages 1 to 12

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 |
| 2 | 6.4 | 1.2 | 0.5 | 0.0 | 0.0 | 0.6 | 6.5 | 0.3 | 0.7 | 1.3 | 1.9 | 4.4 | 2.5 |
| 3 | 1.8 | 42.4 | 0.3 | 2.6 | 0.6 | 6.4 | 2.3 | 6.3 | 9.1 | 0.8 | 10.5 | 16.9 | 1.7 |
| 4 | 4.8 | 10.1 | 2.4 | 4.5 | 1.4 | 8.6 | 1.5 | 4.0 | 19.3 | 5.2 | 4.0 | 36.5 | 5.8 |
| 5 | 10.9 | 26.5 | 0.3 | 18.6 | 2.8 | 4.7 | 1.9 | 2.7 | 5.5 | 2.5 | 23.6 | 12.0 | 10.2 |
| 6 | 10.5 | 16.2 | 1.6 | 0.7 | 3.2 | 0.8 | 1.6 | 1.9 | 4.4 | 0.6 | 16.4 | 25.5 | 7.6 |
| 7 | 4.5 | 10.7 | 1.5 | 3.1 | 0.4 | 1.0 | 0.7 | 0.7 | 1.5 | 1.7 | 5.2 | 11.5 | 9.3 |
| 8 | 2.6 | 3.6 | 0.4 | 2.9 | 0.5 | 0.6 | 1.8 | 0.2 | 1.2 | 0.6 | 1.2 | 1.3 | 3.4 |
| 9 | 0.8 | 2.0 | 0.3 | 0.5 | 0.3 | 0.2 | 1.7 | 0.2 | 0.4 | 0.3 | 0.5 | 0.9 | 1.3 |
| 10 | 0.0 | 0.5 | 0.3 | 0.2 | 0.2 | 0.3 | 1.4 | 0.1 | 0.4 | 0.2 | 0.4 | 0.9 | 0.5 |
| 11 | 0.3 | 0.0 | 0.2 | 0.0 | 0.1 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.4 | 0.2 | 0.1 |
| 12 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 | 0.0 | 0.2 | 0.0 | 0.2 | 0.2 |
| 1-12 | 42.6 | 113.1 | 7.6 | 33.1 | 9.5 | 23.3 | 19.8 | 16.9 | 42.6 | 13.2 | 63.9 | 110.5 | 42.6 |

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 2.8 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 |
| 2 | 4.4 | 7.3 | 0.5 | 1.3 | 0.2 | 0.6 | 4.6 | 0.2 | 1.0 | 0.7 | 0.4 | 0.1 | 1.1 | 1.7 |
| 3 | 22.1 | 10.0 | 3.8 | 6.4 | 3.7 | 2.5 | 4.4 | 15.1 | 0.1 | 3.4 | 3.2 | 1.6 | 4.5 | 4.0 |
| 4 | 7.9 | 10.5 | 19.1 | 11.1 | 4.1 | 17.1 | 11.6 | 9.0 | 11.1 | 5.1 | 6.2 | 3.9 | 7.9 | 7.8 |
| 5 | 10.6 | 13.5 | 126.0 | 8.1 | 5.1 | 13.2 | 29.8 | 3.3 | 5.3 | 44.4 | 5.7 | 7.2 | 7.9 | 5.4 |
| 6 | 10.0 | 8.8 | 52.1 | 17.6 | 8.9 | 31.9 | 17.6 | 3.9 | 3.2 | 15.2 | 14.7 | 1.7 | 6.2 | 2.8 |
| 7 | 1.7 | 3.6 | 22.4 | 6.4 | 6.6 | 26.5 | 32.1 | 2.1 | 0.7 | 4.9 | 7.4 | 7.3 | 2.9 | 3.5 |
| 8 | 3.4 | 1.8 | 7.3 | 4.9 | 2.8 | 18.9 | 25.5 | 2.3 | 0.7 | 3.7 | 1.7 | 1.9 | 3.6 | 1.9 |
| 9 | 1.5 | 1.6 | 1.4 | 2.2 | 1.2 | 6.2 | 8.3 | 0.7 | 0.1 | 1.3 | 0.5 | 0.1 | 0.9 | 1.5 |
| 10 | 0.7 | 0.9 | 0.8 | 1.0 | 0.6 | 1.7 | 1.3 | 0.8 | 0.3 | 0.8 | 0.1 | 0.3 | 0.1 | 0.9 |
| 11 | 0.3 | 0.3 | 0.7 | 0.6 | 1.0 | 0.5 | 0.3 | 0.1 | 0.3 | 0.2 | 0.1 | 0.0 | 0.1 | 0.1 |
| 12 | 0.0 | 0.4 | 0.0 | 0.1 | 0.3 | 0.2 | 0.0 | 0.1 | 0.0 | 0.4 | 0.1 | 0.0 | 0.1 | 0.0 |
| 1-12 | 62.6 | 61.4 | 233.9 | 59.6 | 34.6 | 119.8 | 135.5 | 37.6 | 23.2 | 80.0 | 39.9 | 24.0 | 35.3 | 30.4 |

Table 3. Catch numbers (thousands) at age and total over ages 1 to 15

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 |
| 3 | 26.9 | 14.5 | 12.8 | 6.9 | 5.3 | 23.6 | 16.0 | 10.6 | 33.5 | 14.8 | 6.0 | 0.8 | 0.0 |
| 4 | 299.4 | 328.9 | 373.9 | 133.3 | 137.6 | 127.9 | 229.9 | 330.7 | 225.3 | 179.0 | 62.4 | 44.7 | 0.0 |
| 5 | 1057. | 729.5 | 922.1 | 1400. | 946.3 | 726.3 | 381.6 | 958.3 | 365.0 | 362.0 | 740.8 | 54.3 | 2.2 |
| 6 | 526.0 | 560.8 | 1308. | 1254. | 2194. | 1046. | 795.8 | 628.2 | 381.0 | 123.5 | 714.2 | 165.2 | 4.1 |
| 7 | 813.4 | 440.4 | 729.9 | 1418. | 850.3 | 1285. | 707.1 | 624.5 | 189.8 | 67.7 | 254.7 | 157.4 | 14.1 |
| 8 | 605.8 | 383.2 | 343.0 | 785.9 | 715.7 | 590.2 | 764.3 | 397.4 | 280.7 | 62.9 | 115.5 | 41.0 | 9.6 |
| 9 | 229.3 | 230.6 | 242.9 | 272.2 | 318.6 | 331.8 | 346.0 | 293.4 | 108.4 | 52.0 | 55.9 | 13.8 | 3.1 |
| 10 | 92.3 | 118.7 | 160.3 | 176.6 | 163.2 | 192.4 | 153.6 | 103.7 | 94.0 | 12.8 | 21.3 | 5.1 | 0.6 |
| 11 | 51.9 | 35.7 | 71.9 | 60.3 | 81.0 | 100.3 | 72.2 | 46.3 | 18.0 | 10.8 | 22.7 | 1.4 | 0.5 |
| 12 | 25.0 | 27.9 | 23.7 | 29.7 | 40.0 | 41.9 | 40.5 | 9.6 | 11.8 | 4.2 | 15.5 | 4.2 | 0.2 |
| 13 | 11.8 | 13.8 | 8.9 | 12.3 | 17.7 | 28.6 | 18.2 | 3.5 | 4.8 | 5.8 | 3.3 | 0.7 | 0.1 |
| 14 | 4.9 | 1.0 | 5.3 | 3.6 | 6.0 | 5.9 | 3.7 | 4.5 | 1.7 | 0.0 | 1.9 | 0.2 | 0.0 |
| 15 | 4.0 | 3.1 | 5.0 | 10.0 | 7.2 | 2.8 | 7.0 | 2.4 | 0.6 | 0.6 | 0.9 | 0.0 | 0.0 |
| 1-15 | 3748. | 2888. | 4207. | 5564. | 5483. | 4504. | 3536. | 3413. | 1714. | 896. | 2014. | 488. | 34. |

| | 1995 | 1996 |
|---|---|---|
| 1 | 0.0 | 0.0 |
| 2 | 0.0 | 0.0 |
| 3 | 0.0 | 0.0 |
| 4 | 0.1 | 0.8 |
| 5 | 0.7 | 1.6 |
| 6 | 5.3 | 2.9 |
| 7 | 7.8 | 6.2 |
| 8 | 7.5 | 4.4 |
| 9 | 2.3 | 6.0 |
| 10 | 0.6 | 0.6 |
| 11 | 0.0 | 0.5 |
| 12 | 0.0 | 0.1 |
| 13 | 0.0 | 0.1 |
| 14 | 0.0 | 0.0 |
| 15 | 0.0 | 0.0 |
| 1-15 | 24. | 23. |

Table 4. Summary statistics and residuals from SPA

4a Summary statistics

| Param | Est. | SE | CV | Bias(%) |
|---|---|---|---|---|
| F5 | 0.0021 | 0.00137 | 0.65 | -4.22 |
| F6 | 0.0055 | 0.00302 | 0.54 | -1.10 |
| F7 | 0.0087 | 0.00415 | 0.47 | 0.59 |
| F8 | 0.0124 | 0.00539 | 0.43 | 1.53 |
| F9 | 0.0091 | 0.00402 | 0.44 | -0.19 |
| q4 | 0.0033 | 0.00085 | 0.25 | 2.42 |
| q5 | 0.0056 | 0.00144 | 0.25 | 2.41 |
| q6 | 0.0070 | 0.00181 | 0.25 | 1.24 |
| q7 | 0.0072 | 0.00188 | 0.26 | 0.33 |
| q8 | 0.0087 | 0.00228 | 0.26 | -0.41 |
| q9 | 0.0058 | 0.00151 | 0.26 | -1.04 |
| q10 | 0.0067 | 0.00173 | 0.26 | -1.63 |

4b Residuals

| Age | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | -1.41 | -0.92 | -0.98 | 0.28 | 0.01 | -0.34 | 1.00 | 0.96 | 0.42 | 0.03 | 0.39 | 0.09 | 0.05 |
| 5 | -0.84 | -1.06 | -0.60 | 1.29 | -0.76 | -0.95 | 0.64 | 1.68 | -0.36 | -0.26 | 1.25 | 0.20 | -0.09 |
| 6 | -0.69 | -0.74 | -1.10 | 0.97 | -0.38 | -0.35 | 1.19 | 1.47 | 0.31 | -0.19 | 1.41 | 0.24 | -1.06 |
| 7 | -0.21 | -1.80 | -1.37 | 0.45 | -0.56 | -0.67 | 1.48 | 2.03 | 0.19 | -0.73 | 0.87 | 1.63 | -0.26 |
| 8 | -0.82 | -0.80 | -1.42 | -0.14 | -0.43 | -0.80 | 1.13 | 2.37 | 0.49 | -0.34 | 1.60 | 0.28 | 0.58 |
| 9 | -0.60 | -0.55 | -0.56 | -0.62 | -0.10 | -0.53 | 1.51 | 1.84 | 0.50 | -0.68 | 1.68 | 0.82 | -2.08 |
| 10 | -0.72 | -0.78 | -0.55 | -0.69 | -0.35 | -0.47 | 0.79 | 1.31 | 0.61 | 0.30 | 2.14 | -0.98 | 0.63 |

| Age | 1995 | 1996 |
|---|---|---|
| 4 | 0.28 | 0.24 |
| 5 | 0.32 | -0.44 |
| 6 | -0.30 | -0.79 |
| 7 | -0.33 | -0.71 |
| 8 | -0.94 | -0.76 |
| 9 | 0.53 | -1.19 |
| 10 | -1.78 | 0.53 |

Table 5. Population numbers (thousands) at age and total over ages 1 to 15

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11045 | 8492 | 4500 | 4979 | 3528 | 4512 | 6430 | 1923 | 2757 | 1596 | 1848 | 2863 | 0 |
| 2 | 17596 | 9043 | 6952 | 3685 | 4076 | 2888 | 3694 | 5265 | 1575 | 2257 | 1307 | 1513 | 2344 |
| 3 | 10275 | 14406 | 7404 | 5692 | 3017 | 3337 | 2365 | 3025 | 4310 | 1289 | 1848 | 1070 | 1239 |
| 4 | 9976 | 8388 | 11782 | 6050 | 4654 | 2465 | 2711 | 1922 | 2467 | 3499 | 1042 | 1508 | 875 |
| 5 | 6418 | 7897 | 6570 | 9308 | 4833 | 3686 | 1903 | 2012 | 1274 | 1816 | 2703 | 797 | 1194 |
| 6 | 3174 | 4298 | 5805 | 4545 | 6353 | 3100 | 2361 | 1212 | 780 | 713 | 1159 | 1542 | 603 |
| 7 | 2589 | 2123 | 3011 | 3569 | 2585 | 3216 | 1591 | 1213 | 424 | 294 | 472 | 303 | 1113 |
| 8 | 1580 | 1384 | 1340 | 1805 | 1639 | 1347 | 1470 | 663 | 428 | 176 | 179 | 156 | 105 |
| 9 | 697 | 745 | 786 | 786 | 767 | 694 | 569 | 512 | 183 | 96 | 87 | 42 | 91 |
| 10 | 245 | 363 | 401 | 424 | 398 | 339 | 268 | 153 | 154 | 52 | 32 | 20 | 22 |
| 11 | 154 | 117 | 190 | 184 | 187 | 178 | 104 | 80 | 31 | 41 | 31 | 7 | 12 |
| 12 | 99 | 79 | 64 | 90 | 96 | 80 | 55 | 20 | 24 | 9 | 24 | 5 | 4 |
| 13 | 39 | 58 | 39 | 31 | 47 | 42 | 28 | 8 | 7 | 9 | 4 | 5 | 0 |
| 14 | 20 | 22 | 35 | 24 | 14 | 22 | 9 | 6 | 4 | 2 | 2 | 0 | 4 |
| 15 | 11 | 12 | 17 | 24 | 17 | 6 | 13 | 4 | 1 | 1 | 1 | 0 | 0 |
| 1-15 | 63918 | 57426 | 48897 | 41196 | 32210 | 25915 | 23570 | 18017 | 14419 | 11850 | 10738 | 9831 | 7607 |

| | 1995 | 1996 |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 1919 | 0 |
| 4 | 1014 | 1571 |
| 5 | 716 | 830 |
| 6 | 975 | 586 |
| 7 | 490 | 794 |
| 8 | 899 | 394 |
| 9 | 78 | 729 |
| 10 | 71 | 61 |
| 11 | 18 | 58 |
| 12 | 10 | 14 |
| 13 | 3 | 8 |
| 14 | 0 | 3 |
| 15 | 3 | 0 |
| 1- | 6197 | 5049 |

Table 6. Biomass (Jan. 1) at age and 1+ and 5+ sums

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 638 | 490 | 260 | 287 | 204 | 261 | 371 | 111 | 159 | 92 | 107 | 165 | 0 |
| 2 | 3733 | 1566 | 1204 | 638 | 706 | 500 | 640 | 912 | 273 | 391 | 226 | 262 | 406 |
| 3 | 4925 | 6112 | 2896 | 2270 | 1203 | 1305 | 943 | 1294 | 1844 | 542 | 701 | 262 | 492 |
| 4 | 8003 | 6299 | 8111 | 3889 | 3142 | 1554 | 1753 | 1290 | 1797 | 2351 | 604 | 739 | 347 |
| 5 | 7797 | 8514 | 6801 | 8948 | 4644 | 3585 | 1728 | 1867 | 1238 | 1744 | 2053 | 613 | 888 |
| 6 | 5156 | 6351 | 7816 | 5843 | 8275 | 3671 | 2992 | 1422 | 949 | 866 | 1205 | 1409 | 722 |
| 7 | 5014 | 4234 | 5437 | 5987 | 4381 | 4883 | 2294 | 1876 | 609 | 458 | 625 | 364 | 1533 |
| 8 | 4285 | 3152 | 3072 | 3837 | 3550 | 2818 | 2667 | 1166 | 852 | 291 | 277 | 248 | 185 |
| 9 | 2644 | 2473 | 2057 | 2080 | 1979 | 1860 | 1443 | 1055 | 373 | 230 | 158 | 83 | 210 |
| 10 | 1308 | 1522 | 1365 | 1261 | 1334 | 1100 | 1013 | 432 | 341 | 132 | 71 | 52 | 69 |
| 11 | 859 | 679 | 818 | 665 | 749 | 813 | 481 | 354 | 93 | 115 | 76 | 24 | 47 |
| 12 | 643 | 572 | 417 | 491 | 473 | 464 | 336 | 134 | 125 | 33 | 71 | 13 | 25 |
| 13 | 309 | 505 | 324 | 233 | 322 | 280 | 214 | 66 | 62 | 56 | 22 | 20 | 0 |
| 14 | 157 | 218 | 366 | 222 | 122 | 155 | 82 | 60 | 20 | 16 | 14 | 1 | 26 |
| 15 | 119 | 120 | 202 | 313 | 176 | 61 | 118 | 44 | 12 | 11 | 16 | 0 | 0 |
| 1+ | 45590 | 42808 | 41147 | 36965 | 31261 | 23313 | 17076 | 12082 | 8748 | 7327 | 6228 | 4256 | |
| 5+ | 28292 | 28340 | 28676 | 29881 | 26006 | 19693 | 13368 | 8475 | 4675 | 3951 | 4589 | 2828 | 3706 |

| | 1995 | 1996 |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 762 | 0 |
| 4 | 651 | 1009 |
| 5 | 668 | 774 |
| 6 | 1205 | 724 |
| 7 | 766 | 1241 |
| 8 | 1762 | 773 |
| 9 | 192 | 1798 |
| 10 | 223 | 192 |
| 11 | 71 | 234 |
| 12 | 51 | 77 |
| 13 | 23 | 55 |
| 14 | 0 | 23 |
| 15 | 32 | 0 |
| 1+ | | |
| 5+ | 4993 | 5890 |

Table 7. Fishing mortality at age and average over ages 7 to 9

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 0.003 | 0.001 | 0.002 | 0.001 | 0.002 | 0.008 | 0.008 | 0.004 | 0.009 | 0.013 | 0.004 | 0.001 | 0.000 |
| 4 | 0.034 | 0.044 | 0.036 | 0.025 | 0.033 | 0.059 | 0.098 | 0.211 | 0.106 | 0.058 | 0.068 | 0.033 | 0.000 |
| 5 | 0.201 | 0.108 | 0.169 | 0.182 | 0.244 | 0.246 | 0.251 | 0.748 | 0.381 | 0.249 | 0.361 | 0.078 | 0.002 |
| 6 | 0.202 | 0.156 | 0.286 | 0.364 | 0.481 | 0.467 | 0.466 | 0.850 | 0.776 | 0.212 | 1.142 | 0.126 | 0.008 |
| 7 | 0.426 | 0.260 | 0.312 | 0.579 | 0.452 | 0.583 | 0.675 | 0.842 | 0.682 | 0.294 | 0.907 | 0.855 | 0.014 |
| 8 | 0.551 | 0.365 | 0.333 | 0.656 | 0.659 | 0.662 | 0.855 | 1.086 | 1.292 | 0.504 | 1.244 | 0.344 | 0.106 |
| 9 | 0.452 | 0.419 | 0.418 | 0.482 | 0.615 | 0.752 | 1.115 | 1.003 | 1.061 | 0.910 | 1.244 | 0.448 | 0.038 |
| 10 | 0.538 | 0.449 | 0.582 | 0.617 | 0.604 | 0.985 | 1.004 | 1.387 | 1.127 | 0.319 | 1.358 | 0.321 | 0.028 |
| 11 | 0.467 | 0.410 | 0.543 | 0.450 | 0.650 | 0.976 | 1.464 | 1.013 | 1.008 | 0.345 | 1.670 | 0.266 | 0.046 |
| 12 | 0.327 | 0.495 | 0.531 | 0.453 | 0.619 | 0.864 | 1.696 | 0.772 | 0.787 | 0.687 | 1.287 | 3.663 | 0.049 |
| 13 | 0.402 | 0.301 | 0.288 | 0.586 | 0.540 | 1.374 | 1.299 | 0.644 | 1.270 | 1.259 | 2.780 | 0.149 | 0.000 |
| 14 | 0.323 | 0.055 | 0.179 | 0.177 | 0.639 | 0.346 | 0.635 | 1.642 | 0.728 | 0.000 | 2.830 | 0.471 | 0.011 |
| 15 | 0.483 | 0.344 | 0.399 | 0.596 | 0.645 | 0.714 | 0.885 | 1.193 | 1.104 | 0.572 | 1.290 | 0.488 | 0.044 |
| 7-9 | 0.477 | 0.348 | 0.354 | 0.572 | 0.575 | 0.666 | 0.882 | 0.977 | 1.012 | 0.570 | 1.132 | 0.549 | 0.053 |

| | 1995 | 1996 |
|---|---|---|
| 1 | 0.000 | 0.000 |
| 2 | 0.000 | 0.000 |
| 3 | 0.000 | 0.000 |
| 4 | 0.000 | 0.001 |
| 5 | 0.001 | 0.002 |
| 6 | 0.006 | 0.006 |
| 7 | 0.018 | 0.009 |
| 8 | 0.009 | 0.012 |
| 9 | 0.034 | 0.009 |
| 10 | 0.009 | 0.010 |
| 11 | 0.003 | 0.010 |
| 12 | 0.000 | 0.010 |
| 13 | 0.000 | 0.010 |
| 14 | 0.000 | 0.010 |
| 15 | 0.018 | 0.010 |
| 7-9 | 0.020 | 0.010 |

**Figure 1. 4Vn cod Landings and TAC**

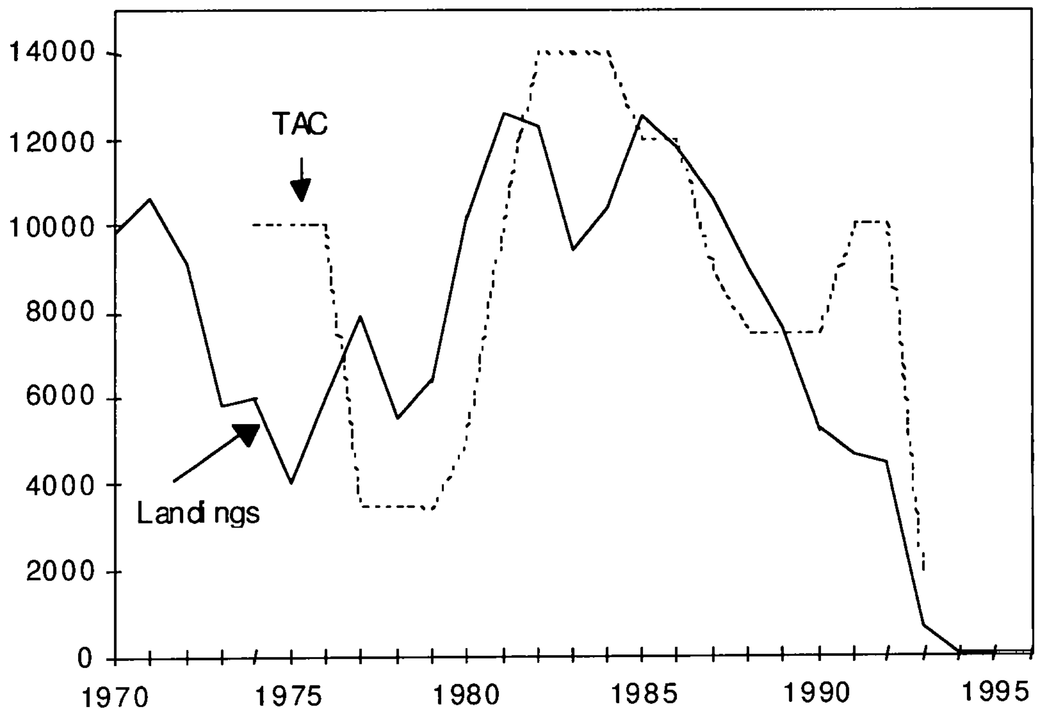


Figure 2. Percentiles of catch by age.

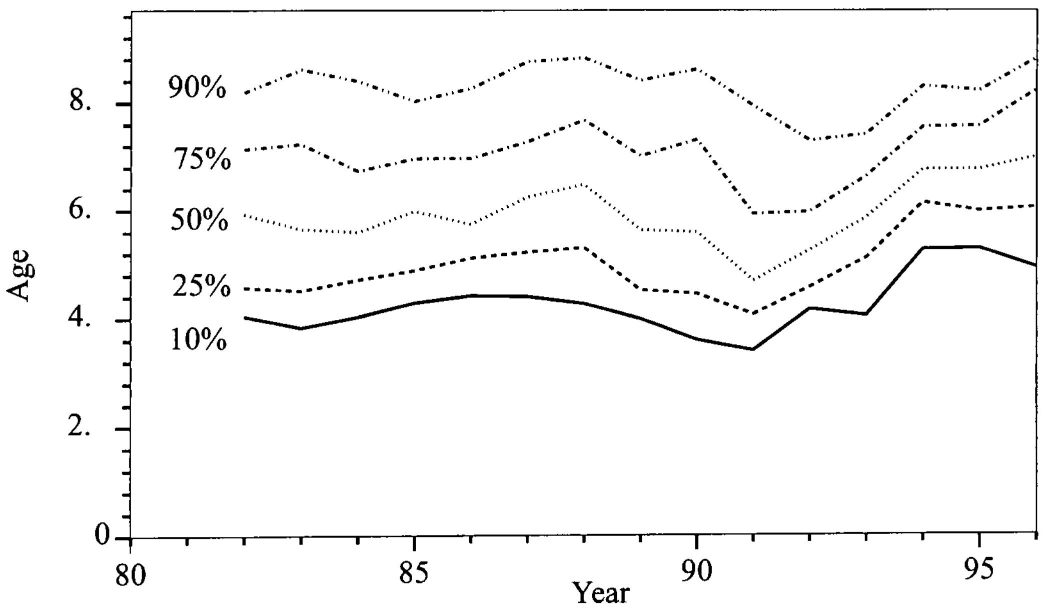



Figure 3. Percentiles of catch by weght.

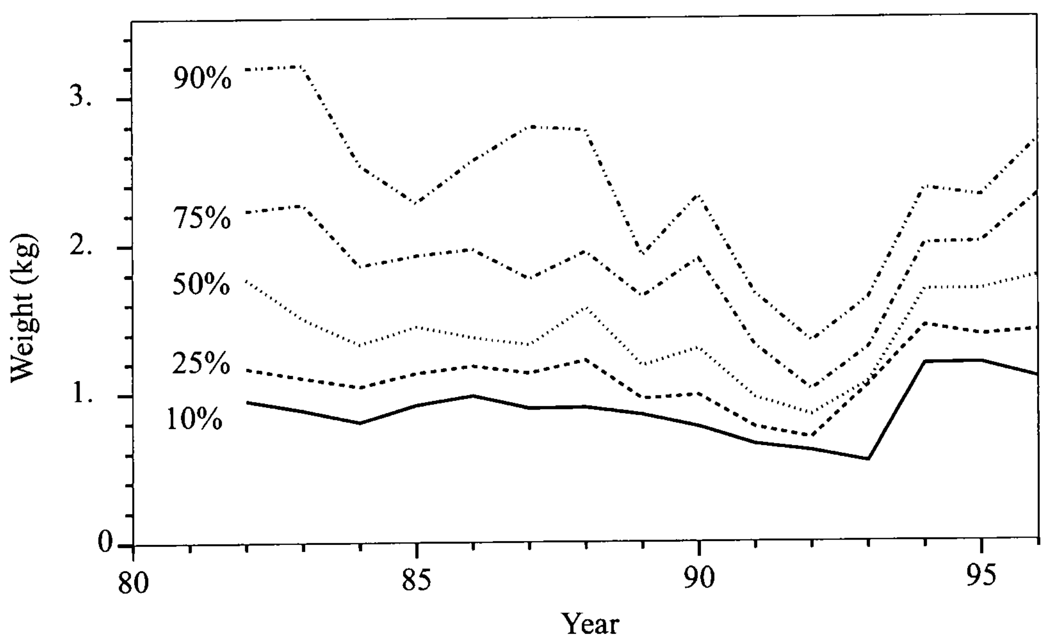


Figure 4. Catch per standard tow from summer research vessel survey.

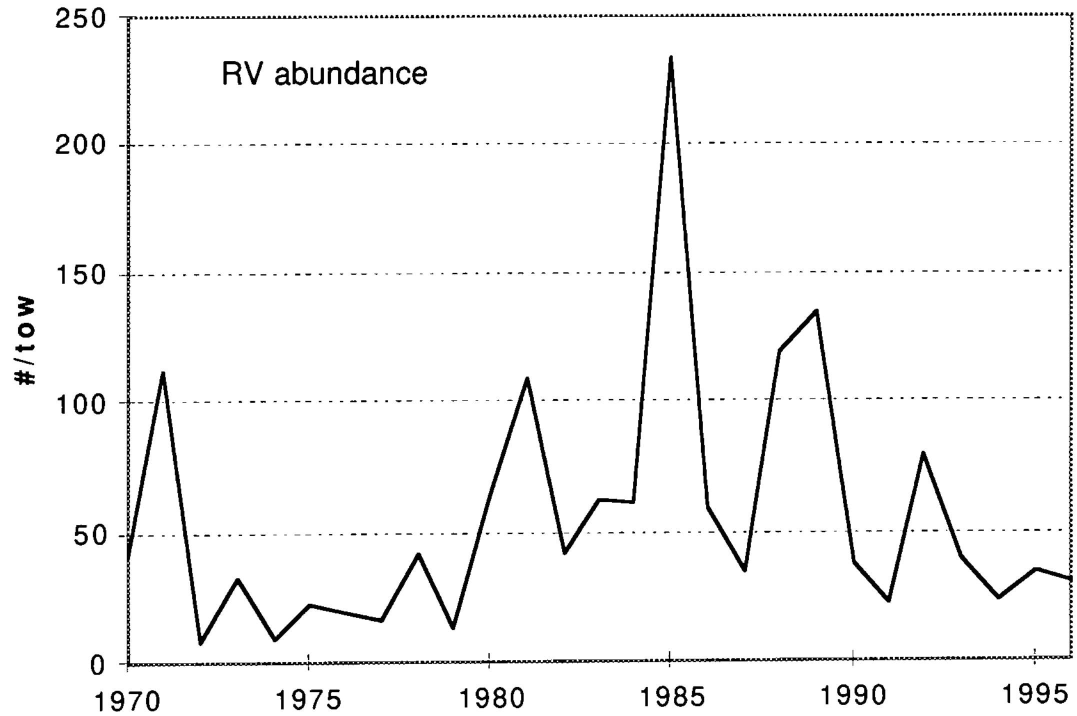


Figure 5. Normalized survey numbers at age for cod.

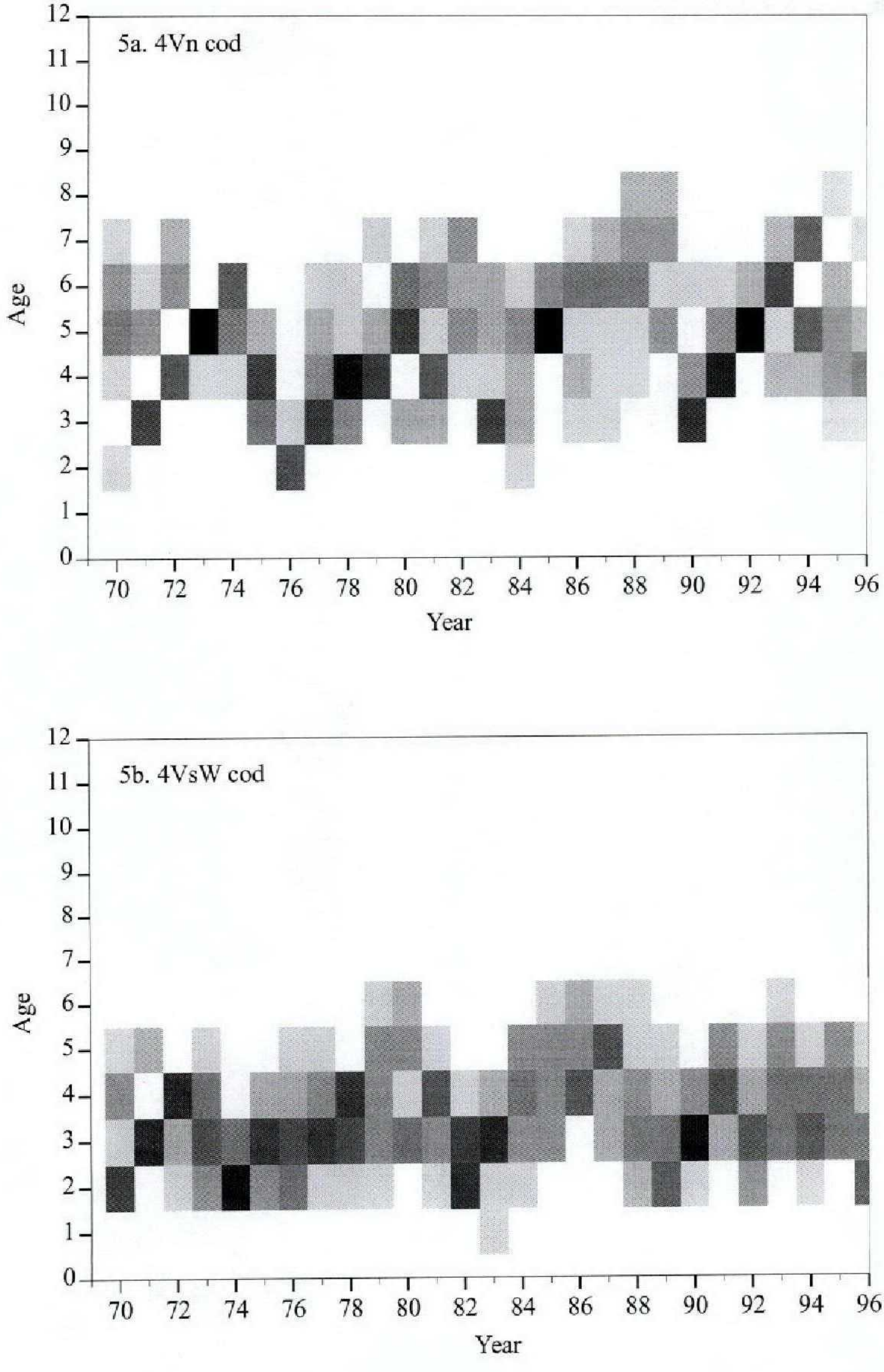


Figure 6. Comparison of average fishing mortality (7-9) estimates from ADAPT and RV surveys.

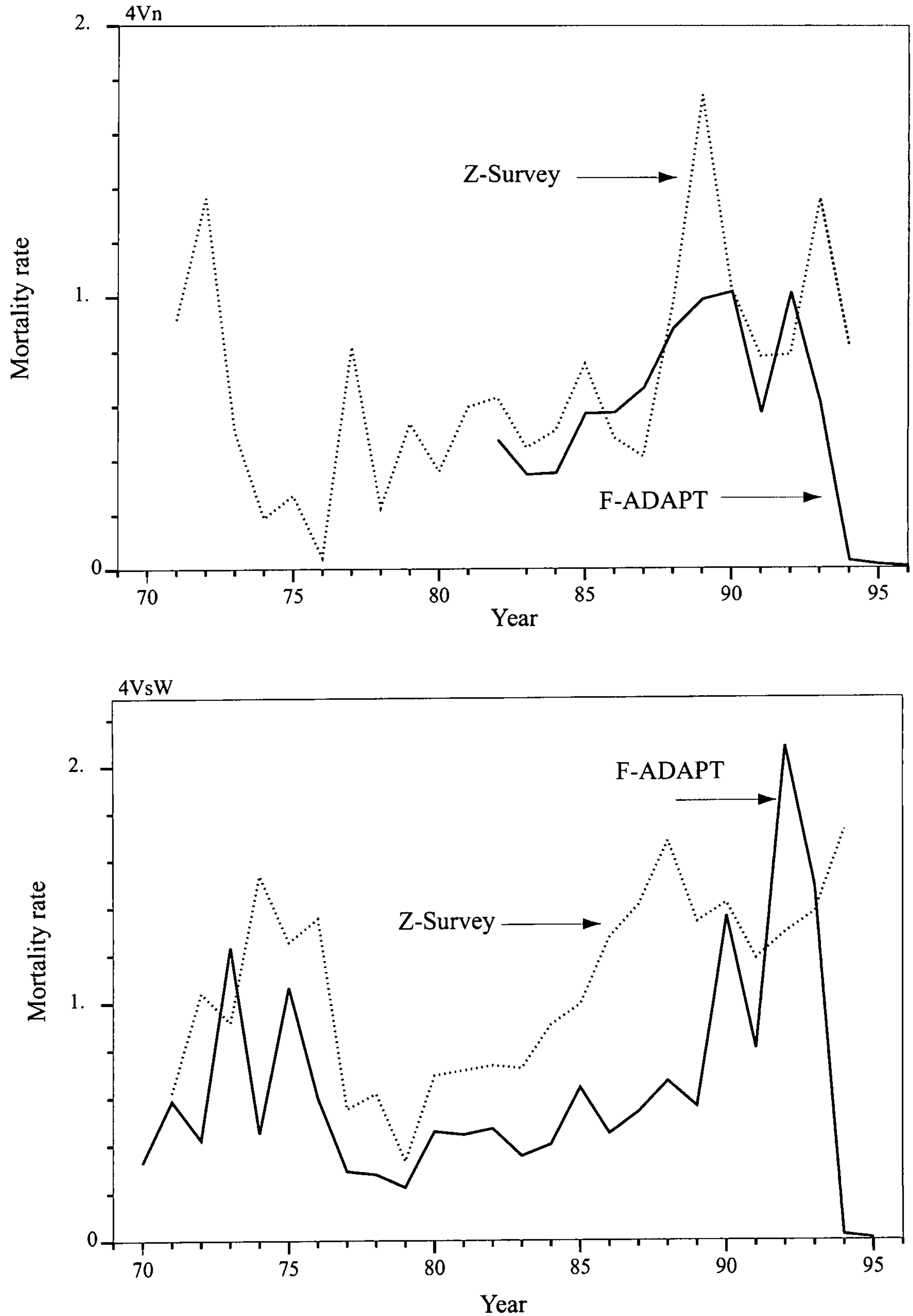


Figure 7. Weight at 30 - 34 cm and 60 - 64 cm cod.

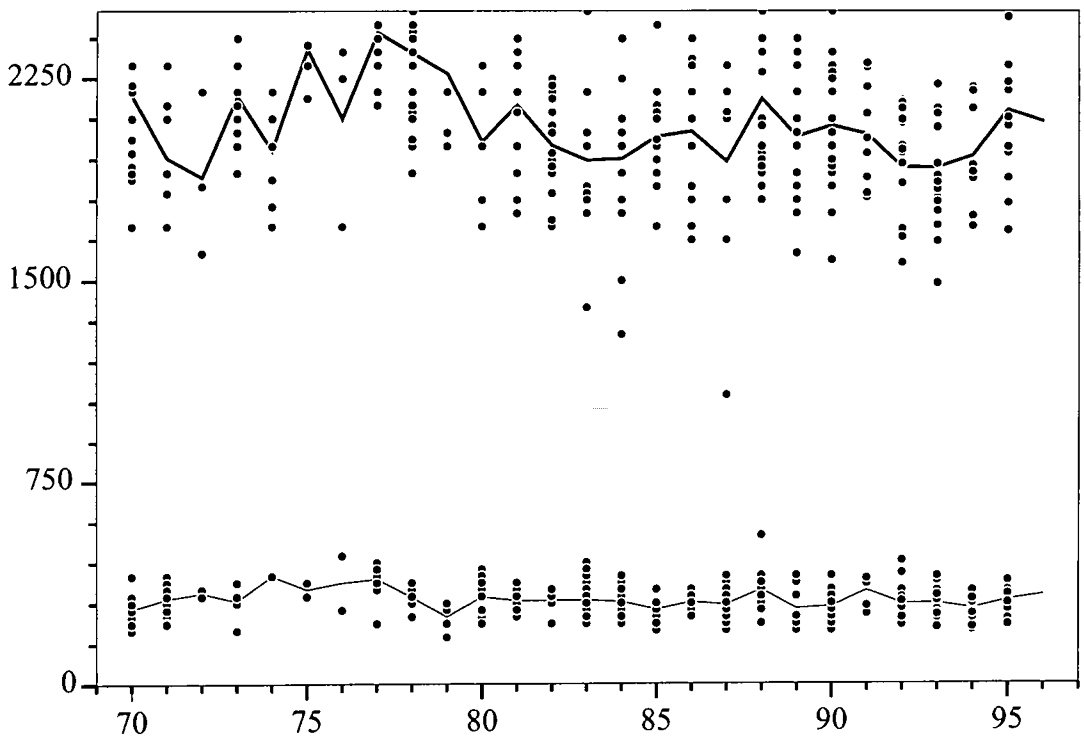



Figure 8 . Normalized weight at 30 - 34 cm and 60 - 64 cm cod.

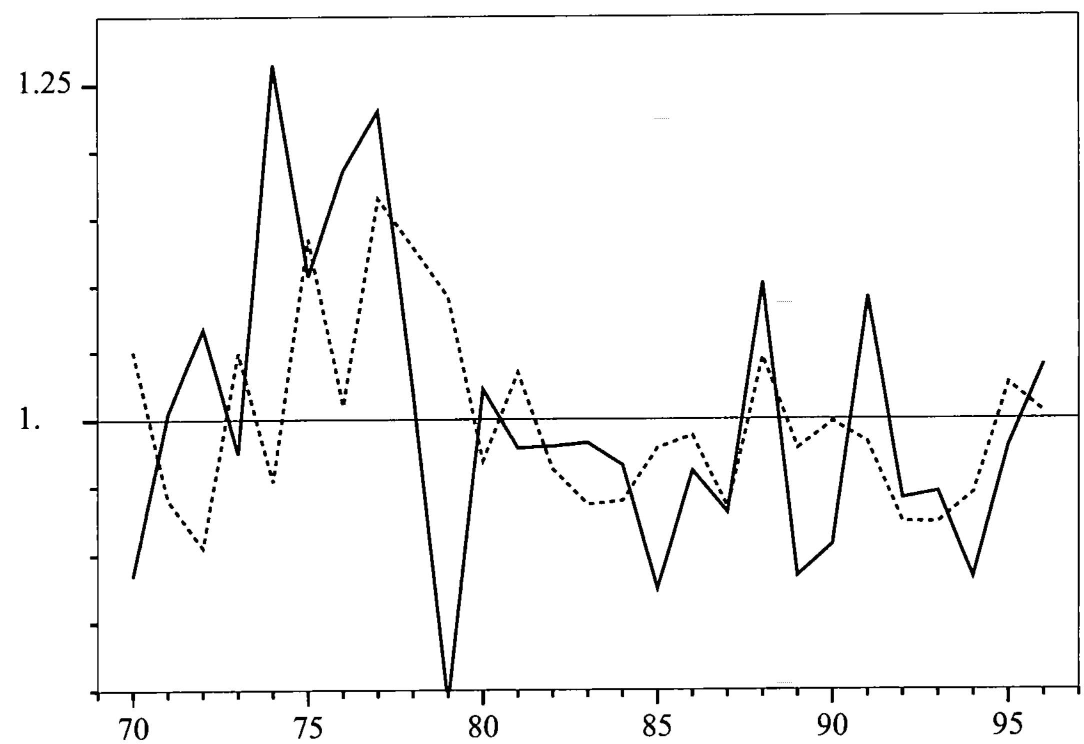


Figure 9. Yearclass strengths from summer RV and inshore surveys.

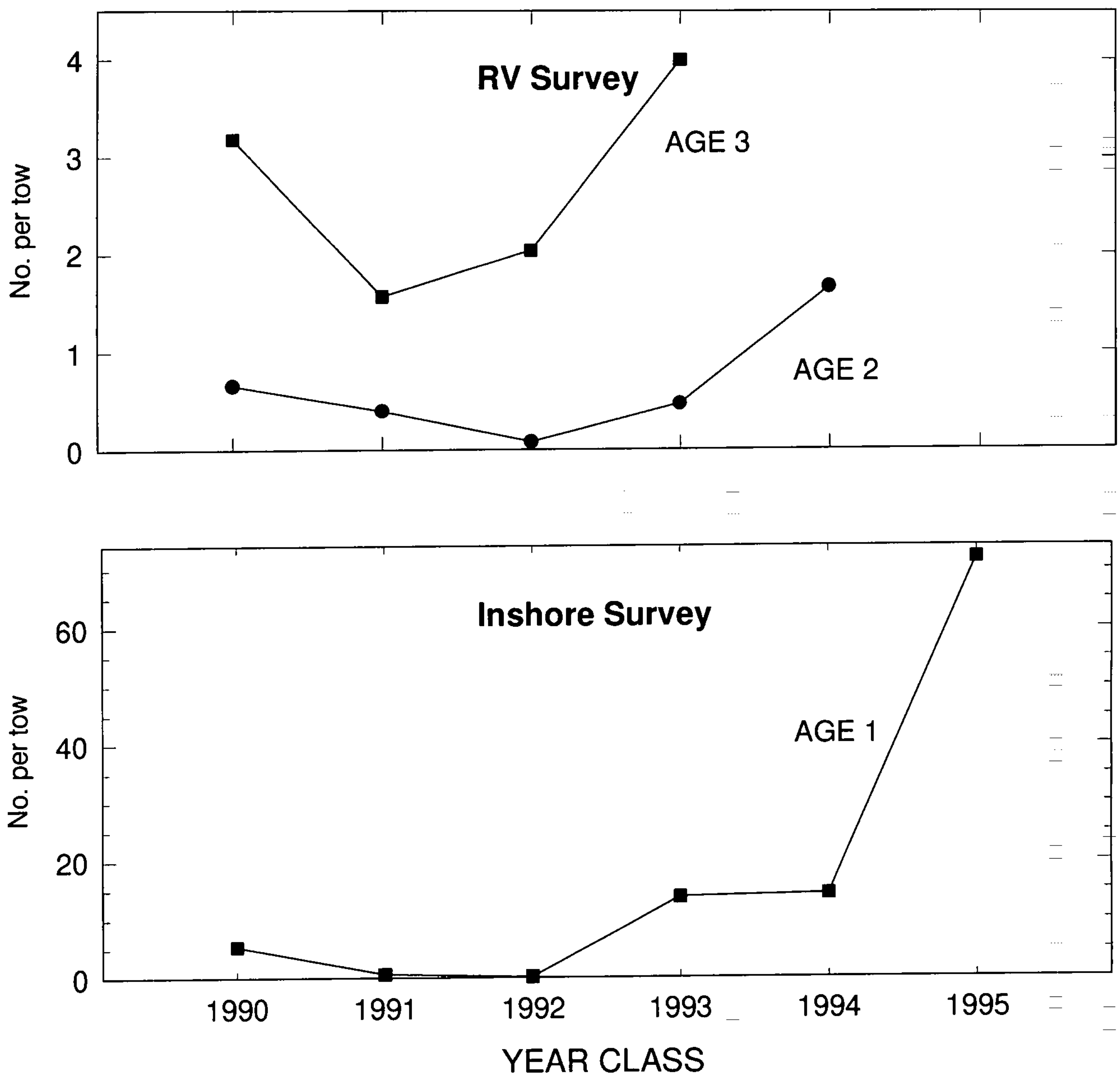


Figure 10. 4Vn Sentinel Fishery catch rates 8 Sep - 2 Oct 1996.

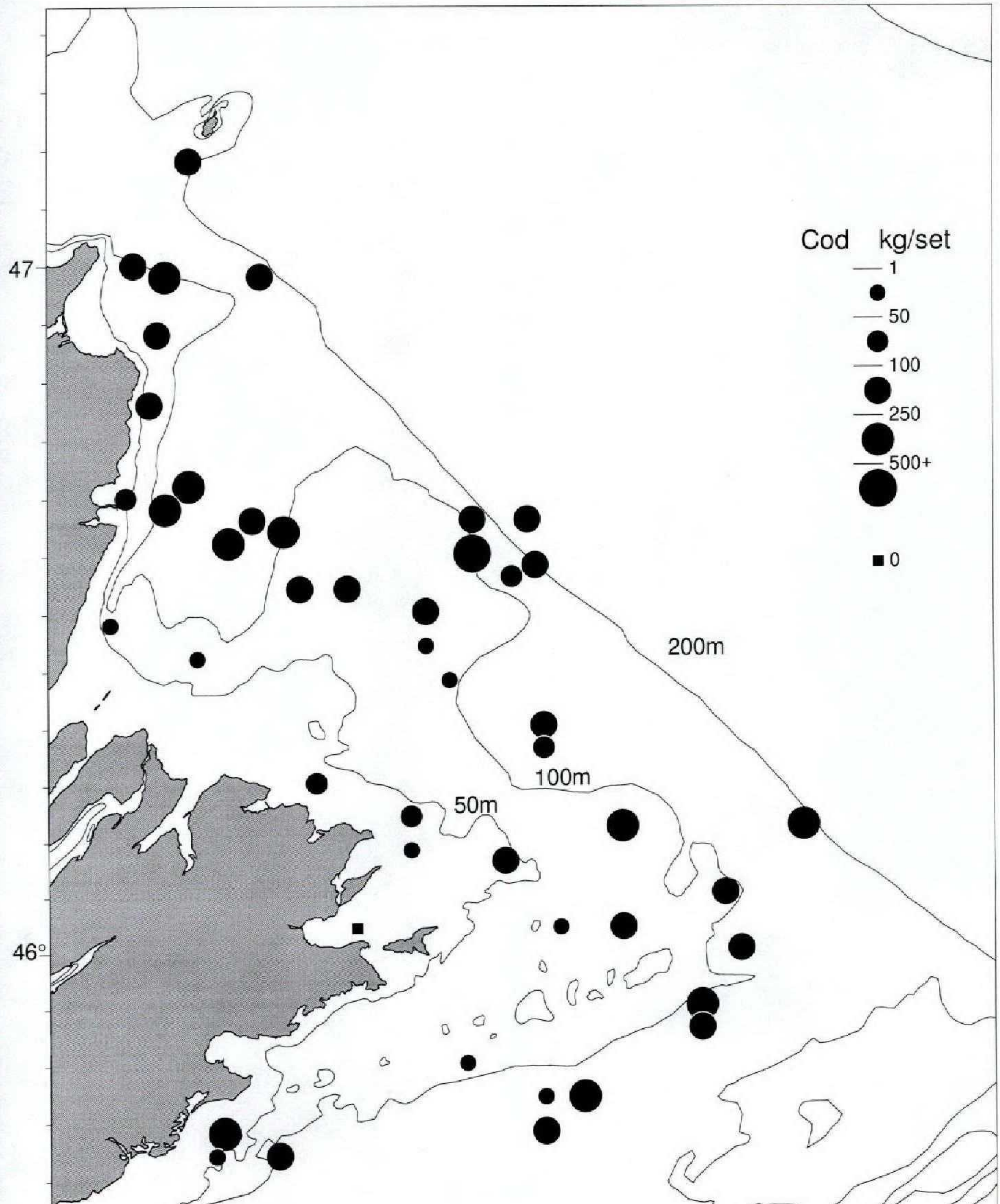


Figure 11. Catch rates from 4Vn Sentinel Fishery.

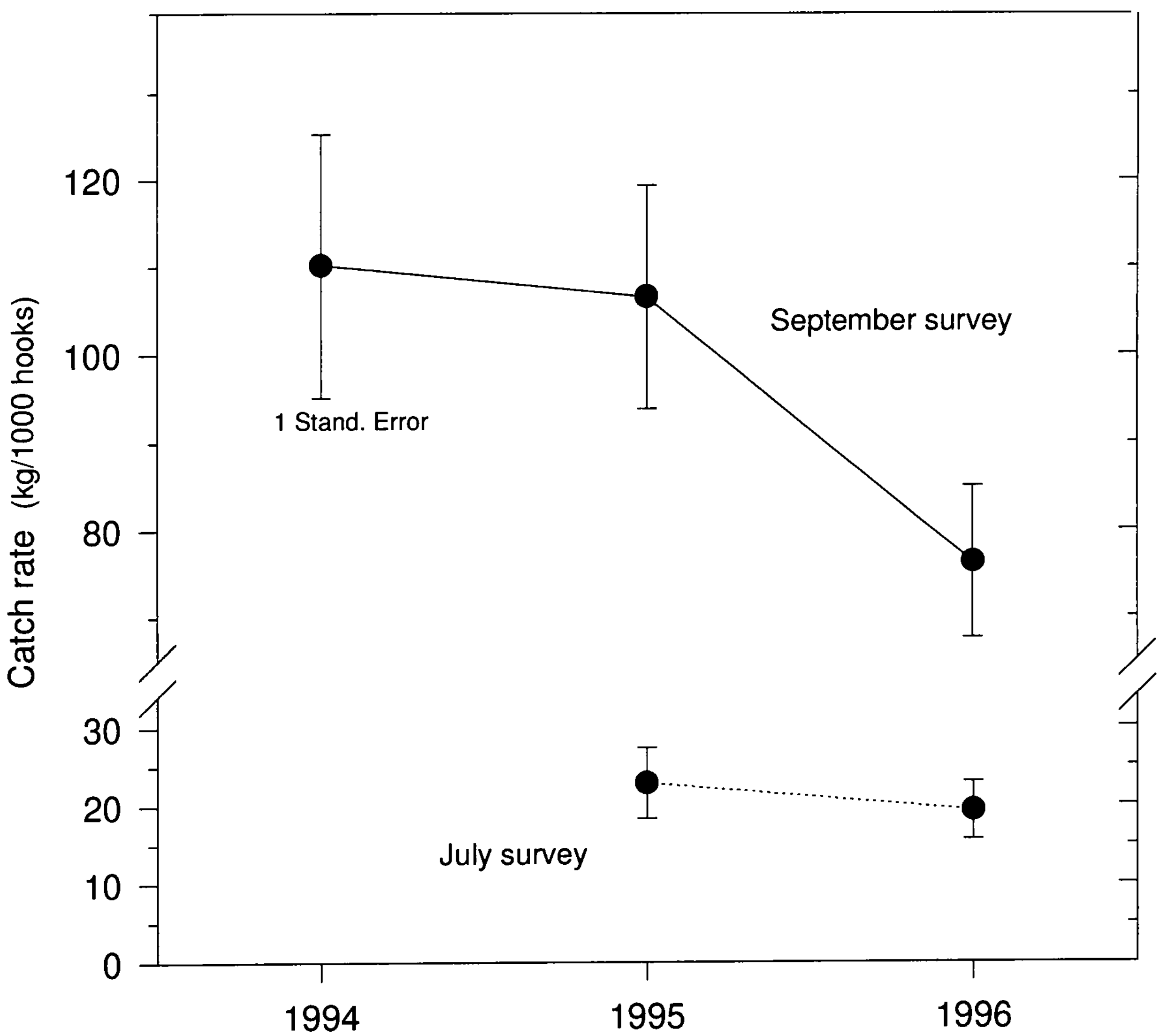


Figure 12. Length frequencies from 1996 Sentinel and Research Surveys

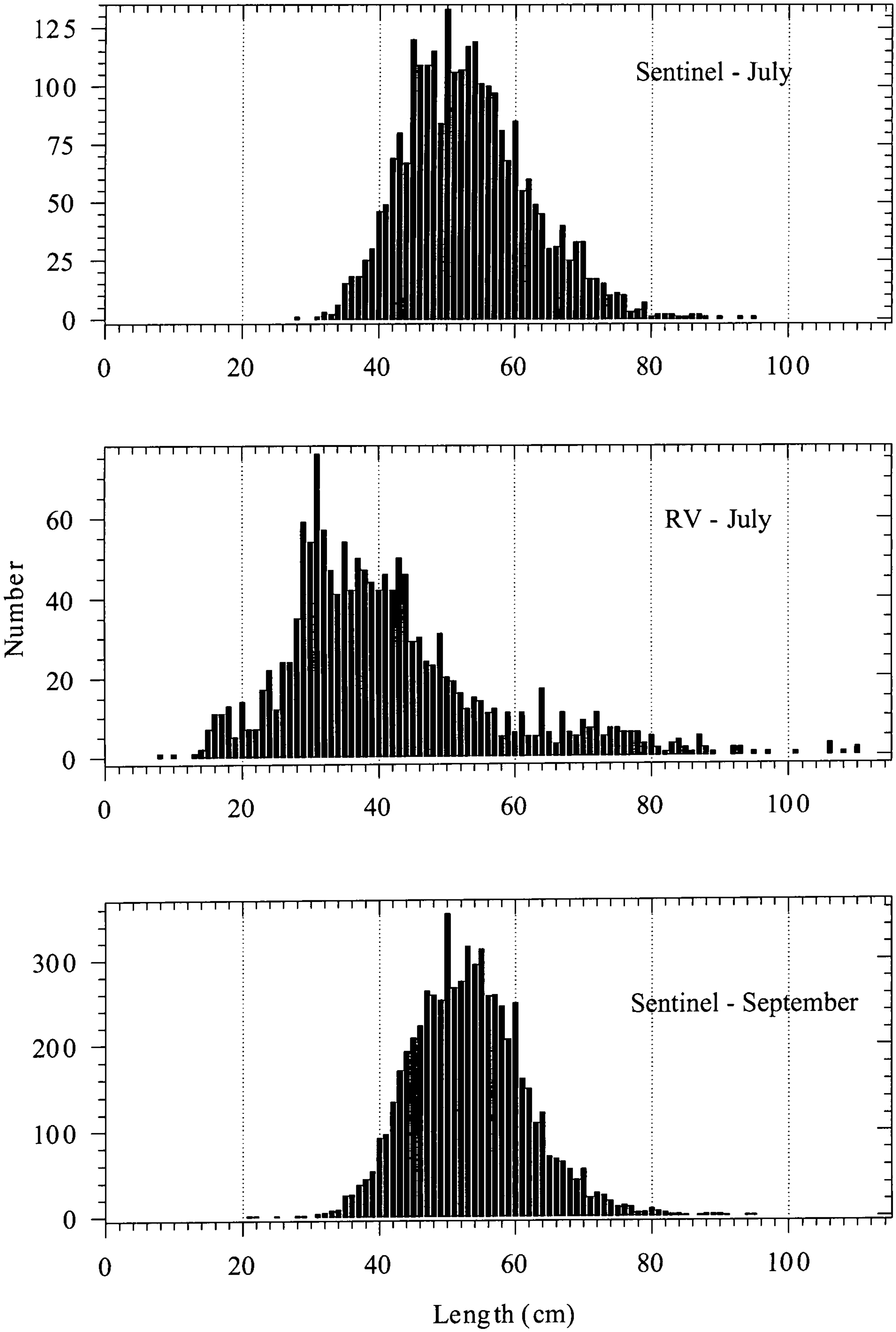


Figure 13. Maturity ogive for 4Vn cod from Sentinel Survey data.

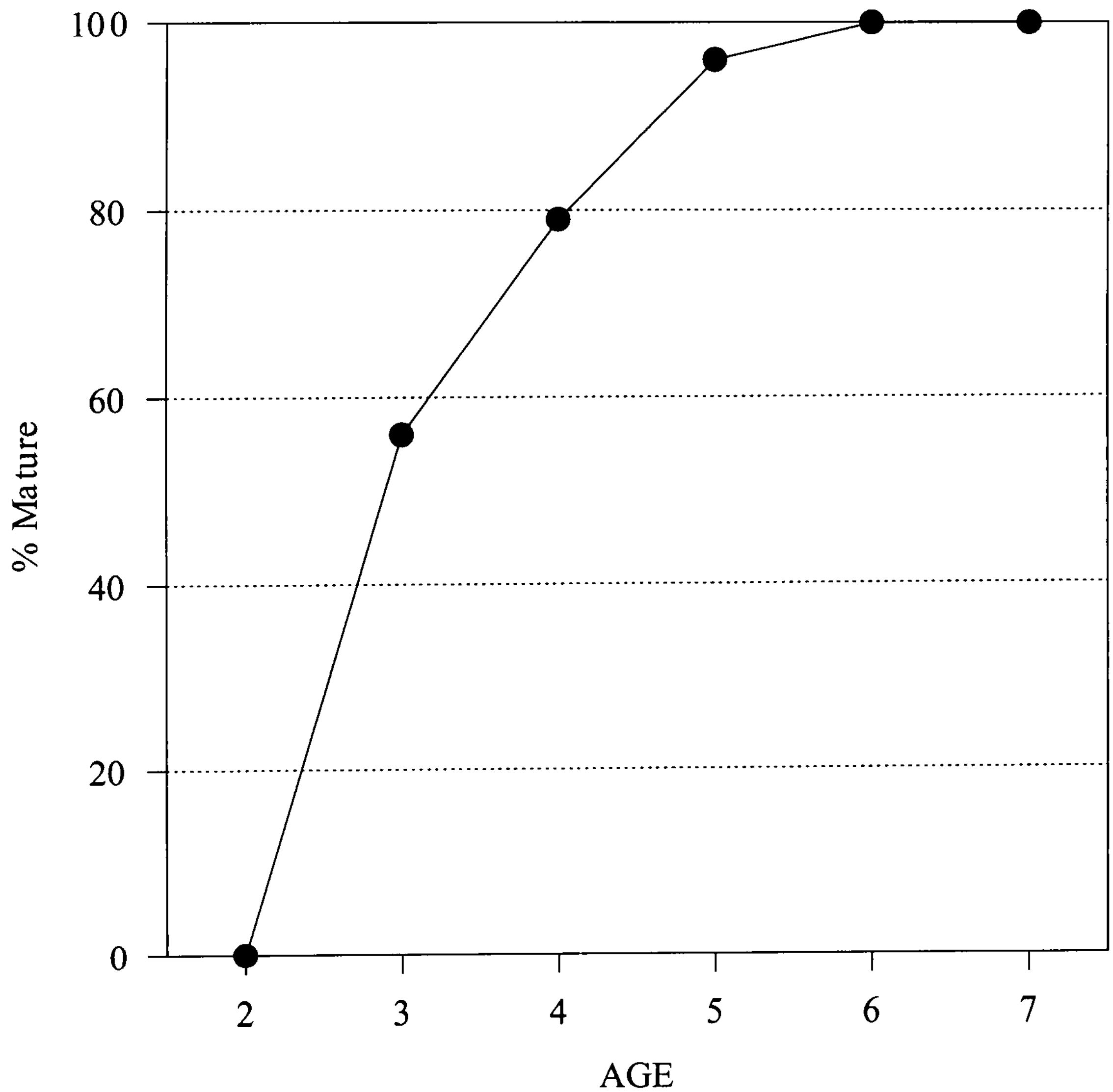


Figure 14. VPA biomass estimates and q-scaled RV indices.

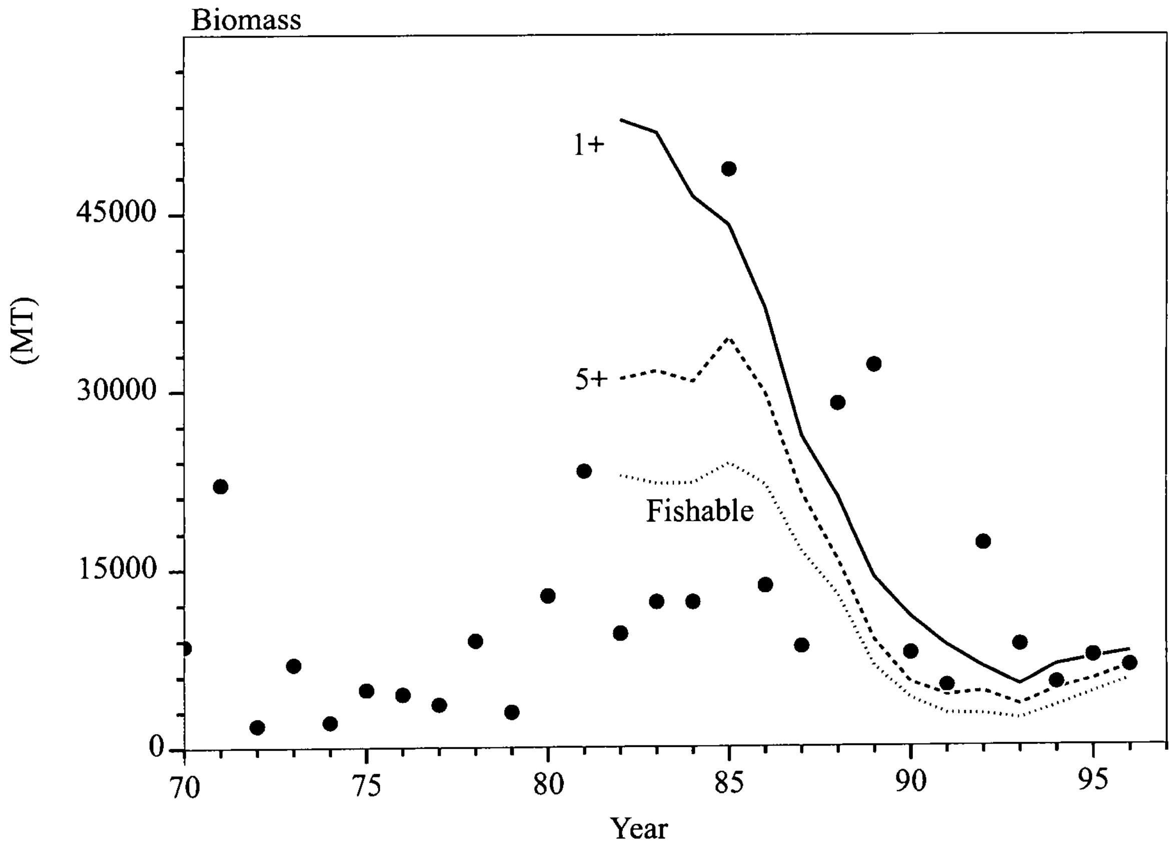


Figure 15. Stock-recruit relationship from VPA for 4Vn cod. The labels are the year of spawning. Only the biomass is plotted for 1993-96.

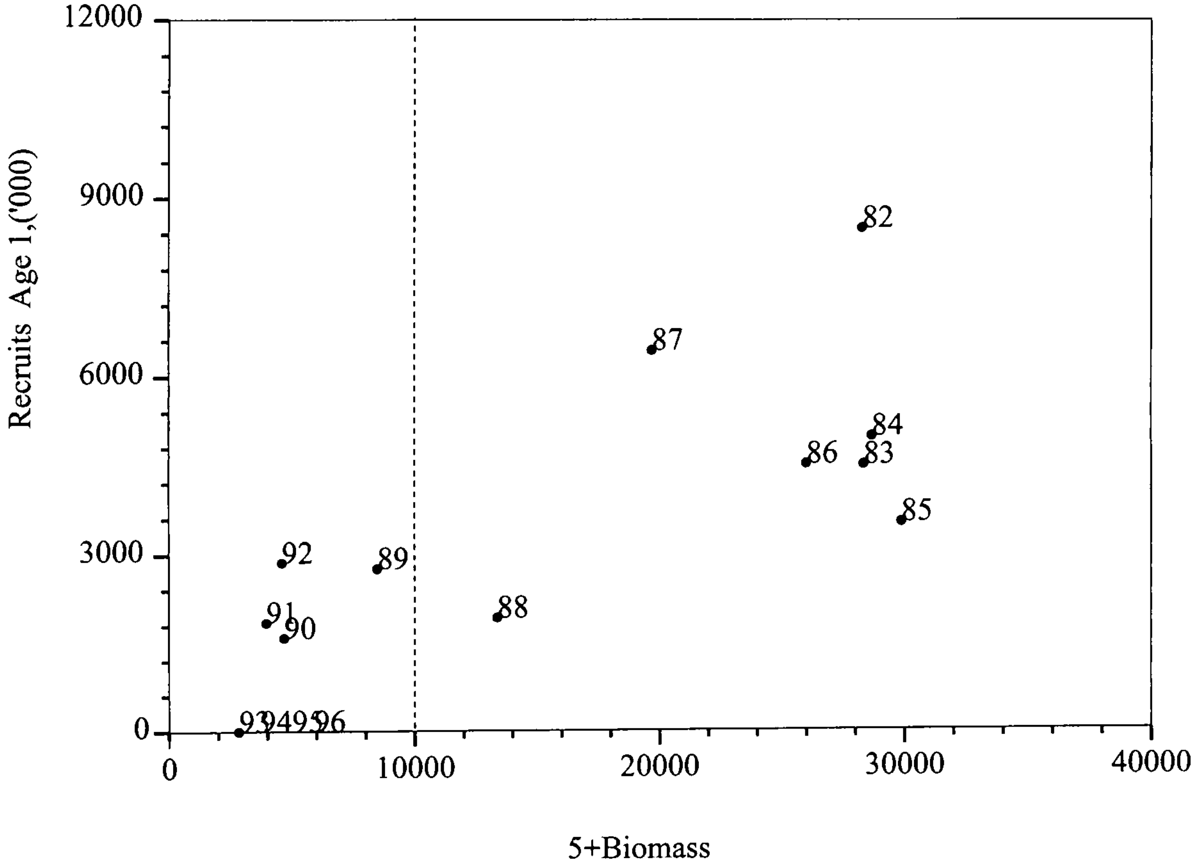


Figure 16. Weighted tag recoveries in 4Vs and 4Vn of cod tagged in 4T, 4Vn and 4Vs.

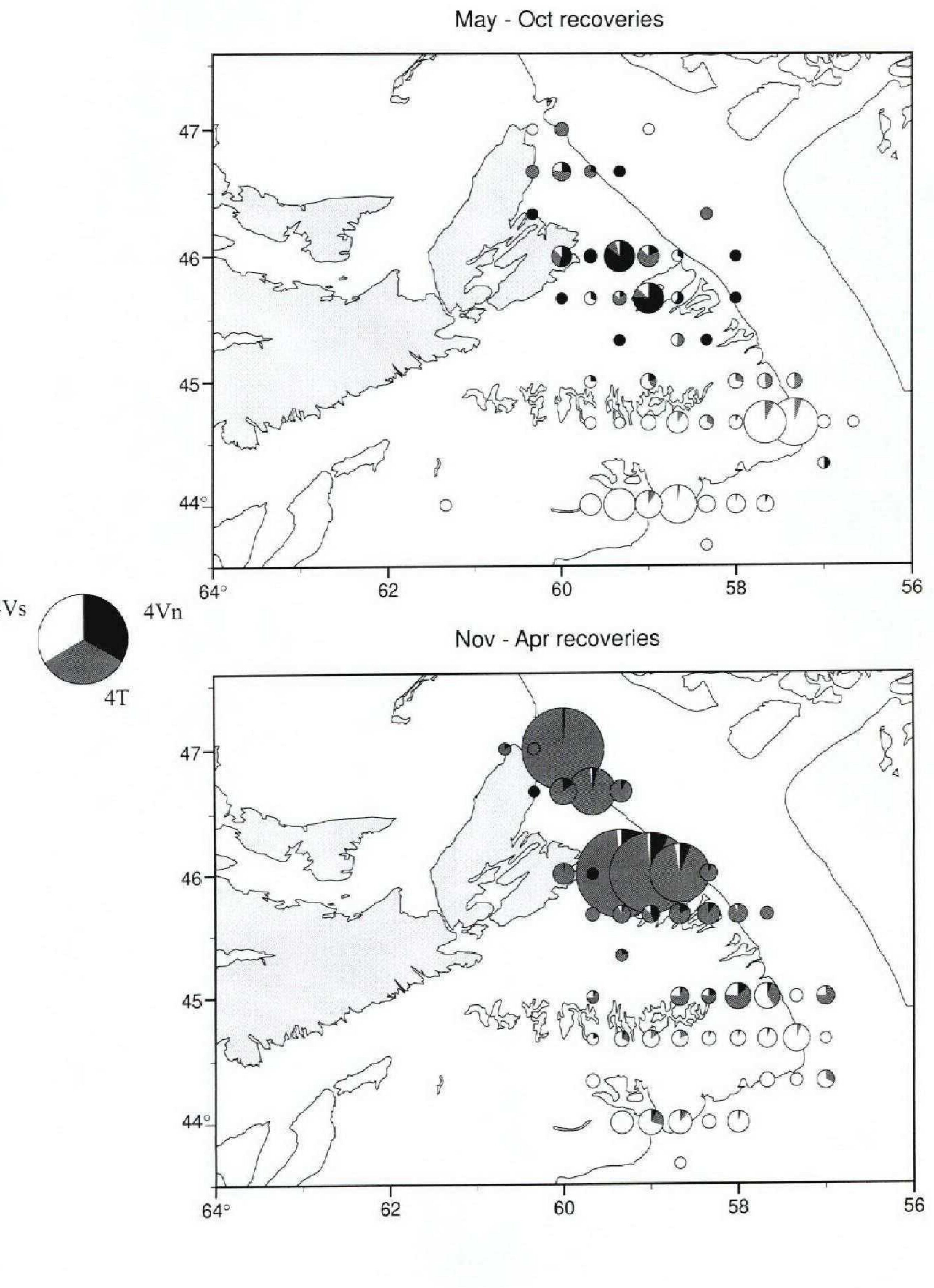


Figure 17. Phaseplot depiction of 4Vn cod history and projections for 1997 and 1999.

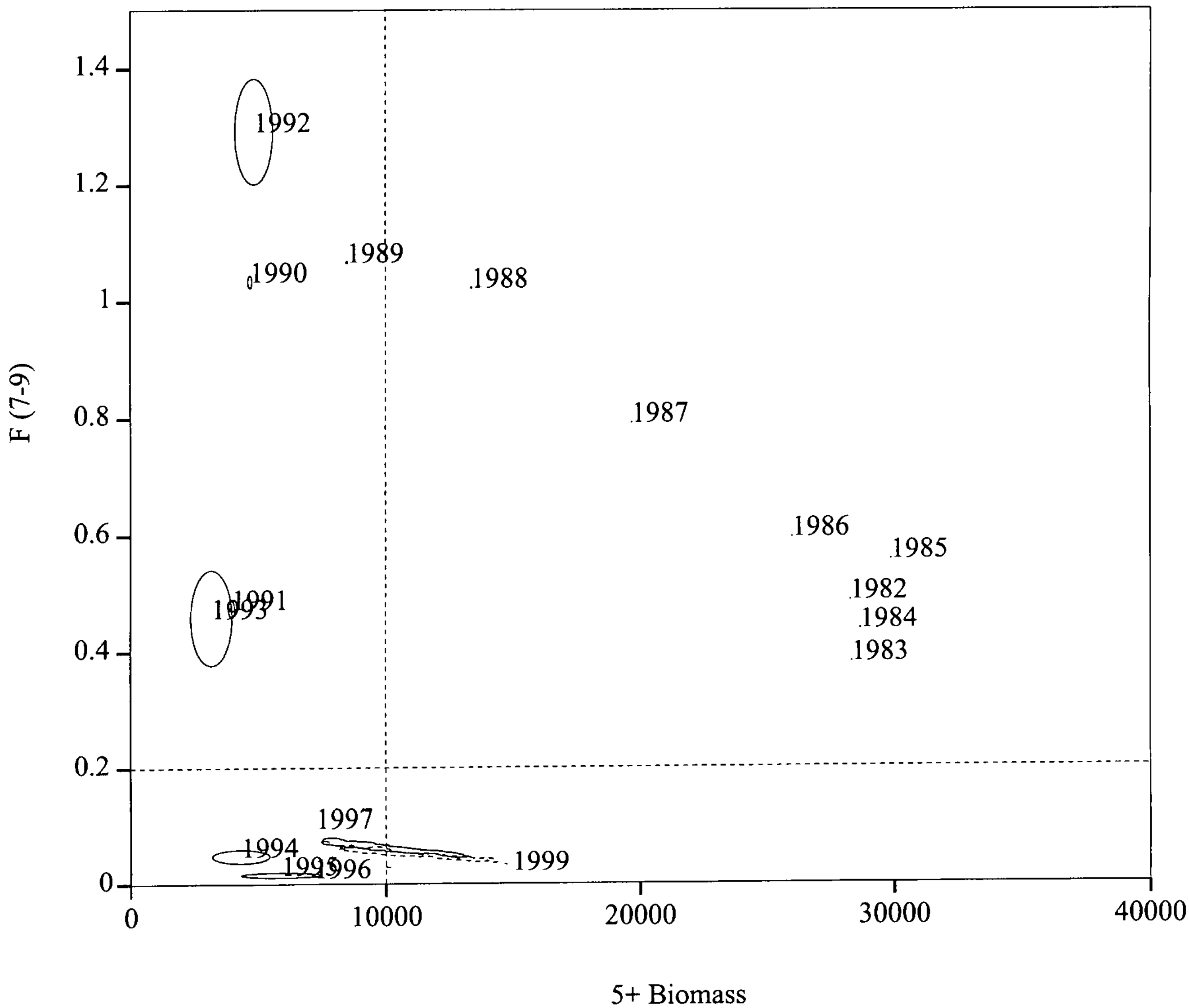
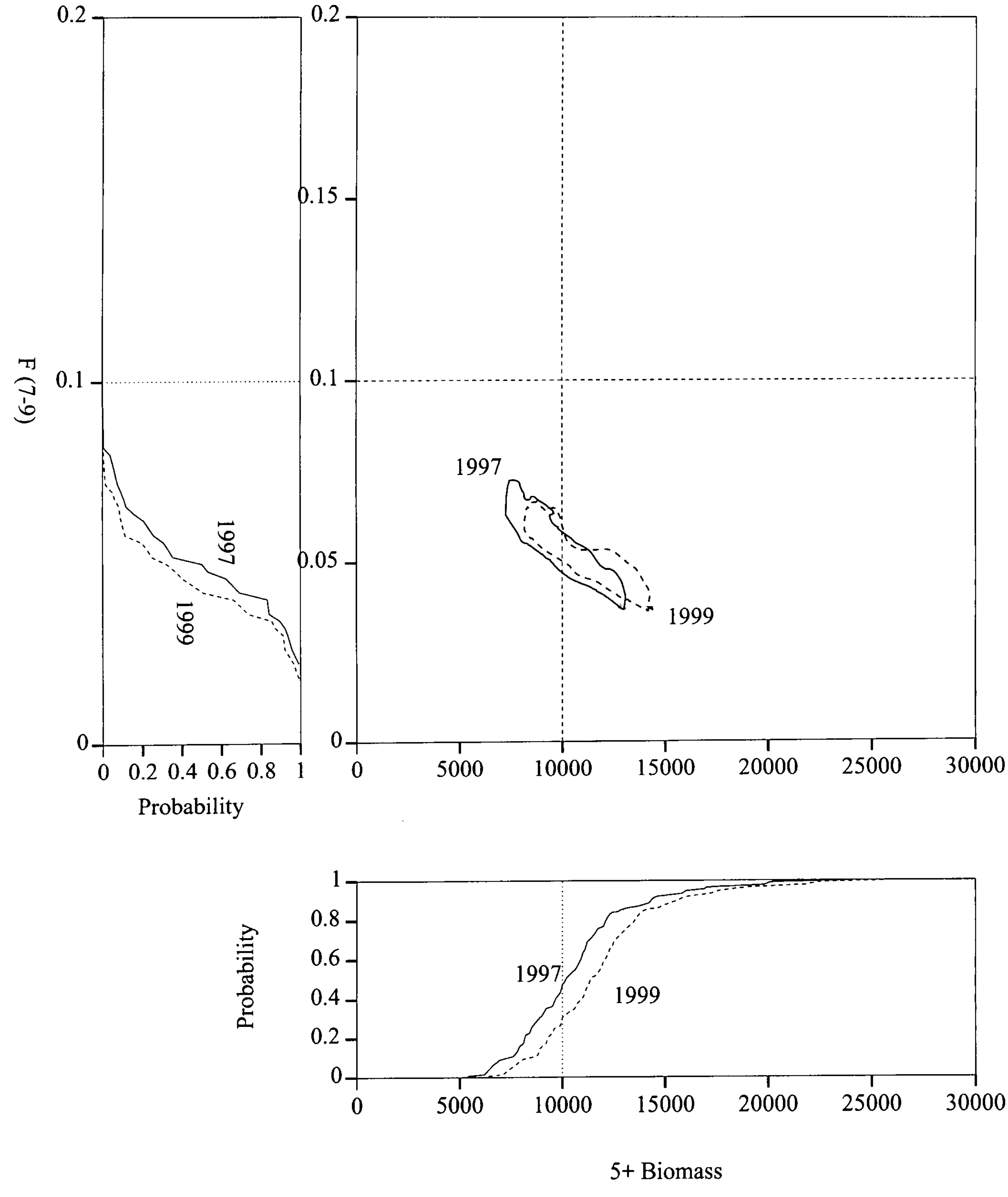


Figure18. Risk projections to 1997 (solid) and 1999 (dashed) with 500 t TAC and 2 million recruits.



**Appendix A. 4T Survey Results**

This appendix contains figures for the 4T surveys that have included 4Vn in recent years. The first two figures (A1 and A2) are September survey for 1994 and 1995. As well as expanding symbols to denote the number per standard tow a size histogram is included. Both years show a mode around 50 cm and the 1995 plot shows a second mode of smaller fish at about 25 cm.

The next 4 figures (A3 to A6) are for the January surveys for 1994-1997 respectively. The size histograms are compiled for 4Vn and 4T separately. As the migration of 4T fish into 4Vn takes place in the fall, the 4Vn sample will contain a large amount of 4Vn fish.

The authors wish to express their appreciation to the staff at the Gulf Fisheries Center, DFO for making these data available.

Figure A1. September, 1994 survey cod distributions.

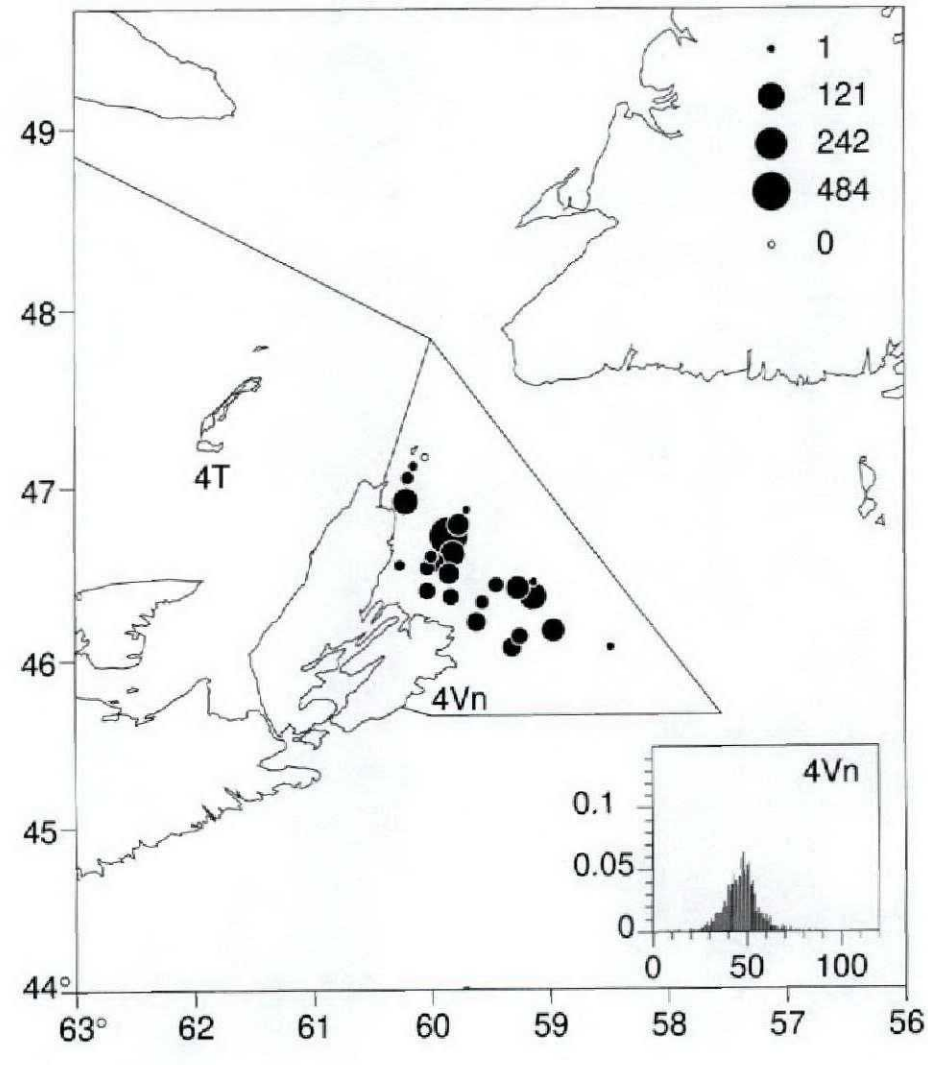


Figure A2. Sepetember, 1995 survey cod distributions.

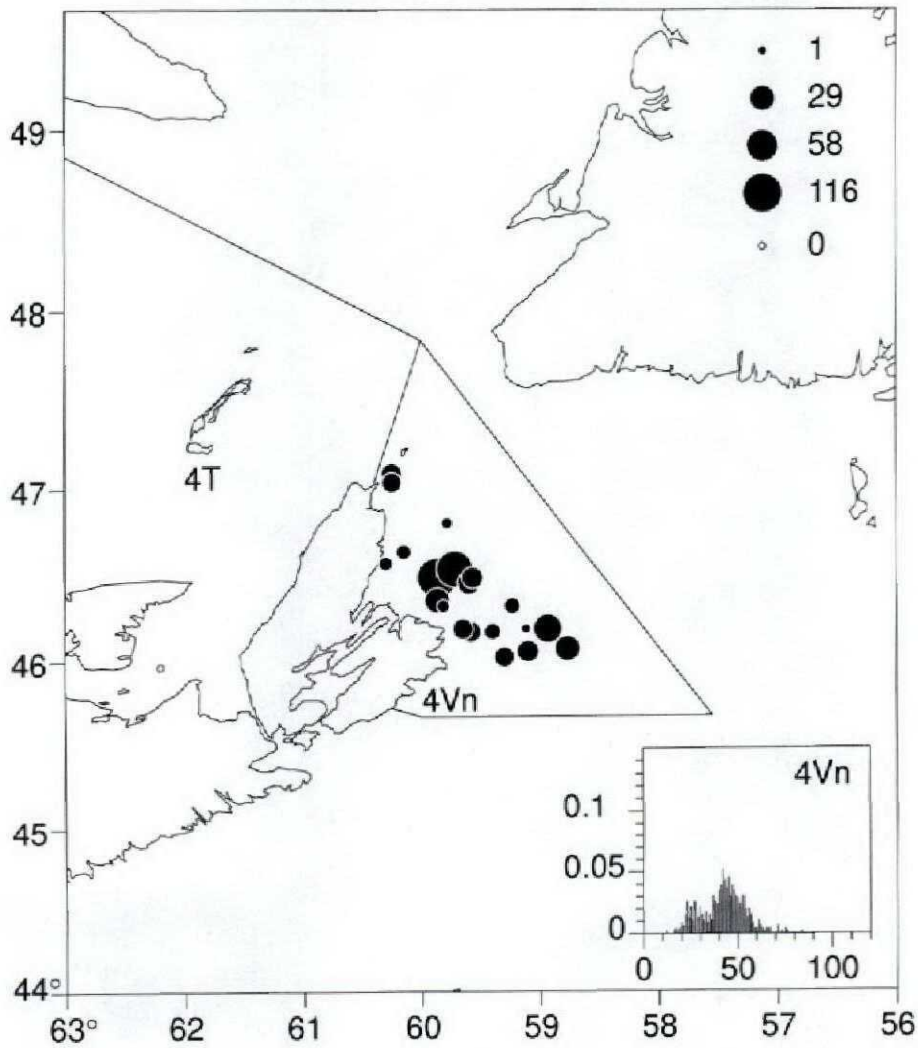


Figure A3. January, 1994 survey cod distributions.

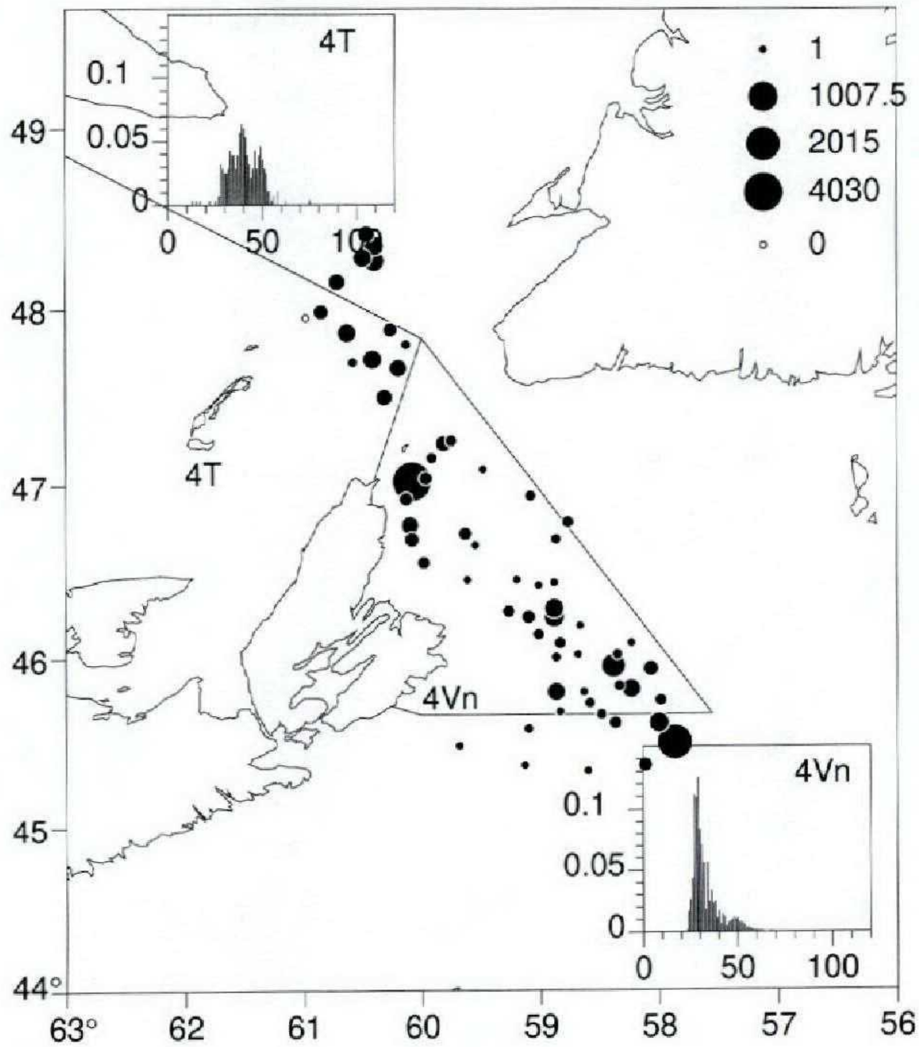


Figure A4. January, 1994 survey cod distributions.

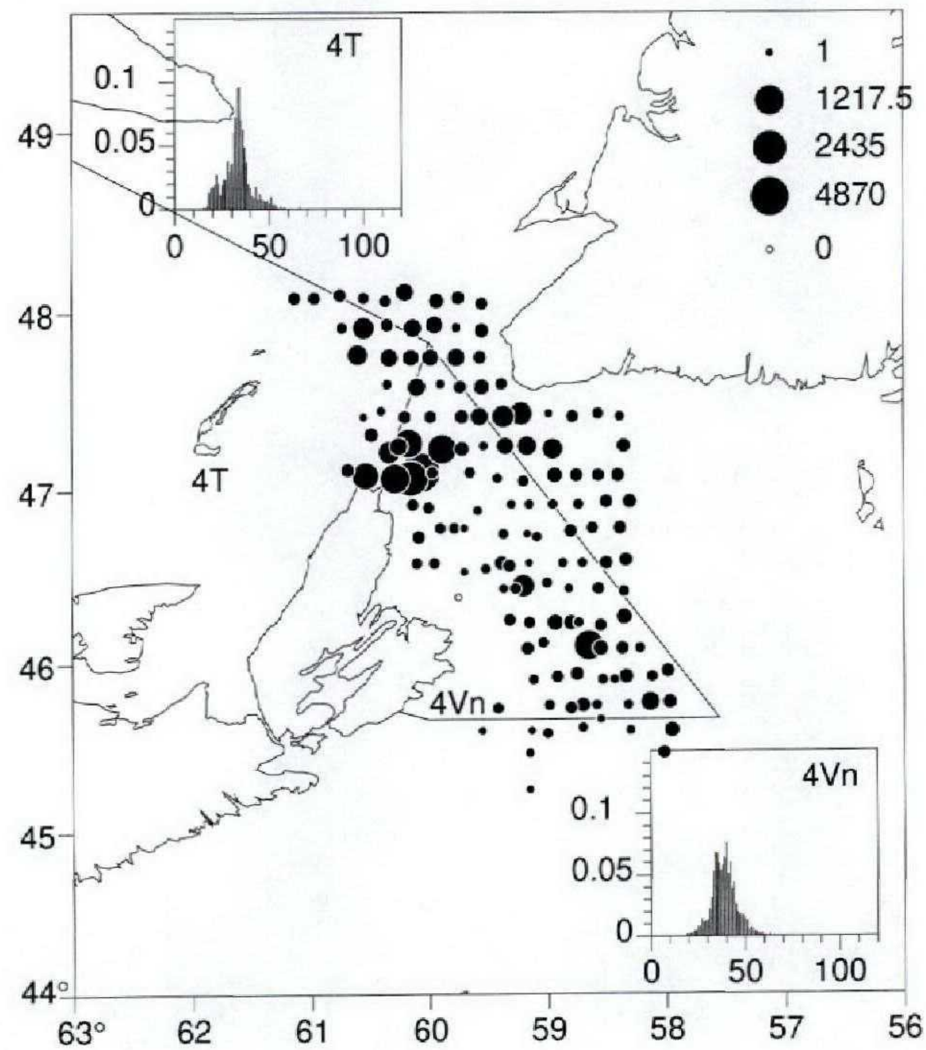


Figure A5. January, 1996 survey cod distributions.

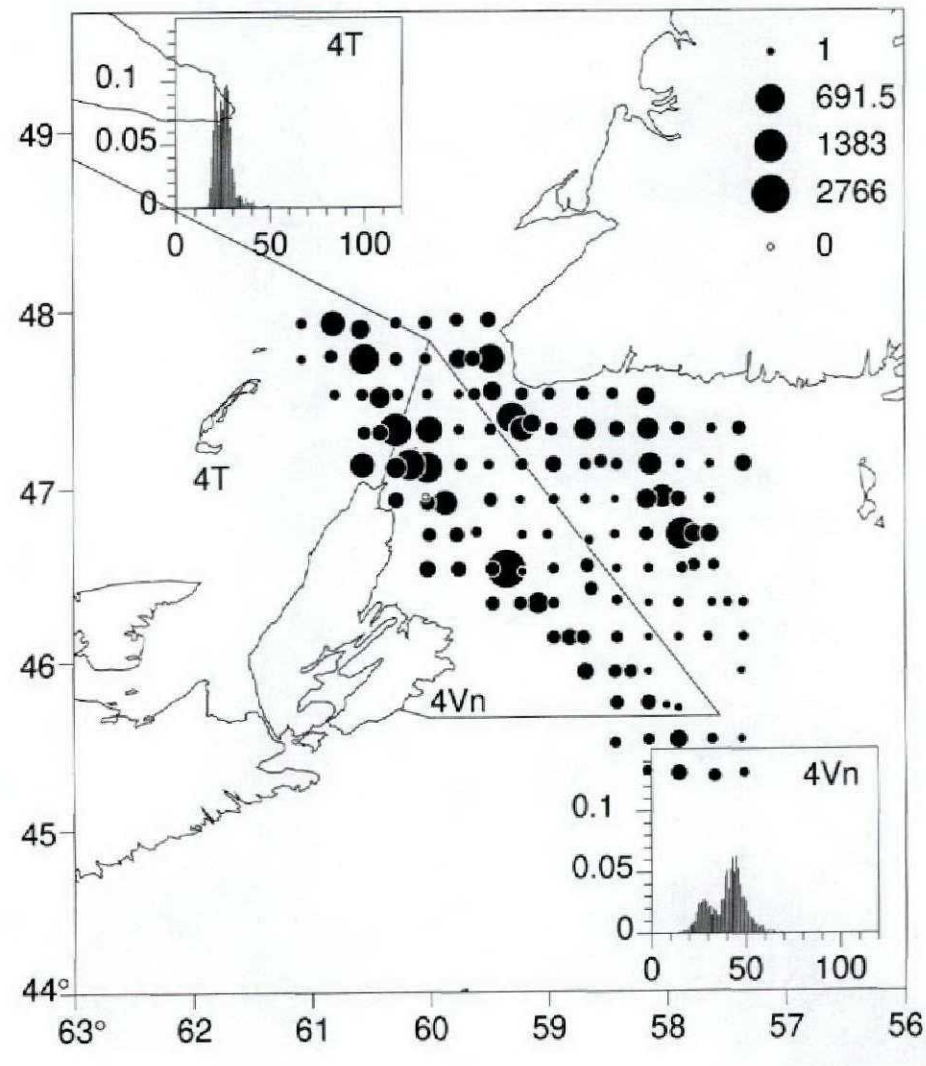


Figure A6. January, 1997 survey cod distributions.