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Assessment of 4VsW Cod

by

A. Sinclair
Marine and Anadromous Fish Division
Gulf Fisheries Center
P.O. Box 5030
Moncton, New Brunswick
E1C 9B6

and

S.J. Smith
Marine Fish Division
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
B2Y 4A2

Abstract

Nominal catch in 1986 was 51,306 t, down 5,756 t for 1985. The catch was 3,000 t over the TAC which had been reduced from 55,000 t in 1985 to 48,000 t in 1986. Comparison of observed and predicted 1986 catch at age indicated a greater than expected catch of the recruiting 1981-1983 year-classes. Size segregation of the cod was noted from an analysis of research vessel survey results, and evidence for shifts in fishery effort in response to the recruitment of the strong 1979 and 1980 year-classes was presented. The 1986 age 5+ population estimates from the research survey was down by 50% from that in 1985, but was comparable to estimates from the 1980's. Otter trawl catch rates continued to increase in 1986. However, the increasing trend may be more indicative of high densities of cod in Subdiv. 4Vs than of overall abundance. Cohort analysis was calibrated with both the research vessel survey and commercial catch rate series, and these indicated a 1986 terminal fishing mortality of .35. Catch projections based on these results indicated that if the 1987 TAC of 44,000 t is taken, the 1988 $F0.1 = 2$ would be 32,000 t.

Résumé

Les prises nominales en 1986 ont été de 51 306 t, soit une réduction de 5756 t par rapport à 1985. Il s'agit d'un excédent de 3000 t par rapport au TPA qui avait été réduit de 55 000 t en 1985 à 48 000 t en 1986. Une comparaison entre les prises par âge observées et prévues en 1986 a indiqué une prise plus élevée que prévue des classes d'âge de 1981-1983 (recrutement). Une répartition de la morue en fonction de la taille a été constatée à partir des résultats des relevés effectués par les navires de recherche et on a relevé des indices montrant que l'effort de pêche aurait changé en réponse au recrutement des classes d'âge très fortes de 1979 et 1980. En 1986, les estimations de la population d'âge 5+ à partir des relevés effectués par les navires de recherche ont diminué de 50 % par rapport à celles de 1985, mais elles étaient comparables aux estimations faites dans les années 1980. Les taux de capture par chalut à panneaux ont continué à augmenter en 1986. Cependant, cette tendance à la hausse pourrait refléter davantage des densités élevées de la morue dans la subdivision 4Vs qu'une augmentation globale de l'abondance. L'analyse par cohorte a été étalonnée à la fois avec les résultats des relevés effectués par les navires de recherche et avec les taux de prise des navires commerciaux; il en découle que le taux de mortalité par pêche de dernière année en 1986 serait de 0,35. Les prévisions des prises fondées sur ces résultats indiquent que si le TPA de 44 000 t pour 1987 est réalisé, le taux de prise en 1988, pour un $F_{0,1} = 2$, sera de 32 000 t.

Introduction

A preliminary estimate of nominal catch in 1986 is 51,306 t, down from 57,062 in 1985 (Table 1 and Figure 1). There was also a reduction in TAC from 55,000 to 48,000 t. The foreign allocation to Portugal (1130 t) was revoked in 1986 and reallocated to the offshore fleet. Consequently, the only foreign catch was bycatch in the silver hake and redfish (Japan) fisheries. Nominal catch declined proportionally in Subdiv. 4Vs and Div. 4W, and Subdiv. 4Vs continued to give over 80% of the catch.

Catch by Canadian gears by Division is given in Table 2. Most of the decrease in catch was realized by otter trawlers, but the catch by seiners also declined by over 50%. Longline catch remained at the 1985 level. Gillnet and pair trawl catches increased in 1985 and 1986 and this is represented by a higher miscellaneous gear catch in the past two years.

The 1986 TAC of 48,000 t was exceeded by 3,300 t. Overruns of quotas in two gear sectors were recorded in quota reports (Table 3); namely the fg < 65' and the mg < 65'. In addition, an audit of landings slips and log records from the mg < 65' fleet conducted by Operations Branch personnel indicated approximately 2,300 t may have been misreported into Subdivision 4Vn. However, the basis of this audit was not considered to be firm enough to adjust the official statistics.

Catch at age

The 1984 catch-at-age estimates were revised due to the incorporation of additional length data not used in the original calculations. Details on these additional data are given in Table 4 and the revised age composition is given in Table 5. Comparison of the original and revised estimates (Table 6) indicate that differences are minimal with the largest difference being that the new age 4 estimate is 3% less than before.

Six age length keys were used to estimate the 1986 commercial catch at age. The input data are described in Table 7. Pair trawl landings were included with otter trawls, and handline landings with longlines. The length-weight parameters were estimated from the 1986 summer survey.

Catch at age by key is given in Table 8. As usual the longlines caught older fish than otter trawlers. There was an increased proportion of catch of ages 4 and 5 by otter trawlers in the second half of the year. These two ages made up 35% of the catch numbers in the first half year and 60% in the second half. In total the 1986 catch was dominated by the 1979-1982 year-classes (ages 4 to 7) which accounted for 87% of the numbers. These 6 keys accounted for 49,289 t, or 96% of the total catch. The total catch at age for these keys was prorated to represent the total nominal catch.

A comparison of the observed and projected 1986 catch at age indicates much higher than expected catch at ages 4 to 6 (1982, 1981 and 1980 year-

classes) (Figure 2). Projections last year used partial recruitment (PR) estimates for age 3 and 4 that were substantially lower than the mean values as shown below.

Age	Mean PR	Projected PR
3	.13	.013
4	.51	.25

The lower values were used in the SPA to give estimates for the 1981 and 1982 year-classes equal to the lowest previously observed. The projections were re-run using average PRs for ages 3 and 4 to see if a better agreement with the observed age compositions could be found. The resulting age composition is shown as P2 in Figure 2. In both cases it is clear that the projections indicated a broader age composition than that observed. This indicates that in 1986 the 1980-1982 year-classes made up a higher proportion of the population than what was expected.

Catches of age 2-4 fish have decreased in recent years (Table 9a). Since 1983 the catch of 2 year old fish has been substantially reduced, while that of age 3 fish has also declined since 1984. Also, the catches at age 4 in 1985 and 1986 have been the lowest observed since 1978. At the same time the total numbers caught over these years was relatively unchanged. Weights at age in the commercial fishery in 1986 were among the lowest since the early to mid 1970s (Table 9b).

Research Survey Results

Spatial segregation of age groups in the management unit were noted in a preliminary analysis of summer research survey results (Sinclair and Annand 1986). The spatial segregation of age groups has important implications on PR in the commercial fishery. If such a condition exists fishermen may be able to track strong year-classes by changing fishing grounds. Further analysis of this aspect of 4VsW cod life history was carried out using seasonal survey results. The authors stress that the following results are preliminary and that further analysis is required before definitive statements can be made about cod migrations and distributions in the area.

In addition to the summer research vessel surveys of 1970-1986, surveys were conducted in the Scotia-Fundy Region on an experimental basis in the spring of 1979-1984 and fall of 1978-1984. At present, age composition data are available for the 1979-1983 spring and 1978-1982 fall surveys. Numbers and weights at age were calculated on a tow by tow basis using the SMS software of O' Boyle and Wallace (1986). Overall mean catches per tow by stratum and age were calculated. For each age the stratum means were standardized to the grand mean catch per tow of the age group over all years. These standardized mean values were then plotted to examine the

geographic distribution of age groups. Maps of strata boundaries from the research surveys and of common fishing banks are given in Figure 3. Standardized mean catch per tow by strata for ages 2, 4, 6, and 8 are given for the spring, summer, and fall surveys in Figures 4, 5, and 6 respectively. For each season there is a tendency for the younger ages to be concentrated in the shallow strata around Sable Island and for the older ages to be concentrated in strata 43-45, in northern 4Vs.

On a finer scale, it is important to note the following. In the spring, the highest densities of age 4 were in strata 54-57, Sable Island Bank and south of Middle Bank. At age 6 the highest densities were in strata 45, 50-52, 54, and 55. That is north of Banquereau and around the Gully, where age 4 are relatively less dense, and Sable Island Bank (Figure 4). In the summer, strata 55 has the highest age 4 density, while at age 6 the highest densities are north of Banquereau (Figure 5). In the fall the two strata on Banquereau Bank (47 and 48) are important for all ages, but tend to be slightly more important for ages 6 and 8 (Figure 6). As is demonstrated later, these are important fishing areas. Shifts in fishing grounds may lead to changes in partial reccruitment.

Depth and temperature distributions at age were estimated by number weighted mean depths and temperatures. Mean depth at age was estimated by:

$$Da = \frac{\sum_{i=i}^{s} N_{ai} D_i}{\sum_{i=i}^{s} N_{ai}}$$

where N_{ai} = the numbers caught at age a in set:
D_i = the depth of set i

This was done for each seasonal data set. In addition, for each age the mean depth and temperature was plotted with the bottom temperature profile for the strata corresponding to Subdiv. 4Vs and Div. 4W (strata 43-52 and 53-66 respectively). The results are given in Figures 7-9 for spring, summer, and fall respectively.

For each season older fish were found at greater depths. In the spring the range of depths was narrower than the other two seasons. In the spring the mean temperatures at age, for all ages but age 1, were between 2-3°C. In the summer the range of temperatures were between 3-4°C. The pattern was much different in the fall with the mean temperature constantly decreasing with age.

Temperature profiles by (Sub) Division differed substantially with water deeper than 75 m being about 3-4°C colder in Subdiv. 4Vs. In the spring and summer the mean depths and temperatures at ages 5 and above were

closest to those found in Subdiv. 4Vs. This also was true for ages 2-4 in the spring. In the summer, however, mean temperatures and depths at ages 2-4 were closer to those in Div. 4W. These trends suggest that as the cod get older they move into Subdiv. 4Vs to stay in water that has a preferred temperature range.

It is cautioned that the trends noted here may be biased by the higher abundance of cod in the management unit in recent years since the averages were weighted by numbers caught. The suggested movement of cod also does not agree with the conclusions of McKenzie (1956) who found two stocks in the area, one on Banquereau Bank and the other on Sable Island Bank. Further analysis of these data on a finer time scale is warranted before firm conclusions can be drawn.

Population estimates from the 1986 summer survey are substantially lower than in 1985 (Table 10). Total numbers are about 54 million, half of the 1985 estimate. This continues a trend from 1982 with total abundance estimates decreasing at a rate of approximately 45% per year. Estimates of age 2 and 3 abundance were the lowest ever observed, and the age 1 estimate was the third lowest. The age 4 and 5 estimates were in the mid range, while those for ages 6 and older were among the highest observed. Thus, the 1986 RV abundance estimates indicate a relatively high mature stock abundance, but low abundance of young fish.

The age 5+ abundance index has been used for calibration purposes. The 1986 value is comparable to those of 1979-1982, but is well below the 1984 and 1985 values (Figure 10). Age 5+ population estimates by strata indicate a large reduction in abundance in Div. 4W, to a level comparable to the mid 1970's (Table 11), while in Subdiv. 4Vs the 1986 value is comparable to the higher estimates of the early 1980's. The percentage of the age 5+ estimate coming from Subdiv. 4Vs has increased in the 1980's, from approximately 65% to the 1986 high of 85%.

Mean weights at age from the surveys were estimated by applying the 1985 summer length-weight coefficients (Sinclair and Annand 1986) to 1970-1986 summer research survey results using the SMS software (O'Boyle and Wallace 1986). These are given in Table 10b and are compared to the commercial mean weights for ages 3-8 in Figure 11. The research vessel survey results suggest an increase in mean weights for ages 6-8 from 1970 to 1976 followed by a decrease. Weights at ages 3-5 have been more stable but in the last two years were among the lowest recorded. In the commercial fishery the weights in all age groups appeared to increase from the early to late 1970s and decrease thereafter. The increasing trend in weight at ages 3 and 4 is likely due to a reduction in the catch of cod in the foreign small mesh fishery and increases in mesh size in the Canadian fishery; both of which would tend to reduce the selectivity of smaller fish in these age groups. The similar pattern in weights at ages 6-8 in both the commercial and research vessel survey results suggest reduced weights at age in the population rather than only in the commercial catch due to shifts in the seasons fished. By plotting these weights in the log scale and joining the

points along year-classes, the slopes of the connecting lines indicate growth rates. In both the research and commercial weights at age, the mid 1970s are characterized by relatively high growth rates, at a time of low cod biomass, while the growth rates for ages 5-8 in the 1980s were lower. This latter period is believed to be a time of high cod biomass.

Commercial Catch Rates

The catch and effort data from 1965-1985 described in Sinclair and Annand (1986) was updated to include preliminary data from 1986. All observations where either catch or effort was less than 10 units were eliminated from the data set. The 1965-1985 series had observations deleted for reasons given in Sinclair and Annand (1986). The only change made here was to include the 1985 TC4 and TC5 Maritime stern otter trawlers in the analysis in order to assess their potential effect on the parameter estimates. Last year the points were removed because it was suspected that the imposition of trip limits on these vessels led to a change in fishing behaviour such that the cod catch rates may have been artificially deflated.

One of last year's research recommendations was to investigate the appropriateness of including longline catch and effort with that of the otter and pair trawls in the multiplicative model used to derive a standard catch rate series. Sinclair (1986) investigated partial recruitments for the two gears and concluded that since otter trawlers caught younger fish than the longliners, it would not be appropriate to combine the two gear types in a single index of stock biomass. Consequently a separate analysis of longliner catch rates was conducted here.

A multiplicative model was fitted to the longline data and the results are presented in Table 12. The initial analysis was done with the STSC-APL workspace STANDAR(D) (Anon 1986). The factor for tonnage class (type 1) was not significant while the factors for month (type 3) and year (type 4) are significant at the 5% significance level. The factor for area (type 2) was highly significant. Examination of the regression coefficients and their associated standard errors in Table 13 indicates that chronologically there probably has not been a year effect since 1977 and given the degrees of freedom available, earlier effects appear to be marginal. The main contributor to the year effect appears to be the very low value for 1968 (Figure 12).

The analysis in STANDAR(D) presents the sum of squares for a factor given that all other factors are already in the model. Further investigation of this model for these data would require more flexibility in assessing the fit of the factors in the model. Although STANDAR(D) does offer partial leverage plots as a diagnostic tool, it does not allow one to look at the effect of sequential addition of the factors in the model. Therefore, further analysis was carried out using the GLIM (Generalized Linear Interactive Modelling) system (Payne, 1986). This software was designed for exploring and evaluating the fit of linear models. The

generalized aspect refers to the fact that it can be used for error distributions that are not normally distributed but do belong to the exponential family of distributions (e.g. poisson, gamma, binomial). The response variable in these analyses was ln (catch rate) and a normal distribution of errors was assumed.

The theory of Generalized Linear Models refers to the measure of discrepancy between the observed and fitted values, formed from the logarithm of the ratio of the likelihoods as deviance (McCullagh and Nelder, 1983). For the Normal distribution the deviance is simply the residual sum of squares. The test statistic used to assess the factors in the model is the deviance divided by an estimate of the scale parameter. For a normal distribution of errors the estimate of the scale parameter is equivalent to the Mean-Square for residuals from the ANOVA table. This statistic has a central Chi-squared distribution under the null hypothesis.

An analysis of deviance for the longliner data is presented in Table 14. The column labelled "Deviance" gives the change in the residual sum of squares as one goes from a model with more parameters (maximal model) to the model with fewer parameters (current model). This measure is then adjusted by the scale parameter (mean deviance for the maximal model) and tested by a Chi-square test. The results of this test are given in the column labelled P-level. The main result to note here is that the factor for gear (TC) is significant at the 5% level if it is entered before the time factors (month and year). Month only becomes significant once Area is entered in the model. It appears that there may be a Month Area interaction and this needs to be explored further. As it stands these results do not change the findings from the STANDAR(D) analysis. That is, the year effect is mainly from the 1968 point and therefore this catch rate series does not appear to exhibit significant yearly trends.

The catch rate analysis was continued by confining attention to otter trawlers and Spanish pair trawlers. The analysis of deviance for these data is presented in Table 15. The factor for area becomes more or less significant depending upon what factors are in the model. There appears to be a relationship between area and year such that area differences are probably temporal. The factor for area was dropped from the model pending further investigation.

The degree of influence or leverage that an observation has on the fitted value is measured from the diagonal elements of what is called that Hat matrix. The estimate for the coefficients for the linear model given above is defined as,

$$\hat{\beta} = (X^T X)^{-1} X^T Y_0$$

where X is the design matrix, X^T is the transpose of this matrix and Y0 is the observation vector (ln catch rate). The fitted values are estimated as:

$$\hat{Y} = X\hat{\beta} \qquad \text{or}$$

$$\hat{Y} = X\,(X^T X)^{-1}\,X^T Y_0$$

$$\hat{Y} = HY_0$$

where H is referred to as the Hat matrix and it essentially relates the observations to the fitted values. The diagonals of this matrix are used as a measure of this relation with those exceeding 2p/n (p=number parameters and n=number of observations) being considered extreme (Belsey, Kuh and Welch, 1980). Leverage values were calculated for the observations after fitting the final model given in Table 15. These values are plotted against year and gear in Figure 13. The top left plot shows the temporal distribution of the gear categories. These categories are coded as,

1 : OTB1 TC4 Maritime
2 : OTB2 TC2 Maritime
3 : OTB2 TC3 Maritime
4 : OTB2 TC4 Maritime
5 : OTB2 TC5 Maritime
6 : OTB1 TC4 Newfoundland
7 : OTB2 TC4 Newfoundland
8 : OTB2 TC5 Newfoundland
9 : PT TC4 Spain
10 : PT TC5 Spain

No gear categories extend completely throughout the series. The years 1967, 1978 and 1979 were all flagged because few gear types were used for those years. Most of the leverage points identified for gear are identified for the same reason. Table 16b gives the analysis of deviance after eliminating these high leverage points. A further calculation of the leverage values was computed after fitting the model to the reduced data set and the results are given in Figure 14. The years 1965 and 1966 are now flagged as having high leverage because there is only one gear in these years. The model was fitted again to the data set with these high leverage points omitted and the analysis of deviance is given in Table 16c. The estimated mean catch rate by year for the fitted values from the three analyses in Table 16 are given in Table 17. These trends are plotted in Figure 15 where the main differences appear to be in the first few years. The mean catch rate by year from the fit given in Table 16c is plotted against the series used last year in Figure 16. This catch rate series follows very closely that used last year with the exception of the trend in 1981-1983. The inclusion of the 1985 otter trawl data referred to earlier did not significantly affect the yearly estimates for those years.

The estimates of the coefficients for each of the levels of the factors are given in Table 18. Comparing the estimates and their respective standard errors for the levels of year, there appear to be changes in the mean catch rate over most of the years relative to the standard. Six levels

of year are designated as aliased in this table and in Table 17. There are two types of aliasing both of which relate to the estimability of the parameters. Intrinsic aliasing refers to the condition where the design matrix can not be inverted when one includes a mean effect and all levels of a factor. STANDAR(D) and GLIM avoid this by setting one level of a factor as a reference against which the other levels are compared. Extrinsic aliasing occurs most often when there are no observations for a level of a factor or when levels of one factor or covariate is a linear combination of some other levels of some other factor or covariate. In this case the years 1965, 1966, 1967, 1978 and 1979 are extrinsically aliased whereas since 1965 has been removed 1986 is intrinsically aliased.

All observations from the years 1965-1967, 1978 and 1979 were identified as having high leverage or influence on the associated fitted values. Removal of the observations from the former set of years resulted in large changes in the year estimates for 1979-1986 (Figure 16). Inclusion or removal of the 1978 and 1979 data did not affect any other estimates. Therefore the final standard catch rate series was calculated using data from 1968-1986 and the yearly estimates are given in Table 19 and in Figure 17. The trend in this series indicates a steady decline from 1968 and 1975, followed by an increase to the 1986 level which was the highest in the series.

Fisheries Distribution

From 1960-1979 less than 60% of the yearly nominal catch was taken in Subdiv. 4Vs, but in the 1980's this increased to over 80% (Figure 18). In 1986 over 85% of the catch came from Subdiv. 4Vs, the highest percentage recorded.

Examination of catch and effort data from the Scotia-Fundy Observer Program indicated a reduction in the area fished in the spring offshore fishery in the recent past (Figure 19). During 1981-1984 the fishery was conducted in both Div. 4W and Subdiv. 4Vs, with high catch rates experienced south of Sable Island. This corresponds to when the strong 1979 and 1980 year-classes were aged 3 to 5 and to where these age groups are concentrated according to research vessel survey results. The shift of fishing effort away from Div. 4W in 1985-1986 may be due in part to the fishing fleet tracking these strong year-classes into Subdiv. 4Vs. Investigation of the age composition of commercial catches in the two areas for the years 1983-1986 may clarify the situation.

High catch rates were experienced throughout Subdiv. 4Vs in 1985 while in 1986 catch rates were high on the edge of the Laurentian Channel but less intense on the banks. The shift in the observed fishing effort corresponds to the recent increase in the proportion of the nominal catch coming from Subdiv. 4Vs. However, it should be noted that with a reduction in the area fished, the high catch rates given in the past two years may be more indicative of high density in Subdiv. 4Vs than the abundance of fish in the

entire management unit. The fall otter trawl fishery has been concentrated in Subdiv. 4Vs since 1981 (Figure 20). There has been little change in the area fished but in 1985 and 1986 high catch rates have been made on the Subdiv. 4Vs - 4Vn border.

Partial Recruitment

Partial recruitment (PR) for input to sequential population analysis (SPA) is usually estimated from tables of fishing mortality (F), standardized to yearly fully recruited F. Often an average of several yearly vectors is used. However, a declining trend in PR has been noted for this management unit in the recent past (Gagné et al. 1984; Sinclair and Gavaris 1985; Sinclair and Annand 1986). These changes may be due to variations in catch by gear (Sinclair 1986) or to shifts in areas fished. Therefore, average PR from the last three years has been used here to minimize the impact of the trend in PR. While this may be indicative of PR in the recent past it may not be indicative of that in the last year. This problem will remain as long as the gear and area effects on PR cannot be quantified.

PR for 1983-1985 was estimated by assuming full recruitment for ages 7-10, calculating a yearly fully recruited F weighted by population numbers, then estimating PR for younger fish. Averages were calculated for all ages over the 3 years, and the average vector was adjusted so that the age 7-10 mean was equal to 1. The process was repeated by introducing the PR vector to cohort analysis until a stable vector was found. Age 6 was found to be fully recruited and there was little variation across ages 6-11. In subsequent analyses the PR for ages 6-15 was set at 1.0.

The resulting vector (PR 83-85) is compared to that obtained using the same procedure for years 1982-1984 last year (PR 82-84) in Table 20. The values for ages 3-5 were lower this year than last, indicating a reduction in PR in the recent past.

Sequential Population Analysis (SPA)

Cohort analysis on ages 1-15 was calibrated using 5+ research vessel survey population numbers against 5+ mean population numbers and otter trawler exploitable biomass against otter trawler catch per unit effort.

Calibrations with research vessel survey estimates used the survey estimates as the dependent variable based on the coefficients of variation of the survey and SPA (Sinclair and Annand 1986). The 1970 point was not included in calibrations as in previous assessments (Sinclair and Gavaris 1985, Sinclair and Annand 1986). The distribution of the last 3 points caused the discriminating power of the regressions to be poor. The correlation coefficient was highest between an F_t of .45 and .50 (.81), but was relatively stable from .35 to .60 (.79-.81) (Table 21). The sums of

squares of the last 5 residuals standardized by the mean square error declined with increasing F_t. In the range of F_t considered, .30 to .60, the intercept values were not significantly different than zero. Given these observations, it was considered most appropriate to use the simplest model, that is to choose an F_t which put the intercept closest to the origin. This was at F_t = .35. A plot of the relationship is given in Figure 21.

Otter trawler exploitable biomass was calculated from yearly otter trawl PR and mean population biomass. Otter trawl PR was estimated from otter trawl partial fishing mortalities. Based on earlier work on otter trawler partial recruitment (Sinclair 1986) full recruitment was assumed for ages 6-7. The estimated otter trawl partial recruitment matrix is given in Table 22.

The calibration was hampered by the relative position of the most recent points. Since the catch rates increased continuously from 1982 to 1986 the correlation coefficient increased and the sum of squares of the last 5 standardized residuals decreased with decreasing F_t (Table 23). These two criteria indicated F_t less than .10. At this value of F_t the intercept was highly significant and negative and the results are highly influenced by the last 3 points. However, as noted above, the recent shift of the fishery to Subdiv. 4Vs could have caused these catch rates to be indicative of density in that area and not of overall stock biomass. Without having a suitable method to weight divisional catch rates, it was not possible to take this into account. Again, the simple model with a zero intercept was considered most appropriate. This procedure indicated F_t = .35. The residuals around the predicted biomass indicated higher than expected catch rates for 1985-1986 (Figure 22). This is consistent with the observed shift of the fishery.

Based on these calibrations it was concluded that an F_t for 1986 of .35 was the best estimate.

No independent recruitment indices are available for this stock due to the lack of internal consistency along cohorts in the survey population estimates. However, the age 2 estimates of the 1983 and 1984 year-classes are the smallest in the survey time series. Also the age 3 estimate of the 1983 year-class was the smallest in the series. Using the 1986 F_t of .35 and the PR estimate given in Table 20, the 1983 year-class was estimated to be extremely small, less than 20 million fish at age 1. The smallest previously observed year-class was the 1972 at 64 million. Due to the uncertainties in the PR in recent years and the indication that these year-classes were small, the 1986 PR was adjusted to increase the 1983 and 1984 year-class estimates to be equal to the 1972 year-class.

Beginning of the year population numbers, fishing mortality, and mean population biomass are given in Tables 24-26.

Assessment Results

Recruitment

The long-term geometric mean age 1 recruitment to the stock is 107 million. The stock experienced above average recruitment from the late 1950's to the mid 1960's (Figure 23 Data prior to 1970 taken from Gagné et al. 1984). Recruitment declined somewhat through to the mid 1970's. However, the 1977-1980 year-classes were average to above average in size. This has been followed by relatively poor recruitment since 1981. The 1985 year-class was assumed to be equal to the geometric mean of the 1969-1980 year-classes of 91 million.

Stock Size and Production

The components of production (recruitment (age 3), growth, natural mortality, catch) were calculated for the 1970-1986 period using the FISH workspace of Rivard (1982). These are compared to the trend in mean biomass for the resource. The calculations were not performed for the period prior to 1970 due to uncertainties in weight at age.

The biomass of the resource was high in the 1960's, between 150,000 t to 200,000 t (ages 3+) (Figure 24). Production in the early 1970's was due mainly to growth with age 3 recruitment being low, largely due to estimated removals of age 1-3 cod as by catch in the silver hake fishery (Figure 25). In this period catch exceeded surplus production and this led to a deline in biomass to a historic low in 1975. A reduction in the catch of young cod, the recruitment of the strong 1977-1980 year-classes, and a general reduction of fishing mortality have all occured since the extension of fisheries jurisdiction. As a result surplus production has increased and exceeded catch for the period 1976-1983, allowing the stock to grow to an historic high level of approximately 250,000 t in 1983. Recent declines in mean weight at age has contributed to reduced growth production, and there has also been a decline in recruitment. Catch has exceeded surplus production for the past three years causing a slight decline in stock biomass.

It should be noted that the trends described for the past 4-5 years are highly dependent on the estimated stock size in 1986.

Prognosis

Catch projections were made using the beginning of the year 1987 population numbers (estimated using 1986 population numbers [Table 24] and the 1986 F [Table 25]), the average weights at age for 1984-1986, and the average PR from 1983-1985. The 1986-1987 year-classes were assumed to be equal in size to the geometric mean of the 1969-1980 year-class age 1 abundance of 91 million. Input for projections are as follows:

Age	1987 Population Nos.	Weight	Partial Recruitment
1	91,000	.000	.00
2	74,656	.485	.00
3	43,015	.703	.06
4	35,501	1.002	.35
5	28,384	1,383	.80
6	20,886	1.858	1.00
7	19,343	2.466	1.00
8	7,559	3.126	1.00
9	3,254	3.704	1.00
10	2,368	5.029	1.00
11	936	6.165	1.00
12	604	7.020	1.00
13	227	9.644	1.00
14	139	10.272	1.00
15	24	11.610	1.00

If the 1987 TAC of 44,000 t is taken, which would generate a fishing mortality of .28, the projected $F_{0.1}$ = .20 catch in 1988 is 32,000 t. If $F_{0.1}$ is taken in 1987 and 1988, the yields would be 32,000 t and 34,000 t respectively. Projected catch at age under both options is given in Table 27.

A summary of vital parameter estimates from the past 4 assessments of the stock are given below:

		Year-class size at age 3 (x10-6)				
Assessment Year	F_t	1979	1980	1981	1982	1983
1984	.35	111	112	(72)*	(72)*	
1985	.40	81	69	43	(72)*	
1986	.30	89	71	44	43	(61)*
1987	.35	74	87	54	48	43

*Assumed

Each estimate of Ft has been well above $F_{0.1}$ = .2. The major differences between the 1984 and 1985 assessments were the estimated sizes of the 1979 and 1980 year-classes. Estimates of the 1979-81 year-classes were consistent between 1985 and 1986, but the 1982 year-class estimate was revised downward. The most recent estimates are lower for the 1979 and 1983 year-classes, but higher for the 1980 to 1982 year-classes.

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Table 1. 4VsW cod nominal catches by country and NAFO Divisions.

YEAR	CANADA	FRANCE	PORTUGAL	SPAIN	USSR	OTHERS	TOTAL	SUBDIV. 4Vs	DIV. 4W	TAC
1958	17938	4577	1095	14857	-	124	38591	23790	14801	-
1959	20069	16378	8384	19999	-	1196	66026	47063	18963	-
1960	18389	1018	1720	29391	-	126	50645	27689	22956	-
1961	19697	3252	2321	40884	113	42	66309	34237	32072	-
1962	17579	2645	341	42146	2383	60	65154	26350	38804	-
1963	13144	72	617	44528	9505	307	68173	27566	40607	-
1964	14330	1010	-	39690	7133	1094	63257	25496	37761	-
1965	23104	536	88	39280	7856	122	70986	36713	34273	-
1966	17690	1494	-	43157	5473	711	68525	27177	41348	-
1967	18464	77	102	33934	1068	513	54158	26607	27551	-
1968	24888	225	-	50418	4865	32	80428	48781	31647	-
1969	14188	217	-	32305	2783	672	50165	22316	27849	-
1970	11818	420	296	41926	2521	453	57434	28639	28795	-
1971	17064	4	18	30864	4506	107	52563	24128	28435	-
1972	19987	495	856	28542	4646	7119	61645	36533	25112	-
1973	15929	922	849	30883	2918	2592	54093	23401	30692	60500
1974	10700	35	1464	27384	3097	1061	43741	19611	24130	60000
1975	9939	1867	546	15611	3041	1512	32517	11694	20823	60000
1976	9567	697	-	11090	1018	2035	24407	11553	12854	30000
1977	9890	68	-	-	97	335	10390	2873	7517	7000
1978	24642	437	-	57	218	51	25405	10357	15048	7000
1979	39219	18	-	2	683	108	40030	15393	24637	30000
1980	48821	17	5	5	338	66	49252	31378	17874	45000
1981	53053	-	-	-	630	35	53718	32107	21611	50000
1982	55675	-	-	-	45	34	55754	40110	15644	55600
1983	50898	-	1230	-	190	62	52380	33170	19210	64000
1984	52104	-	303	-	110	30	52546	42578	9968	55000
1985	56090[1]	-	954[2]	-	9[2]	9[2]	57062	47830	9232	55000
1986	51248[1]	-	-	-	27[2]	31[2]	51306	43819	7487	48000

[1] Preliminary Scotia-Fundy and Newfoundland

[2] FLASH

Table 2. Canadian catch of 4VsW cod by gear and (sub) Division (from NAFO).

	4Vs					4W					4VsW				
YEAR	OTB	LL	SDN	MIS	TOTAL	OTB	LL	SDN	MIS	TOTAL	OTB	LL	SDN	MIS	TOTAL
1964	2056	42	2	-	2100	7324	708	88	4110	12230	9380	750	90	4110	14330
1965	7366	84	22	-	7472	10290	1339	159	3844	15632	17656	1423	181	3844	23104
1966	6374	143	14	-	6531	6614	1472	38	3035	11159	12988	1615	52	3035	17690
1967	6735	99	27	-	6861	6460	1453	71	3619	11603	13195	1552	98	3619	18464
1968	9501	48	18	-	9567	8360	1928	89	4944	15321	17861	1976	107	4944	24888
1969	3540	43	7	-	3590	4695	2647	13	3243	10598	8235	2690	20	3243	14188
1970	3054	21	1	-	3076	3602	3039	62	2039	8742	6656	3060	63	2039	11818
1971	5827	40	-	-	5867	4768	4173	26	2230	11197	10595	4213	26	2230	17064
1972	9856	115	4	-	9975	4732	3350	7	1923	10012	14588	3465	11	1923	19987
1973	6392	82	3	-	6477	4723	3173	20	1536	9452	11115	3255	23	1536	15929
1974	4644	56	-	-	4700	1335	2512	5	2148	6000	5979	2568	5	2148	10700
1975	1824	63	-	-	1887	3566	2558	11	1917	8052	5390	2621	11	1917	9939
1976	3755	42	-	-	3797	937	2289	14	2530	5770	4692	2331	14	2530	9567
1977	2751	50	4	-	2805	1873	3121	68	2023	7085	4624	3171	72	2023	9890
1978	9561	294	19	-	9874	7997	4321	839	1611	14768	17558	4615	858	1611	24642
1979	14853	438	86	-	15377	13784	5577	3245	1236	23842	28637	6015	3331	1236	39219
1980	28941	2116	321	-	31378	6298	6032	3440	1673	17443	35239	8148	3761	1673	48821
1981	27662	4274	171	-	32107	9148	7660	2433	1705	20946	36810	11934	2604	1705	53053
1982	32247	7069	794	-	40110	6352	5877	1943	1393	15565	38599	12946	2737	1393	55675
1983	26817	4475	671	-	31963	11280	4451	1936	1268	18935	38097	8926	2607	1268	50898
1984	37270	4122	879	21	42292	3475	3067	2144	1126	9812	40745	7189	3023	1147	52104
1985[1]	38192	7390	718	567	46867	3010	2756	1230	2227	9223	41202	10146	1948	2794	56090
1986[1]	34515	8145	250	880	43791	2206	2700	626	1925	7457	36721	10845	875	2807	51248

[1] Preliminary Scotia-Fundy, preliminary Newfoundland

Table 3. 4VsW cod - 1986 allocations and catches.

Gear Sector	Initial Allocation	Final Allocation	Catch (QR)*
Vessels > 100'	30420	31550	30431
fg 65-100'	930	18	19
mg 65-100'	640	840	734
fg < 65'	9350	9350	12216
mg < 65'	5530	6242	7357
foreign	1130		
	48000	48000	50757

*QR - Quota Report

Table 4 Data used to calculate the 1984 age length keys for 4VsW cod.

Key	Gear	Period Covered	Length-Weight Coeff. a	b	No. Measured	No. Aged	Catch
1	OTB	Jan.-Mar.	.0042	3.150	4266	575	7756
2	OTB	Apr.-Jun.	.0042	3.150	11034	670	14232
3	OTB	Jul.-Sept.	.0123	2.925	1696	252	4994
4	OTB	Oct.-Dec.	.0123	2.925	14393	429	13364
5	LL	Jan.-Jun.	.0042	3.150	4774	570	2590
6	LL	Jul.-Dec.	.0123	2.925	5474	863	4601
7	SNU	Jan.-Jun.	.0042	3.150	2870	201	1356
8	SNU	Jul.-Dec.	.0123	2.925	2229	174	1665
TOTAL							50558

Table 5. 4VsW cod catch at age ('000) by key recalculated for 1984.

Age	OTB				LL		SNU		Total
	Q_1	Q_2	Q_3	Q_4	H_1	H_2	H_1	H_2	
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	2	2
3	2	79	39	210	0	4	2	28	364
4	478	2219	638	1867	57	82	114	351	5806
5	1012	2912	1227	2821	191	223	340	351	9077
6	1314	1914	553	1166	202	265	254	241	5909
7	978	1302	170	661	206	339	274	103	4033
8	342	287	75	238	108	167	26	25	1268
9	168	104	32	80	72	95	2	4	557
10	51	29	19	72	39	76	0	0	286
11	6	9	7	46	27	53	2	0	150
12	3	4	4	11	11	28	0	0	61
13	1	4	1	0	9	18	0	0	33
14	2	1	1	0	3	9	0	0	16
15	0	0	0	0	1	1	0	0	2
16+	0	0	0	0	7	5	0	0	12
Total	4358	8864	2766	7172	932	1366	1013	1105	27576

TABLE 6: COMPARISON OF NEW AND OLD 1984 CATCH AT AGE FOR 4VsW COD.

AGE	OLD	NEW
1	0	0
2	2	2
3	421	378
4	6210	6034
5	9371	9434
6	6113	6141
7	4102	4192
8	1294	1318
9	569	579
10	293	297
11	149	156
12	61	63
13	35	34
14	17	17
15	2	2

Table 7. Data used to generate 1986 age length keys for 4VsW cod.

Key	Gear	Period Covered	Length-Weight Coeff. a	b	No. Measured	No. Aged	Catch
1	OTB, OTM, PTB	Jan.-Mar.	.0084	3.011	5745	536	9118
2	OTB, OTM, PTB	Apr.-Jun.	.0084	3.011	8965	370	11740
3	OTB, OTM, PTB	Jul.-Sept.	.0084	3.011	3349	288	11570
4	OTB, OTM, PTB	Oct.-Dec.	.0084	3.011	1998	165	5521
5	LL, LHP	Jan.-Jun.	.0084	3.011	3438	460	4465
6	LL, LHP	Jul.-Dec.	.0084	3.011	3980	533	6875
Total							49289

Table 8. 4VsW cod catch at age ('000) by key in 1986.

Age	OTB, OTM, PTB				LL, LHP		Total
	Q_1	Q_2	Q_3	Q_4	H_1	H_2	
1	0	0	0	0	0	0	0
2	0	0	0	2	0	0	2
3	0	67	23	22	3	1	116
4	640	878	1457	879	33	72	3959
5	1401	1504	2597	1371	109	229	7211
6	2377	2315	2220	980	295	484	8671
7	872	1025	592	299	218	382	3388
8	391	381	184	117	134	251	1458
9	231	230	41	48	210	302	1062
10	105	48	8	20	103	136	420
11	39	73	1	1	55	102	271
12	17	2	1	3	28	51	102
13	3	6	0	0	27	26	62
14	3	0	0	0	4	4	11
15	0	1	0	0	11	6	18
16+	1	0	0	0	11	6	18
Total	6081	6532	7123	3741	1241	2053	26771

TABLE 9A; 4VSW COD CATCH AT AGE (x10-3). 24/ 6/87

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	1293	2311	2383	1418	1482	1792	728	2	177	12	31	3	5	0	0	0	0
2	8631	15218	17738	12142	8451	9979	4061	24	153	81	152	348	149	0	2	4	2
3	8886	12582	14227	14881	12885	9485	3587	386	1004	1629	2034	3742	2500	3048	378	154	121
4	14802	9146	13361	7507	9947	4341	3713	1073	3650	6164	5119	9724	7664	8251	6034	2323	4121
5	13673	8809	9661	9755	7130	4549	4818	1559	4621	9145	7112	7276	9953	7368	9434	8353	7506
6	4539	10262	8780	3823	2766	2594	2412	871	2441	4871	6147	4852	3449	5967	6141	7782	9026
7	1942	5160	3432	2996	944	2627	1426	501	768	1162	2929	2991	2408	1938	4192	3922	3527
8	759	1849	1919	3724	1323	612	611	220	213	371	1066	1455	1273	999	1318	2224	1518
9	236	496	358	1166	413	497	184	128	112	76	319	393	674	576	579	978	1105
10	72	114	393	273	369	660	49	35	80	23	88	126	304	229	297	427	437
11	137	131	79	299	15	153	22	44	26	10	47	62	156	140	156	274	282
12	56	72	2	3	5	126	107	55	28	5	26	32	67	50	63	168	106
13	9	98	37	7	0	36	1	11	26	4	4	21	57	22	34	65	65
14	12	12	0	5	0	9	4	3	9	1	1	2	51	16	17	19	11
15	4	51	1	5	0	9	1	2	4	0	4	6	19	6	2	16	19
1+	55051	66311	72371	58004	45730	37469	21724	4914	13312	23554	25079	31033	28728	28610	28647	26709	27846
2+	53758	64000	69988	56586	44248	35677	20996	4912	13135	23541	25048	31030	28723	28610	28647	26709	27846
3+	45127	48782	52250	44444	35797	25698	16935	4888	12982	23460	24896	30682	28574	28610	28645	26705	27844
4+	36241	36200	38023	29563	22912	16213	13348	4502	11978	21831	22862	26940	26074	25562	28267	26551	27723
5+	21439	27054	24662	22056	12965	11872	9635	3429	8328	15666	17743	17216	18409	17311	22233	24228	23602
6+	7766	18245	15001	12301	5835	7323	4817	1870	3707	6522	10631	9940	8457	9943	12799	15875	16096

TABLE 9B; 4VSW COD COMMERCIAL WEIGHTS AT AGE (KG.). 24/ 6/87

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.02	0.01	0.05	0.08	0.13	0.10	0.10	0.10	0.20	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00
2	0.15	0.11	0.18	0.22	0.33	0.27	0.28	0.28	0.62	0.53	0.57	0.62	0.58	0.39	0.56	0.63	0.26
3	0.45	0.32	0.44	0.45	0.62	0.53	0.57	0.81	0.95	0.76	0.80	0.83	0.81	0.81	0.72	0.70	0.68
4	0.91	0.64	0.81	0.79	1.02	0.89	0.96	1.09	1.25	1.06	1.15	1.14	1.07	1.08	1.00	1.04	0.96
5	1.50	1.07	1.29	1.21	1.53	1.34	1.46	1.67	1.68	1.70	1.60	1.69	1.58	1.55	1.42	1.46	1.27
6	2.19	1.56	1.85	1.72	2.13	1.87	2.03	2.36	2.47	2.39	2.21	2.13	2.39	2.10	1.91	1.98	1.68
7	2.94	2.09	2.48	2.28	2.82	2.47	2.66	3.17	3.61	3.13	3.08	2.96	2.78	3.10	2.49	2.49	2.42
8	3.73	2.65	3.14	2.90	3.58	3.12	3.35	4.58	5.23	3.71	4.31	3.94	4.07	3.53	3.44	3.17	2.77
9	4.51	3.21	3.83	3.54	4.41	3.81	4.07	4.14	5.59	4.77	5.26	5.70	5.49	4.38	3.78	3.93	3.70
10	5.28	3.75	4.52	4.22	5.28	4.53	4.80	5.33	6.54	6.84	6.92	7.16	7.08	5.76	4.96	5.10	5.02
11	6.02	4.28	5.20	4.90	6.19	5.27	5.55	4.65	7.92	7.96	7.56	7.67	8.74	6.99	6.84	6.37	5.29
12	6.71	4.77	5.87	5.59	7.13	6.01	6.29	4.91	9.21	9.41	10.19	9.26	9.10	9.04	8.10	6.12	6.84
13	7.36	5.23	6.52	6.28	8.09	6.76	7.02	7.14	10.40	10.63	7.92	11.87	11.43	10.63	8.94	9.93	10.05
14	7.95	5.65	7.14	6.96	9.05	7.51	7.74	8.59	9.75	10.03	8.13	8.65	10.59	11.71	10.23	11.17	9.42
15	8.49	6.04	7.73	7.62	10.01	8.24	8.43	10.60	8.68	11.45	14.45	9.84	12.48	12.69	11.85	11.25	11.73

TABLE 10A; 4VSW COD SUMMER SURVEY POPULATION ESTIMATES (x10-3). 24/ 6/87

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	0	0	0	0	0	0	0	0	174	1017	50	74	9	57	200	0	79
1	1478	1539	6210	6430	5174	3372	2242	808	3033	1213	690	4589	2633	39572	1165	3697	1026
2	16388	7680	9674	43907	32961	8412	14066	10145	13065	10612	7064	12770	226028	37813	20894	4834	3791
3	5250	35664	11881	69024	19246	13000	16098	26372	31245	16044	18488	18936	188892	120818	36823	22643	4368
4	7714	8027	31536	56081	5623	6171	10187	17059	34205	16595	10260	30753	65976	48451	54858	27478	16126
5	3742	15803	5812	22484	2017	2959	6621	11353	9461	18075	17365	12057	14824	24808	37171	26772	10552
6	1228	5775	5989	1870	2244	675	1264	4893	3490	9053	12099	8570	8020	11398	17253	14701	11462
7	1532	3459	1621	2907	372	867	656	1081	889	2696	4794	4404	4325	2611	11861	7358	3339
8	466	1475	547	901	463	235	1308	878	185	1009	1302	1553	1850	1444	1170	2896	1678
9	104	638	495	431	224	433	0	244	90	411	338	533	413	395	955	1391	679
10	249	70	153	514	161	23	929	0	79	83	265	650	419	222	284	330	443
11	209	137	0	166	63	0	38	161	0	45	93	163	226	64	674	319	101
12	101	58	0	0	59	68	0	62	79	5	0	74	0	29	17	610	0
0+	38461	80325	73918	204715	68607	36215	53409	73056	95995	76858	72808	95126	513615	287682	183325	113029	53644
1+	38461	80325	73918	204715	68607	36215	53409	73056	95821	75841	72758	95052	513606	287625	183125	113029	53565
2+	36983	78786	67708	198285	63433	32843	51167	72248	92788	74628	72068	90463	510973	248053	181960	109332	52539
3+	20595	71106	58034	154378	30472	24431	37101	62103	79723	64016	65004	77693	284945	210240	161066	104498	48748
4+	15345	35442	46153	85354	11226	11431	21003	35731	48478	47972	46516	58757	96053	89422	124243	81855	44380
5+	7631	27415	14617	29273	5603	5260	10816	18672	14273	31377	36256	28004	30077	40971	69385	54377	28254
6+	3889	11612	8805	6789	3586	2301	4195	7319	4812	13302	18891	15947	15253	16163	32214	27605	17702

TABLE 10B; 4VSW COD SUMMER SURVEY WEIGHTS AT AGE (KG.). 24/ 6/87

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.07	0.05	0.07	0.09	0.13	0.09	0.08	0.14	0.08	0.05	0.07	0.08	0.06	0.07	0.08	0.06	0.08
2	0.24	0.19	0.31	0.25	0.31	0.28	0.26	0.28	0.40	0.26	0.29	0.34	0.29	0.24	0.28	0.14	0.26
3	0.86	0.44	0.72	0.62	0.55	0.58	0.50	0.63	0.71	0.48	0.58	0.63	0.48	0.51	0.56	0.43	0.46
4	1.17	1.05	0.85	1.03	1.12	0.96	0.94	1.04	1.20	0.94	0.96	1.17	0.72	0.97	0.96	0.75	0.84
5	1.65	1.40	1.54	1.30	1.57	1.58	1.41	1.80	1.81	1.37	1.49	1.76	1.33	1.37	1.55	1.18	1.29
6	2.39	1.74	1.74	2.10	2.05	2.27	2.11	2.52	2.74	2.15	2.26	2.14	2.15	2.11	1.86	1.67	1.71
7	3.44	2.08	1.90	2.10	3.45	3.28	3.22	3.42	3.06	3.55	2.93	2.83	2.60	3.07	2.27	2.18	2.22
8	3.55	2.63	2.67	2.89	3.46	3.46	3.24	5.29	4.68	5.28	4.72	4.34	3.41	3.48	3.83	3.01	2.73
9	5.31	3.56	7.62	2.24	2.71	4.77	0.00	5.09	6.47	5.59	7.70	6.55	4.33	4.95	3.04	3.79	3.97
10	5.68	3.10	2.34	7.96	4.01	6.17	4.99	0.00	11.96	8.26	8.33	8.79	6.17	4.83	3.33	4.34	4.93
11	3.13	2.72	0.00	4.57	8.27	0.00	6.17	5.42	0.00	7.54	10.65	8.42	8.16	8.17	7.60	7.08	7.18
12	12.74	9.06	0.00	0.00	6.17	9.06	0.00	3.97	0.00	12.74	0.00	12.74	0.00	11.74	13.80	4.46	0.00

Table 11: 4VsW cod age 5+ population estimates ('000) by strata, Division and depth zone.

DIV	DEPTH	STR	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
4VS	<50 FM	43	421	943	362	597	146	397	92	81	50	464	3188	1323	1229	5446	30937	17494	3156
		47	175	0	74	155	96	939	36	275	480	1592	10139	2386	1492	6444	512	3732	5618
		48	90	216	94	397	27	11	17	445	401	4233	192	354	254	92	268	2038	288
	50-100 FM	44	4219	16132	11436	4068	2969	1671	4374	7572	528	5250	4971	12332	11015	7499	16361	11031	14003
		49	5	17	6	39	0	10	0	5	0	57	34	0	39	58	2	22	4
		50	12	3	37	11	30	0	6	81	1	13	0	86	99	77	93	171	46
	>100 FM	45	86	2397	332	964	77	242	143	1081	264	203	4902	2150	4431	1754	2526	6681	1625
		46	60	65	81	36	39	4	169	6	0	68	280	562	1029	319	486	1162	350
		51	0	17	29	0	7	31	0	0	0	73	15	32	133	175	102	49	0
		52	0	13	0	0	139	157	57	89	0	383	12	0	293	568	277	72	64
4W	<50 FM	55	21	78	599	44	195	109	508	752	728	4278	3834	2022	7436	5622	1184	773	288
		56	25	483	125	517	66	98	703	287	204	5628	1047	797	175	487	767	495	100
		58	119	377	264	17	57	89	157	991	173	2482	2797	1017	627	1305	2698	1549	379
		63	0	54	46	0	71	161	67	78	57	103	64	127	27	0	171	60	27
		64	280	316	199	1674	818	341	893	160	518	2910	2011	1005	1168	439	934	310	150
	50-100 FM	54	0	0	37	1	0	0	23	27	1	288	44	123	94	169	0	87	0
		57	1	36	0	0	24	0	0	0	9690	0	1905	41	72	54	112	96	287
		60	330	209	0	1	0	131	0	0	106	0	146	65	67	118	0	0	10
		62	10	148	74	0	51	55	387	79	0	55	0	0	59	106	0	208	0
		65	238	245	46	43	103	106	128	46	481	231	436	37	187	118	202	95	77
	>100 FM	53	0	0	0	0	0	0	0	0	0	0	0	64	0	0	0	0	0
		61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		66	0	0	0	0	0	0	0	0	0	9	0	5	0	0	0	7	0
		59	1926	5766	749	20707	690	703	3051	6613	585	3065	225	3418	111	10013	11750	7869	1639
	TOTAL 4VS		5068	19803	12451	6267	3530	3462	4894	9635	1724	12336	23733	19225	20014	22432	51564	42452	25154
	TOTAL 4W		2950	7712	2139	23004	2075	1793	5917	9033	12543	19040	12518	8716	10028	18431	17818	11549	2957

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... .630
MULTIPLE R SQUARED..... .397

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	5.853E0002	5.853E0002	
REGRESSION	32	4.889E0001	1.528E0000	8.593
TYPE 1	2	1.477E-001	7.384E-002	0.415
TYPE 2	1	2.310E0001	2.310E0001	129.917
TYPE 3	11	6.550E0000	5.955E-001	3.350
TYPE 4	18	9.641E0000	5.356E-001	3.013
RESIDUALS	418	7.431E0001	1.778E-001	
TOTAL	451	7.084E0002		

Table 12: Analysis of variance for the 1965-1986 longliner catch rate data.

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1	8	INTERCEPT	-0.037	0.245	451
2	1				
3	1				
4	1				
1	9	1	0.004	0.044	182
	10	2	-0.059	0.072	53
2	2	3	-0.580	0.051	282
3	2	4	-0.160	0.145	20
	3	5	-0.270	0.141	25
	4	6	-0.529	0.128	45
	5	7	-0.482	0.127	47
	6	8	-0.469	0.128	46
	7	9	-0.504	0.129	42
	8	10	-0.451	0.127	49
	9	11	-0.499	0.128	44
	10	12	-0.585	0.129	42
	11	13	-0.421	0.129	40
	12	14	-0.414	0.132	35
4	3	15	-0.249	0.248	12
	4	16	-1.691	0.478	1
	7	17	-0.026	0.234	20
	8	18	-0.251	0.234	20
	9	19	-0.244	0.234	20
	10	20	-0.438	0.245	13
	11	21	-0.617	0.247	12
	12	22	-0.609	0.246	12
	13	23	-0.345	0.234	20
	14	24	-0.251	0.227	29
	15	25	-0.340	0.228	28
	16	26	-0.239	0.223	39
	17	27	-0.251	0.222	44
	18	28	-0.345	0.222	46
	19	29	-0.482	0.222	44
	20	30	-0.193	0.229	24
	21	31	-0.115	0.228	26
	22	32	-0.205	0.224	37

Table 13: Regression coefficients for the 1965-1986 longliner catch rate data.

Table 14. Analysis of deviance for multiplicative model for longliners all data, 1965-1986 (4VsW cod).

Model	Deviance	df	P-level
1			
+gear	2.625	2	0.008
+area	29.060	1	0.000
+month	7.557	11	0.000
+year	9.641	18	0.000
+area	31.14	1	0.000
+month	7.489	11	0.000
+year	10.11	18	0.000
+gear	0.147	2	0.660
+month	4.604	11	0.107
+year	19.98	18	0.000
+gear	1.206	2	0.075
+area	23.10	1	0.000
+year	20.25	18	0.000
+gear	1.565	2	0.036
+area	20.52	1	0.000
+month	6.550	11	0.000
Final Model			
1			
+area+month+year	48.74	30	0.000

Scale parameter = 0.2050

Table 15. Analysis of deviance for four factor model, otter trawlers and pair trawlers (Spain) all data 1965-1986 (4VsW cod).

Model				Deviance	df	P-level
1						
+ gear				62.25	9	0
	+ area			6.272	1	0
		+ month		32.22	11	0
			+ year	145.8	21	0
+ area				7.778	1	0
	+ month			33.85	11	0
		+ year		126.7	21	0
			+ gear	78.20	9	0
+ month				34.89	11	0
	+ year			130.9	21	0
		+ gear		79.76	9	0
			+ area	1.015	1	.063
+ year				123.2	21	0
	+ gear			83.98	9	0
		+ area		0.677	1	.151
			+ month	38.62	11	0
				scale parameter = 0.2920		

				Deviance	df	P-level
Final Model						
1						
+ gear				62.25	9	0
	+ month			31.75	11	0
		+ year		151.6	21	0
				scale parameter = 0.2926		

Table 16. Comparison of analysis deviance when high leverage points omitted from analysis.

a) Full data set

Model	Deviance	df	P-level
1			
+ gear	62.25	9	0
+ month	31.75	11	0
+ year	151.6	21	0
	scale parameter = 0.2926		

b) First cycle: delete 56 points

Model	Deviance	df	P-level
1			
+ gear	53.79	9	0
+ month	31.55	11	0
+ year	141.44	18	0
	scale parameter = 0.2955		

c) 2nd cycle: delete 18 points

Model	Deviance	df	P-level
1			
+ gear	52.40	9	0
+ month	30.81	11	0
+ year	137.6	16	0
	scale parameter = 0.2966		

Table 17. Comparison of predicted catch rates for 4VsW cod for all observations and then after removal of high leverage points.

Year	Full Data Set (F) Mean	S.E.	First Cycle (1) Mean	S.E.	Second Cycle (2) Mean	S.E.
1965	1.412	0.242	1.133	0.436	aliased	
1966	1.327	0.222	1.276	0.239	aliased	
1967	1.056	0.177	aliased		aliased	
1968	1.201	0.173	1.239	0.187	1.372	0.219
1969	1.194	0.165	1.213	0.169	1.245	0.175
1970	1.069	0.151	1.077	0.156	1.107	0.161
1971	0.762	0.105	0.772	0.107	0.831	0.118
1972	0.729	0.087	0.736	0.089	0.744	0.090
1973	0.697	0.079	0.703	0.081	0.709	0.082
1974	0.523	0.051	0.527	0.053	0.530	0.053
1975	0.388	0.040	0.390	0.041	0.394	0.041
1976	0.518	0.051	0.523	0.052	0.528	0.053
1977	0.526	0.060	0.523	0.060	0.520	0.060
1978	0.565	0.112	aliased		aliased	
1979	1.096	0.200	aliased		aliased	
1980	0.954	0.094	0.954	0.095	0.946	0.095
1981	0.921	0.088	0.919	0.089	0.913	0.088
1982	1.113	0.105	1.112	0.106	1.102	0.105
1983	1.080	0.107	1.080	0.108	1.073	0.108
1984	1.162	0.117	1.162	0.118	1.155	0.118
1985	1.527	0.150	1.525	0.152	1.511	0.151
1986	1.672	0.151	1.669	0.153	1.652	0.152

Table 18: Parameter estimates for otter trawler catch rates for model 1+gear+month+year.

	estimate	s.e.	parameter
1	0.3575	0.09226	1
2	-0.6404	0.08622	GEAR(2)
3	-0.1033	0.06904	GEAR(3)
4	0.09127	0.06689	GEAR(4)
5	0.2417	0.06153	GEAR(5)
6	-0.07912	0.09177	GEAR(6)
7	0.3023	0.1185	GEAR(7)
8	0.1951	0.08190	GEAR(8)
9	0.4918	0.08101	GEAR(9)
10	0.9143	0.08628	GEAR(10)
11	0.07002	0.08455	MONT(2)
12	0.009919	0.08046	MONT(3)
13	-0.1709	0.08235	MONT(4)
14	-0.3156	0.08599	MONT(5)
15	-0.4644	0.09226	MONT(6)
16	-0.5316	0.09782	MONT(7)
17	-0.4028	0.09396	MONT(8)
18	-0.3194	0.09268	MONT(9)
19	-0.3520	0.08905	MONT(10)
20	-0.06408	0.09022	MONT(11)
21	0.02240	0.09370	MONT(12)
22	0.000	aliased	YEAR(2)
23	0.000	aliased	YEAR(3)
24	-0.1764	0.1529	YEAR(4)
25	-0.2771	0.1329	YEAR(5)
26	-0.3935	0.1380	YEAR(6)
27	-0.6806	0.1333	YEAR(7)
28	-0.7940	0.1108	YEAR(8)
29	-0.8426	0.1053	YEAR(9)
30	-1.135	0.08776	YEAR(10)
31	-1.431	0.09463	YEAR(11)
32	-1.140	0.08981	YEAR(12)
33	-1.153	0.1062	YEAR(13)
34	0.000	aliased	YEAR(14)
35	0.000	aliased	YEAR(15)
36	-0.5564	0.07976	YEAR(16)
37	-0.5923	0.07385	YEAR(17)
38	-0.4042	0.07194	YEAR(18)
39	-0.4300	0.08020	YEAR(19)
40	-0.3567	0.08233	YEAR(20)
41	-0.08802	0.07683	YEAR(21)
42	0.000	aliased	YEAR(22)

scale parameter taken as 0.2966

Current model:

number of units is 1151

y-variate CATR
weight WATE
offset *

probability distribution is NORMAL
link function is IDENTITY
scale parameter is to be estimated by the mean deviance

terms = 1 + GEAR + MONT + YEAR

Table 19. Standardized otter trawler catch rate.

Year	CPUE
1968	1.372
1969	1.245
1970	1.103
1971	.828
1972	.745
1973	.711
1974	.532
1975	.396
1976	.528
1977	.526
1978	.575
1979	1.081
1980	.953
1981	.922
1982	1.112
1983	1.083
1984	1.165
1985	1.524
1986	1.665

Table 20. Partial recruitment estimates for 4VsW cod.

Age	PR 82-84	PR 83-85
3	.13	.06
4	.51	.35
5	.87	.80
6	1.00	1.00
7	1.00	1.00

Table 21. Calibration results using SPA 5+ mean numbers as the independent variable and RV 5+ numbers as the dependent variable. The results are the correlation coefficient (r), the intercept (a), the slope (b) student T for the intercept (T), and the sum of standardized residuals (RES).

	Ft						
	.30	.35	.40	.45	.50	.55	.60
r	.77	.79	.80	.81	.81	.80	.79
a	2350	-769	-3458	-5563	-7100	-8108	-8657
b	.57	.68	.77	.85	.81	.96	.99
T	.38	-.12	-.52	-.80	-.98	-1.07	-1.10
Res	9.83	9.40	8.81	8.20	7.67	7.32	7.14

TABLE 22: OTTER TRAWL PARTIAL RECRUITMENT FOR 4VSW COD 8/ 7/87

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
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	0.000	0.000	0.000	0.000
2	0.000	0.005	0.102	0.001	0.006	0.000	0.000	0.000	0.001	0.002	0.001	0.007	0.004	0.000	0.000	0.000	0.001
3	0.002	0.052	0.200	0.074	0.526	0.005	0.000	0.008	0.106	0.153	0.039	0.131	0.123	0.157	0.027	0.009	0.076
4	0.181	0.234	0.760	0.212	1.000	0.110	0.157	0.067	0.538	0.813	0.260	0.449	0.644	0.748	0.337	0.153	0.475
5	0.456	0.439	1.000	0.592	1.000	0.537	0.628	0.403	1.000	1.000	0.591	0.867	1.000	1.000	0.950	0.530	1.000
6	0.507	0.509	1.000	0.633	0.989	0.728	0.771	0.585	1.000	1.000	0.963	0.950	1.000	1.000	1.000	1.000	1.000
7	0.977	0.746	0.868	0.732	0.735	1.000	1.000	0.971	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	0.894	1.000	1.000	1.000	1.000	0.635	1.000	1.000	0.674	0.944	1.000	0.944	0.904	0.837	0.893	0.874	1.000
9	1.000	0.998	0.931	1.000	0.338	0.988	0.653	1.000	0.690	0.398	0.744	0.657	0.626	0.997	0.650	0.948	0.714
10	0.876	1.000	1.000	0.910	0.826	1.000	0.490	0.531	0.655	0.412	0.439	0.408	0.755	0.614	0.641	0.579	0.594
11	1.000	1.000	1.000	1.000	0.000	0.682	0.432	1.000	0.471	0.243	0.526	0.324	0.482	0.960	0.399	0.711	0.580
12	1.000	1.000	0.124	0.424	0.000	1.000	1.000	1.000	0.671	0.121	0.408	0.334	0.437	0.438	0.496	0.739	0.311
13	1.000	1.000	1.000	0.338	0.000	1.000	0.000	1.000	1.000	0.457	0.091	0.327	1.000	0.134	0.164	0.263	0.199
14	0.346	1.000	0.000	1.000	0.000	0.588	0.000	0.578	1.000	0.297	0.089	0.071	0.174	0.686	0.244	0.107	0.391
15	1.000	0.292	1.000	0.834	0.000	0.165	0.000	1.000	0.513	0.000	0.762	0.316	0.136	0.275	0.000	0.065	0.075

Table 23. Calibration results with CPUE vs Fishable Biomass.

	F_t				
	.10	.20	.30	.35	.40
r	.88	.86	.80	.76	.72
a	-158038	-47044	-10033	542	8472
b	348	176	118	102	89
T	-3.33	-1.81	-.45	.03	.40
Σ Res.	5.00	6.09	7.03	7.28	7.44

TABLE 24: 4VSW COD BEGINING OF THE YEAR POPULATION NUMBERS, 8/ 7/87

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	94640	96103	74173	63597	77279	84016	74051	69652	111325	95650	111321	129063	80427	71694	64891	64173	91185
2	87620	76315	76592	58571	50786	61929	67165	59969	57025	90985	78301	91113	105665	65843	58698	53128	52541
3	51826	63927	48711	46658	36968	33933	41674	51315	49077	46550	74419	63970	74283	86376	53908	48056	43494
4	54245	34391	40955	27008	24735	18608	19200	30874	41664	39272	36637	59089	48988	58555	67961	43794	39206
5	45685	31019	19882	21441	15320	11251	11307	12360	24307	30809	26576	25364	39579	33173	40475	50182	33754
6	19352	25032	17425	7536	8728	6091	5096	4898	8709	15720	16950	15323	14183	23399	20493	24602	33527
7	6290	11737	11209	6322	2711	4643	2640	1989	3222	4921	8463	8315	8155	8491	13758	11222	13101
8	2929	3393	4941	6072	2465	1365	1424	871	1176	1943	2978	4279	4102	4498	5198	7471	5639
9	585	1712	1105	2309	1601	821	564	613	514	770	1255	1474	2187	2207	2779	3063	4105
10	319	265	953	581	835	937	223	295	386	320	562	739	851	1181	1285	1751	1623
11	320	196	114	424	228	350	170	138	210	244	241	380	491	421	759	784	1047
12	211	138	42	22	77	173	148	120	73	148	191	155	255	261	218	481	394
13	30	122	48	33	15	58	28	24	48	35	117	133	98	148	169	122	241
14	156	16	11	6	20	12	15	22	10	16	25	92	90	28	101	107	41
15	15	117	2	9	0	17	2	9	15	0	12	19	74	28	9	68	71
1+	364223	344482	296161	240588	221769	224206	223707	233151	297761	327382	358046	399508	379426	356304	330704	309004	319968
2+	269583	248379	221988	176991	144490	140191	149656	163498	186436	231732	246726	270445	298999	284610	265812	244831	228783
3+	181963	172064	145397	118420	93704	78261	82491	103529	129411	140747	168425	179331	193334	218767	207114	191703	176243
4+	130137	108137	96685	71762	56736	44328	40817	52214	80334	94197	94006	115362	119051	132390	153206	143646	132748
5+	75891	73746	55731	44754	32001	25720	21617	21340	38670	54925	57369	56273	70063	73835	85246	99852	93543
6+	30206	42727	35849	23312	16681	14469	10310	8980	14363	24116	30793	30909	30484	40662	44770	49671	59789

TABLE 25: 4VSW COD FISHING MORTALITIES 8/ 7/87

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.015	0.027	0.036	0.025	0.021	0.024	0.011	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.115	0.249	0.296	0.260	0.203	0.196	0.069	0.000	0.003	0.001	0.002	0.004	0.002	0.000	0.000	0.000	0.000
3	0.210	0.245	0.390	0.435	0.486	0.369	0.100	0.008	0.023	0.039	0.031	0.067	0.038	0.040	0.008	0.004	0.003
4	0.359	0.348	0.447	0.367	0.588	0.298	0.240	0.039	0.102	0.191	0.168	0.201	0.190	0.169	0.103	0.060	0.123
5	0.402	0.377	0.770	0.699	0.722	0.592	0.637	0.150	0.236	0.398	0.351	0.381	0.326	0.282	0.298	0.203	0.280
6	0.300	0.603	0.814	0.822	0.431	0.636	0.741	0.219	0.371	0.419	0.512	0.431	0.313	0.331	0.402	0.430	0.350
7	0.417	0.665	0.413	0.742	0.486	0.982	0.909	0.326	0.306	0.302	0.482	0.507	0.395	0.291	0.411	0.488	0.350
8	0.337	0.922	0.561	1.133	0.899	0.684	0.643	0.327	0.223	0.237	0.504	0.471	0.420	0.282	0.329	0.399	0.350
9	0.591	0.386	0.443	0.817	0.335	1.105	0.447	0.262	0.275	0.115	0.330	0.349	0.416	0.340	0.262	0.435	0.350
10	0.287	0.645	0.609	0.733	0.670	1.505	0.279	0.140	0.260	0.081	0.190	0.209	0.503	0.241	0.295	0.314	0.350
11	0.642	1.342	1.455	1.509	0.075	0.660	0.154	0.434	0.147	0.046	0.242	0.199	0.431	0.458	0.258	0.488	0.350
12	0.348	0.862	0.054	0.165	0.075	1.624	1.606	0.710	0.550	0.037	0.163	0.259	0.344	0.238	0.384	0.488	0.350
13	0.410	2.197	1.954	0.272	0.000	1.145	0.040	0.693	0.909	0.134	0.038	0.192	1.039	0.179	0.252	0.892	0.350
14	0.089	1.743	0.000	7.427	0.000	1.634	0.344	0.163	7.679	0.071	0.046	0.024	0.979	0.976	0.205	0.218	0.350
15	0.338	0.648	0.643	0.914	0.521	0.890	0.802	0.286	0.338	0.344	0.449	0.415	0.328	0.273	0.289	0.301	0.350

TABLE 26: 4VSW COD MEAN POPULATION BIOMASS, 8/ 7/87

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	1703	860	3303	4556	9012	7528	6676	6313	20163	0	0	0	0	7798	0	0	0
2	11273	6763	10871	10328	13792	13806	16488	15215	31998	43685	40410	50766	55626	23274	29739	30576	12381
3	19132	16509	16192	15545	16582	13712	20523	37521	41793	31461	53167	46770	53236	62013	35241	30480	26950
4	37816	16945	24424	16286	17459	13043	14908	29931	44955	34462	35254	55451	43512	52995	58564	40253	32291
5	51494	25222	16417	17115	15310	10413	11184	17415	33100	39429	32697	32565	48634	40777	45338	60127	34101
6	33350	26839	20260	8117	13785	7720	6704	9443	16391	28009	26795	24241	26544	38117	29419	36157	43412
7	13799	16416	20781	9338	5532	6728	4244	4904	9128	12109	18895	17678	17081	20823	25618	20208	24377
8	8453	5404	10862	9727	5354	2828	3225	3101	5012	5839	9216	12282	12453	12598	13876	17818	12020
9	1822	4158	3121	5130	5468	1748	1690	2033	2288	3149	5124	6460	8964	7463	8404	8919	11694
10	1333	671	2952	1593	2944	2038	850	1334	2025	1906	3218	4344	4326	5501	5034	6991	6266
11	1301	428	289	996	1236	1236	796	475	1406	1722	1474	2405	3182	2158	4166	3608	4263
12	1089	405	217	102	479	479	431	385	474	1244	1630	1151	1790	1912	1339	2126	2072
13	163	242	127	163	111	217	175	115	302	312	825	1303	642	1309	1213	736	1867
14	1076	40	72	5	166	43	91	158	12	140	178	715	558	195	852	978	296
15	100	475	12	42	0	83	11	74	103	0	129	142	715	279	82	598	637
1+	183904	121378	129901	99042	107232	81621	87995	128419	209151	203466	229013	256274	277263	277212	258886	259575	212626
2+	182201	120518	126597	94486	98220	74094	81319	122106	188988	203466	229013	256274	277263	269415	258886	259575	212626
3+	170928	113755	115727	84159	84428	60287	64831	106891	156989	159781	188603	205508	221637	246141	229147	228999	200245
4+	151796	97246	99535	68613	67846	46576	44308	69370	115197	128320	135436	158738	168401	184128	193906	198519	173295
5+	113981	80301	75111	52328	50386	33532	29400	39438	70242	93858	100181	103287	124889	131132	135342	158266	141004
6+	62487	55078	58694	35212	35077	23119	18215	22024	37142	54429	67485	70723	76255	90356	90004	98139	106904

Table 27. Projected catch at age('000) for 1987 and 1988 for 4VsW cod under two assumptions: A) TAC of 44,000 t caught in 1987, B) $F_{0.1}$ catch in 1987.

A.

Age	1987	1988
1	0	0
2	0	0
3	657	661
4	3043	2125
5	5237	3540
6	4687	3054
7	4345	2123
8	1698	1967
9	731	769
10	532	331
11	210	241
12	136	95
13	51	61
14	31	23
15	5	14

B.

Age	1987	1988
1	0	0
2	0	0
3	465	661
4	2179	2136
5	3815	3642
6	3443	3265
7	3189	2308
8	1246	2137
9	536	835
10	390	360
11	154	262
12	100	103
13	37	67
14	23	25
15	4	15

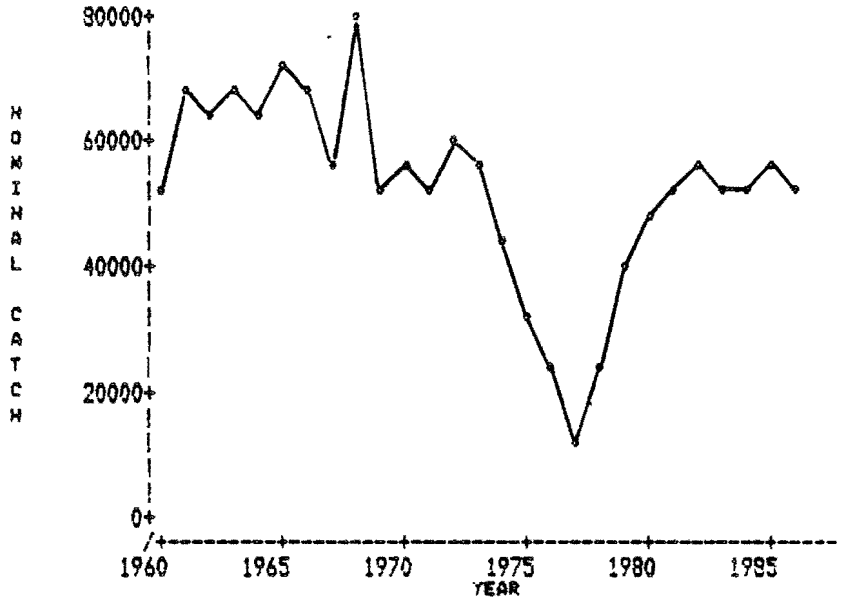


Figure 1: Nominal catch for 4VsW cod.

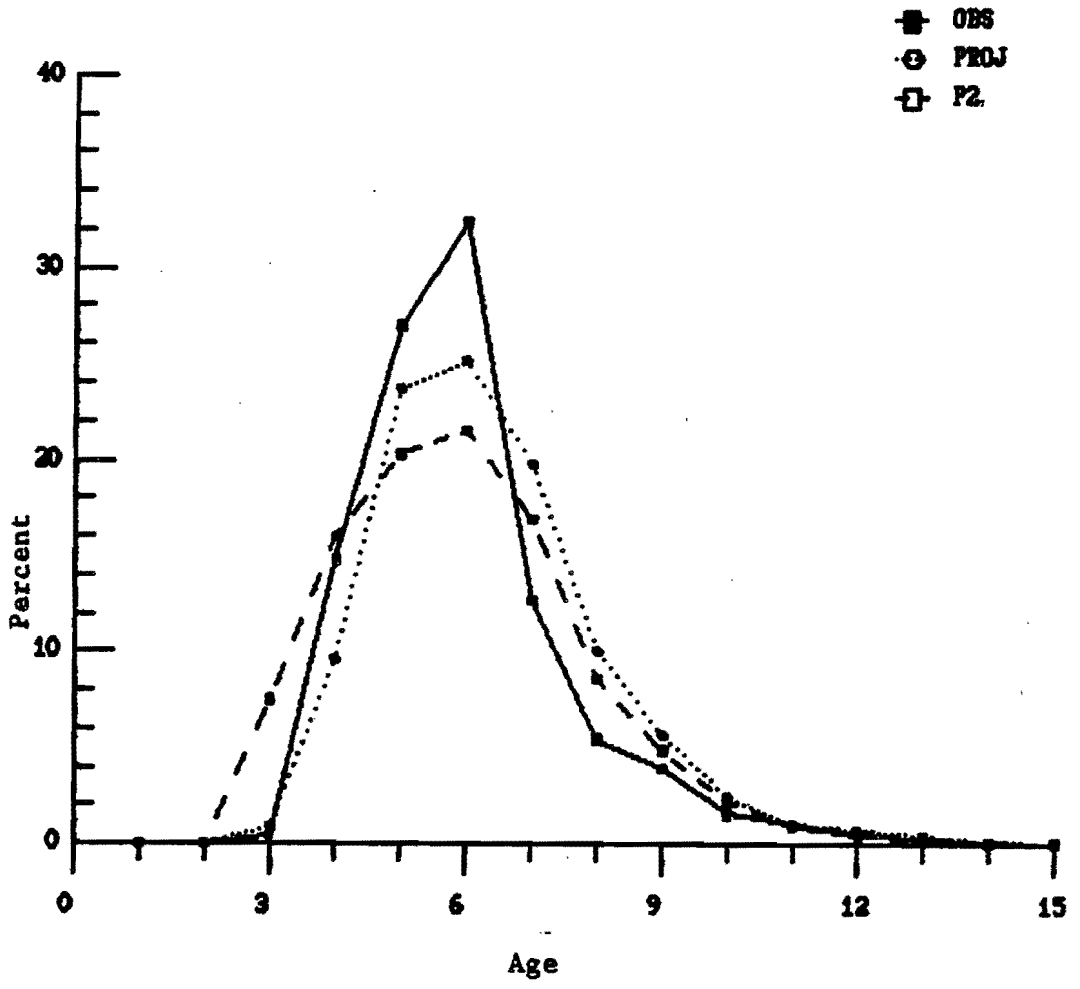
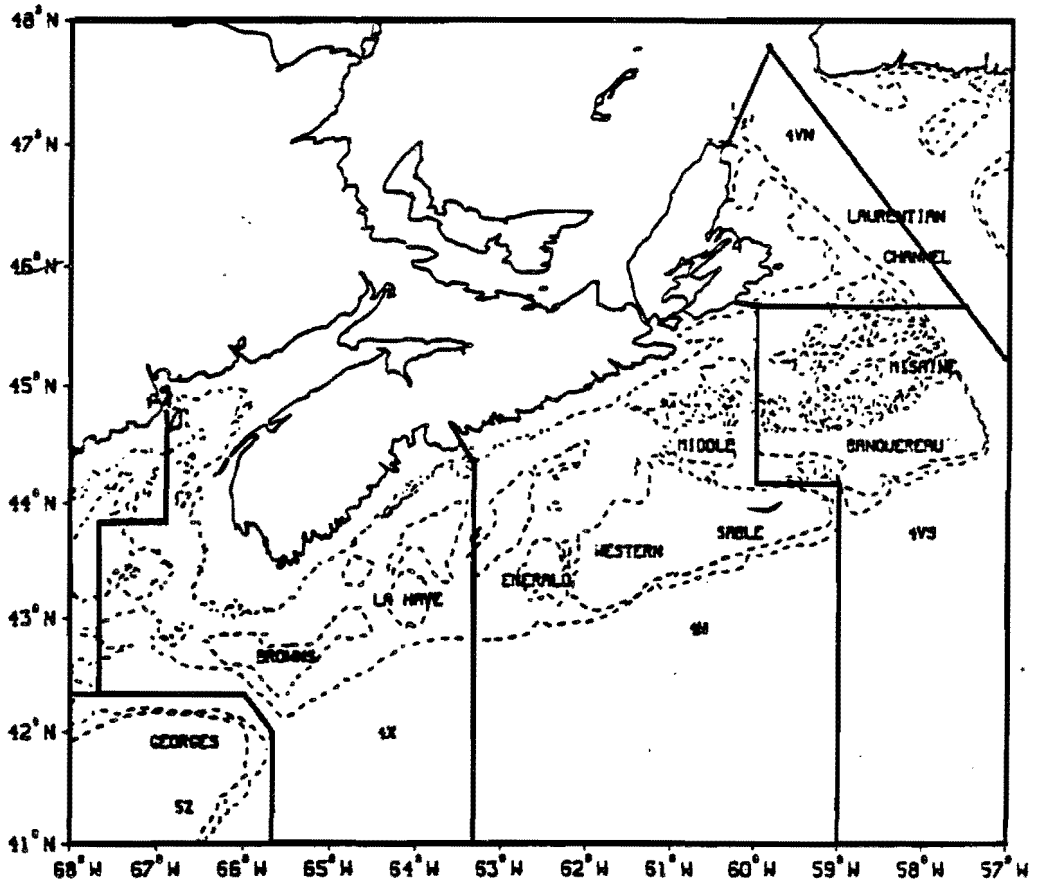


Figure 2: Comparison of observed and projected catch at age. Two projections are presented; that projected last year assuming PR used in the cohort analysis (Proj), and that projected from last year's population estimate but using average PR.

A.



B.

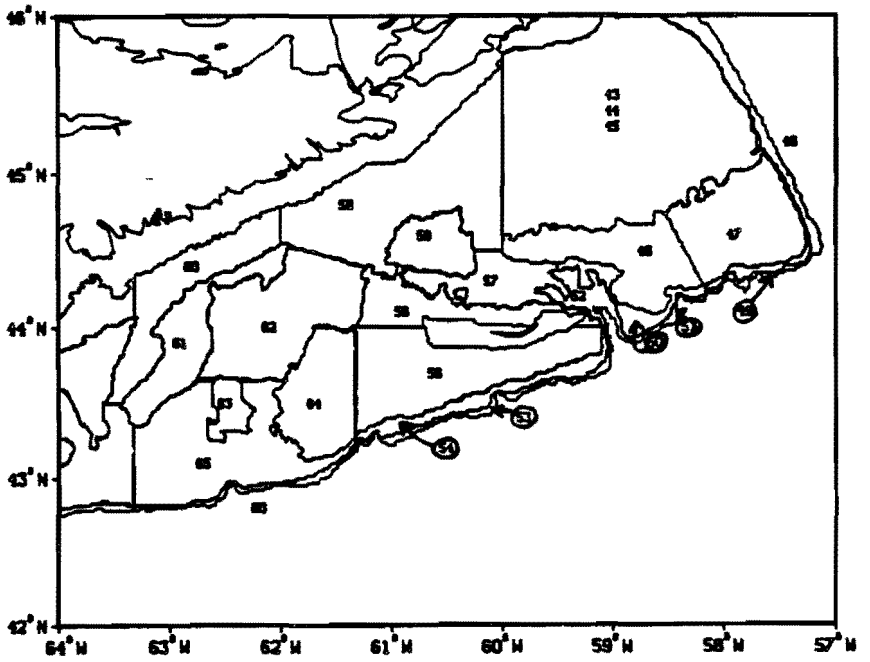
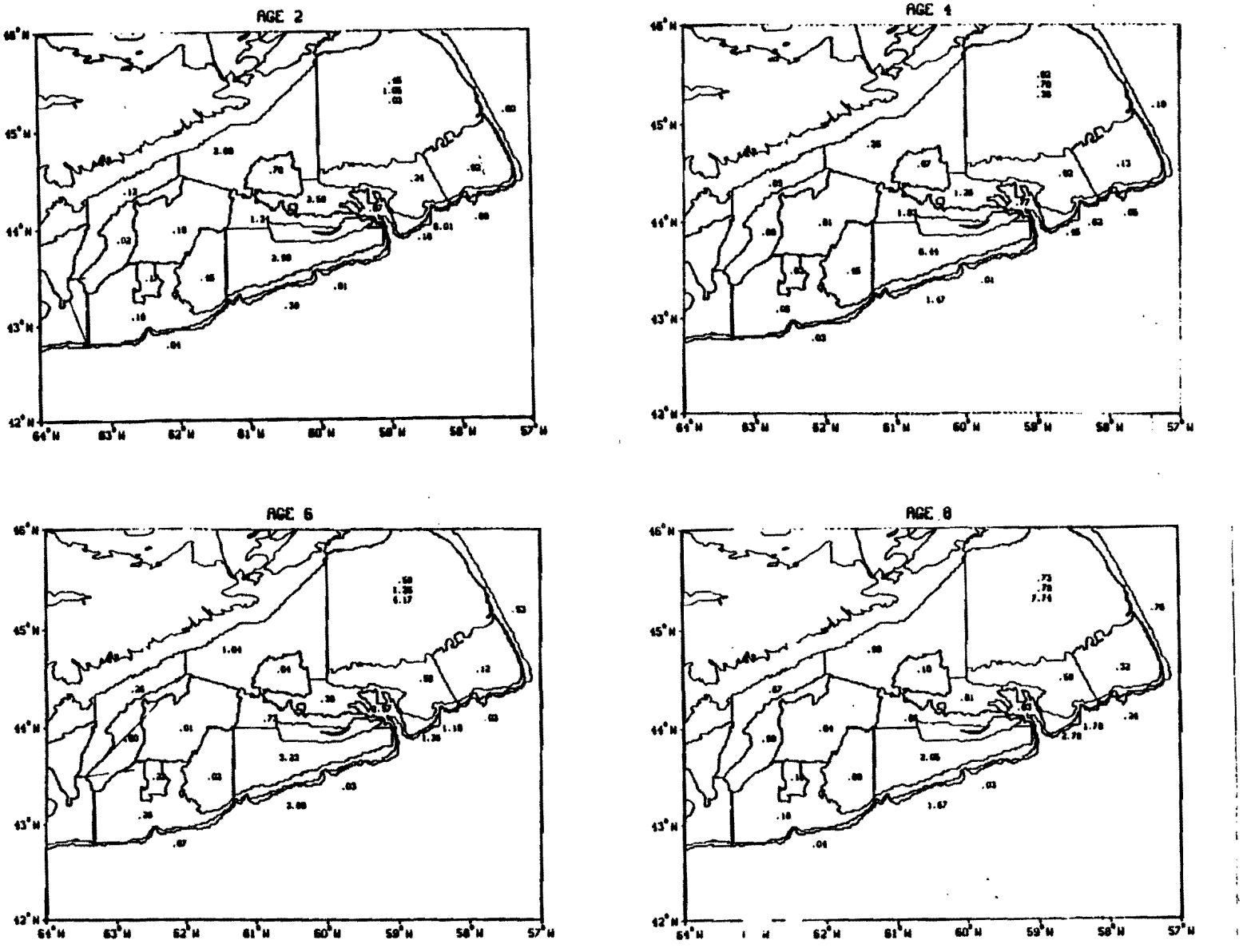
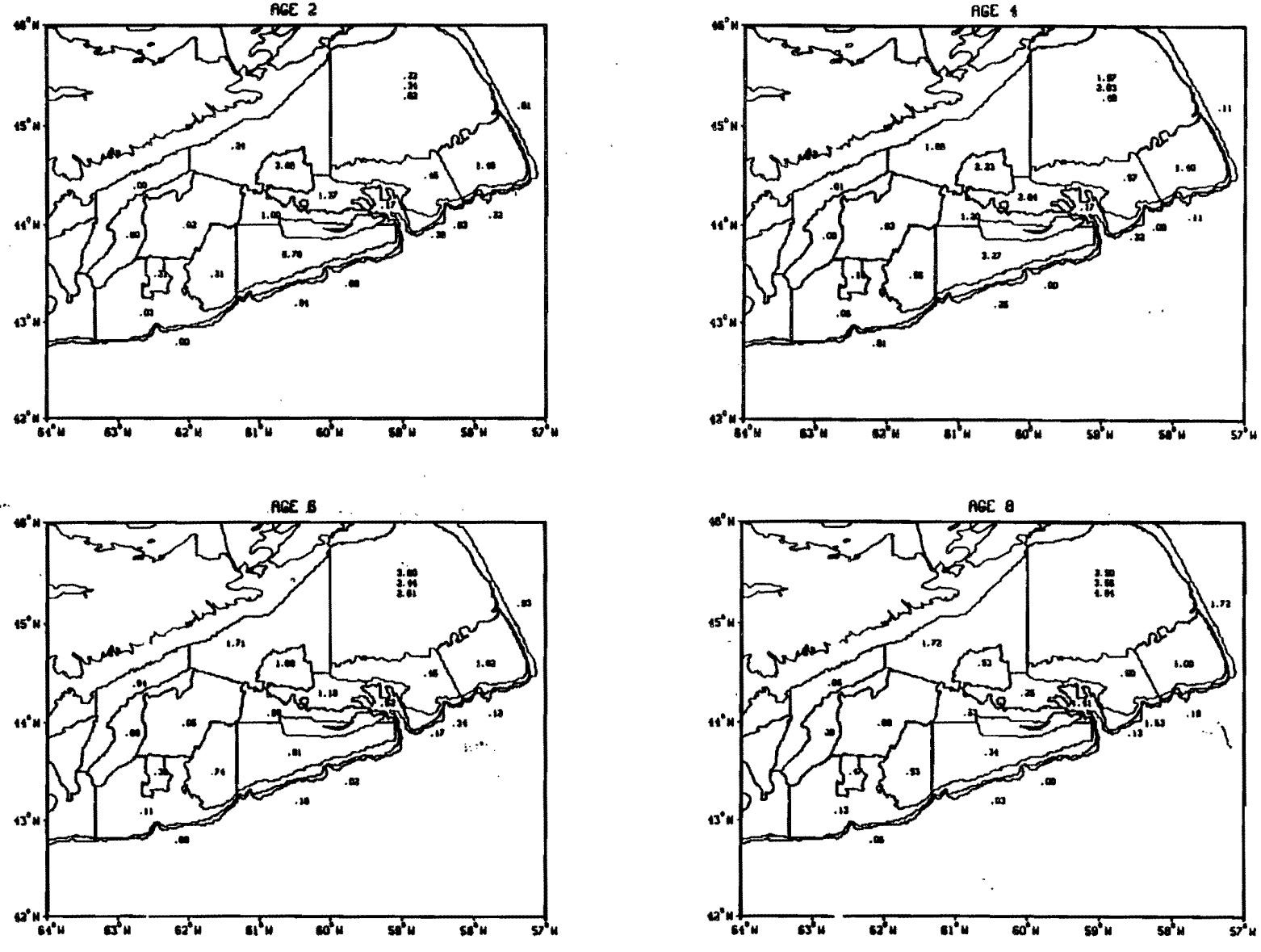


Figure 3: Maps of the study area showing A) NAFO boundaries and common fishing banks, and B) Research vessel survey strata.

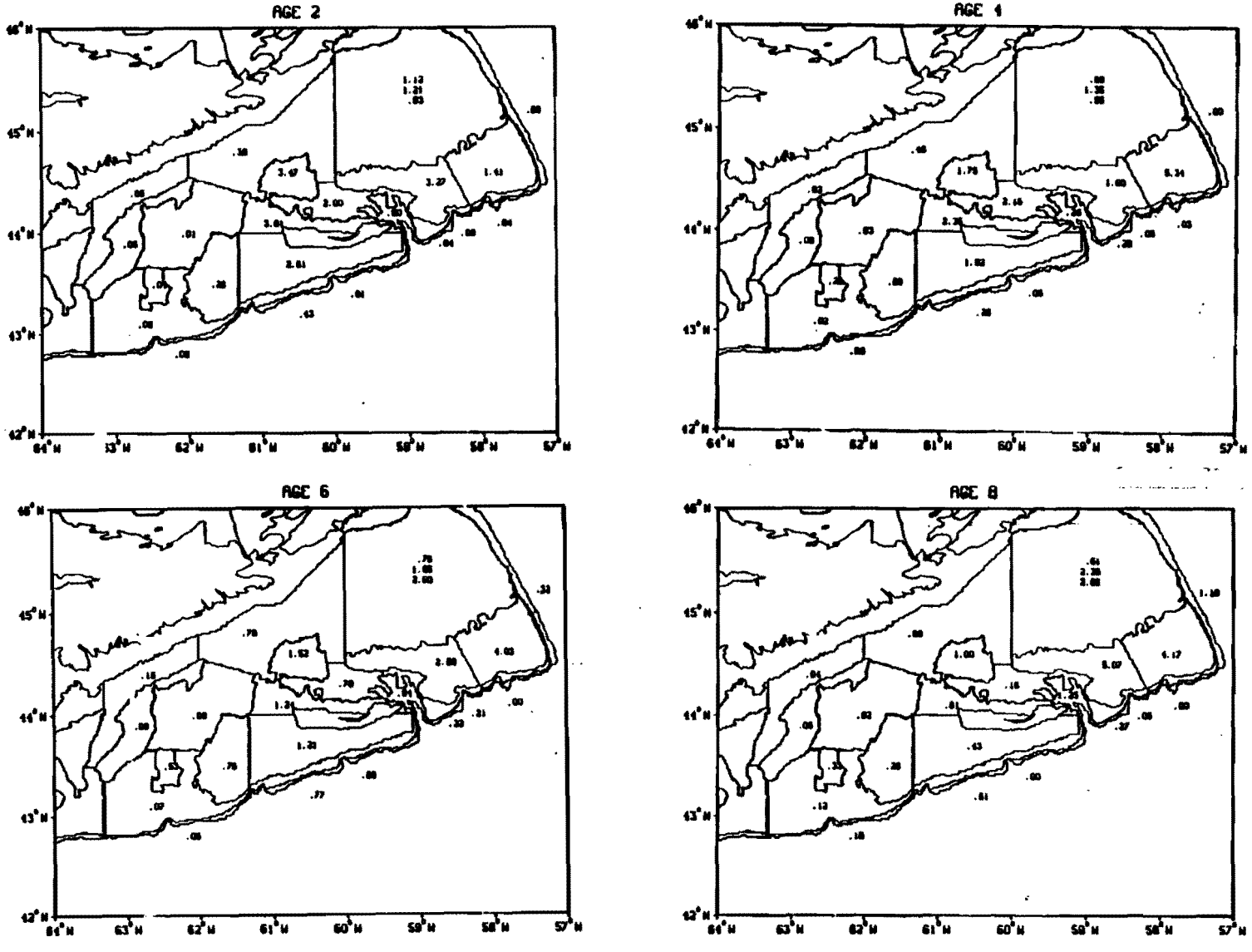


RV SPRING DATA 1979-1983
RELATIVE TO GRAND MEAN

Figure 4:



Summer RV DATA 1970-1985
Figure 5: RELATIVE TO GRAND MEAN



RV FALL DATA 1978-1982
RELATIVE TO GRAND MEAN

Figure 6:

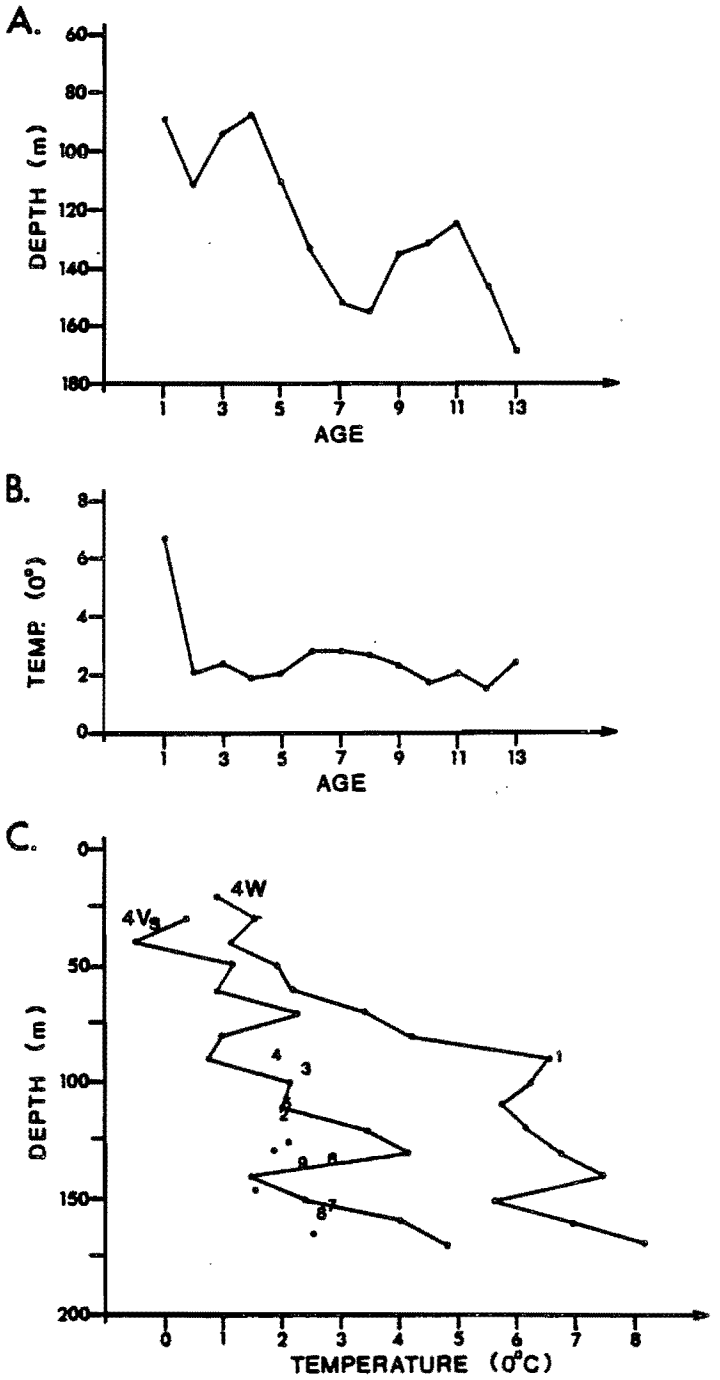


Figure 7: A) Mean depth at age, B) mean temperature at age, C) mean temperature at depth from Subdiv. 4Vs and Div. 4W (solid line) compared to mean depth and temperature at age. Numbers indicate age and unnumbered dots are for ages 10 and above. SPRING SURVEYS.

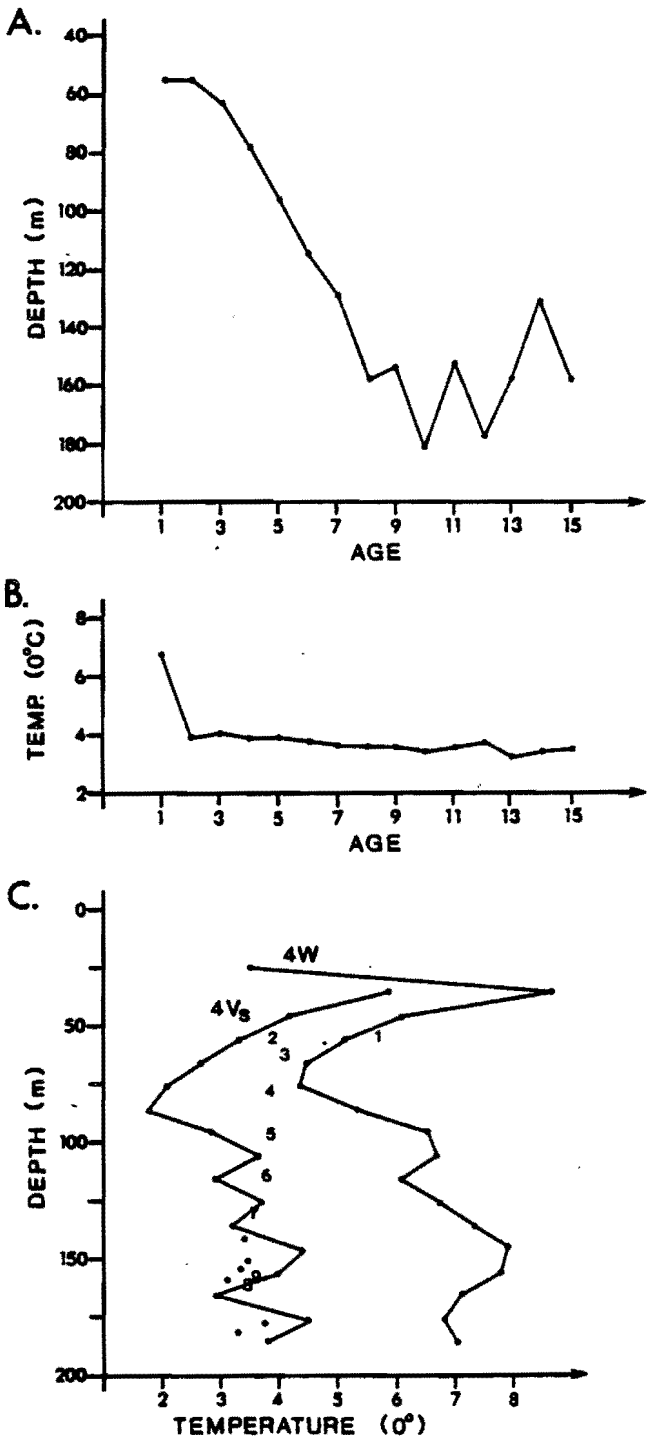


Figure 8: as for Figure 7, SUMMER SURVEYS.

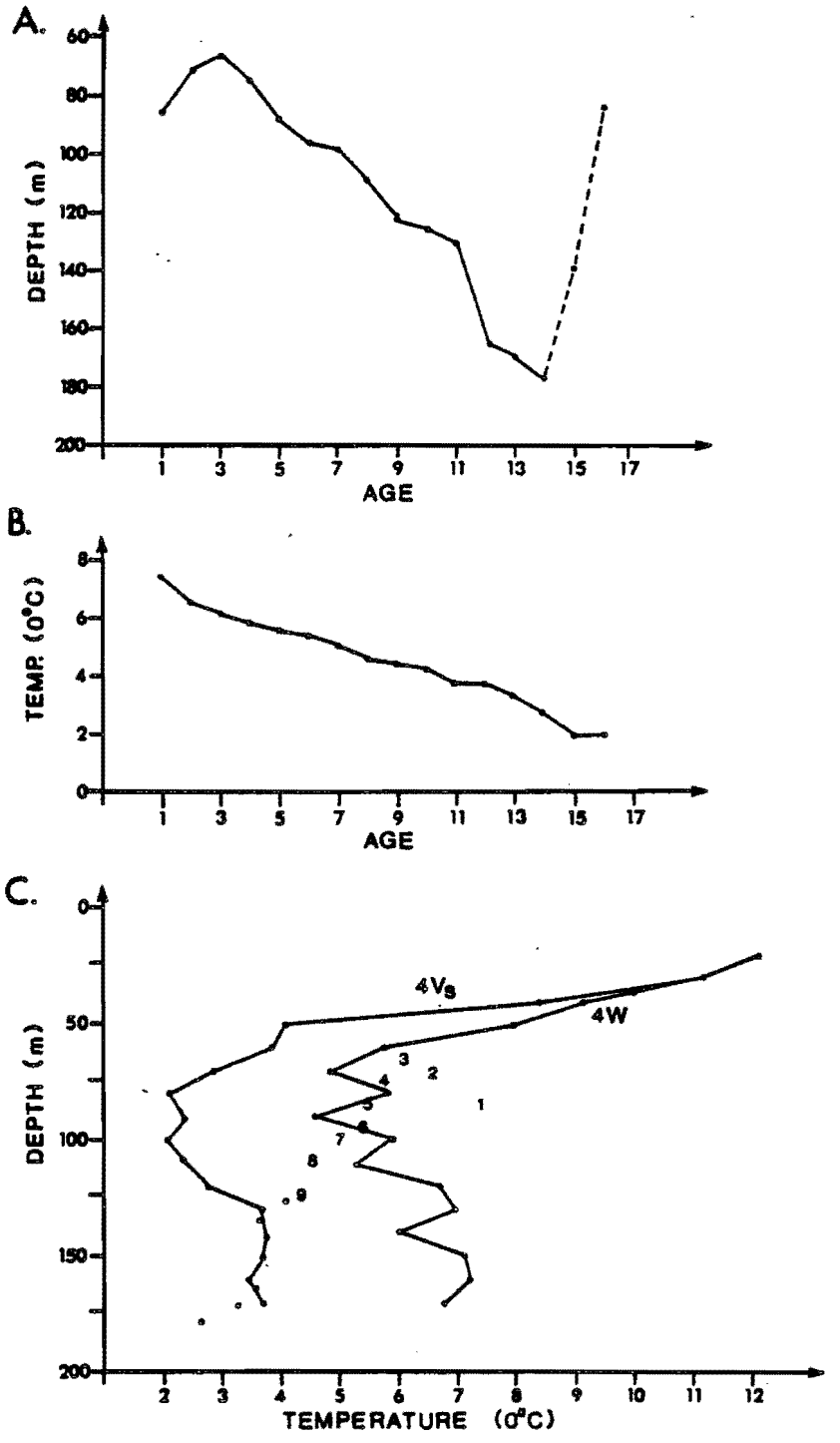


Figure 9: as for Figure 7, FALL SURVEYS.

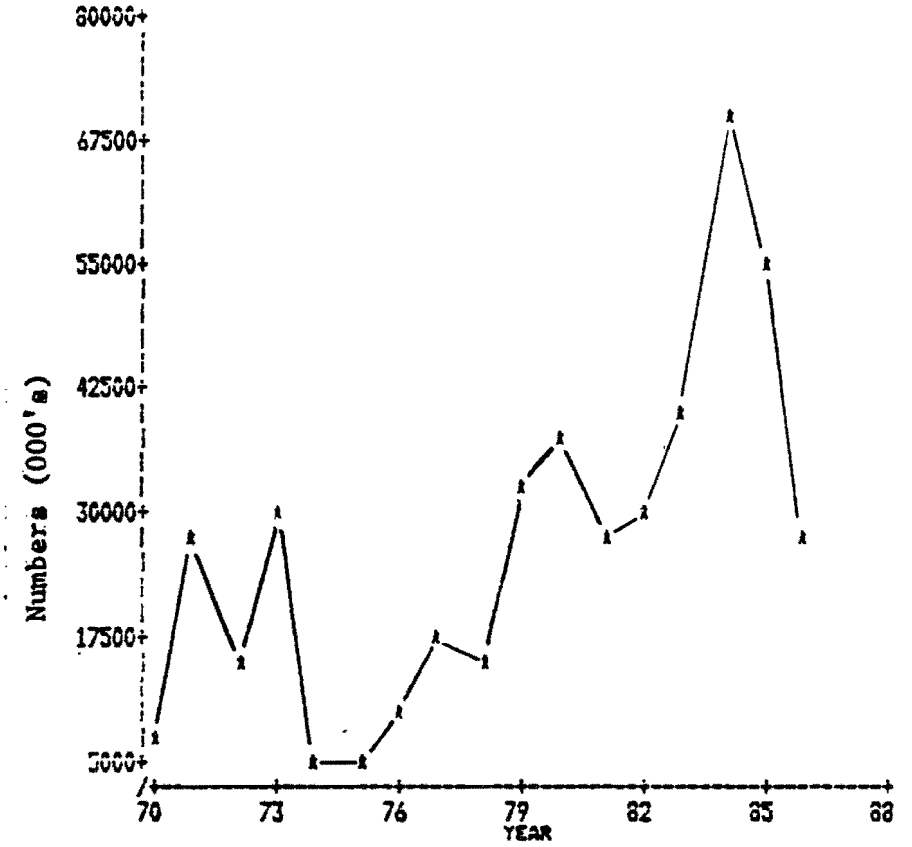
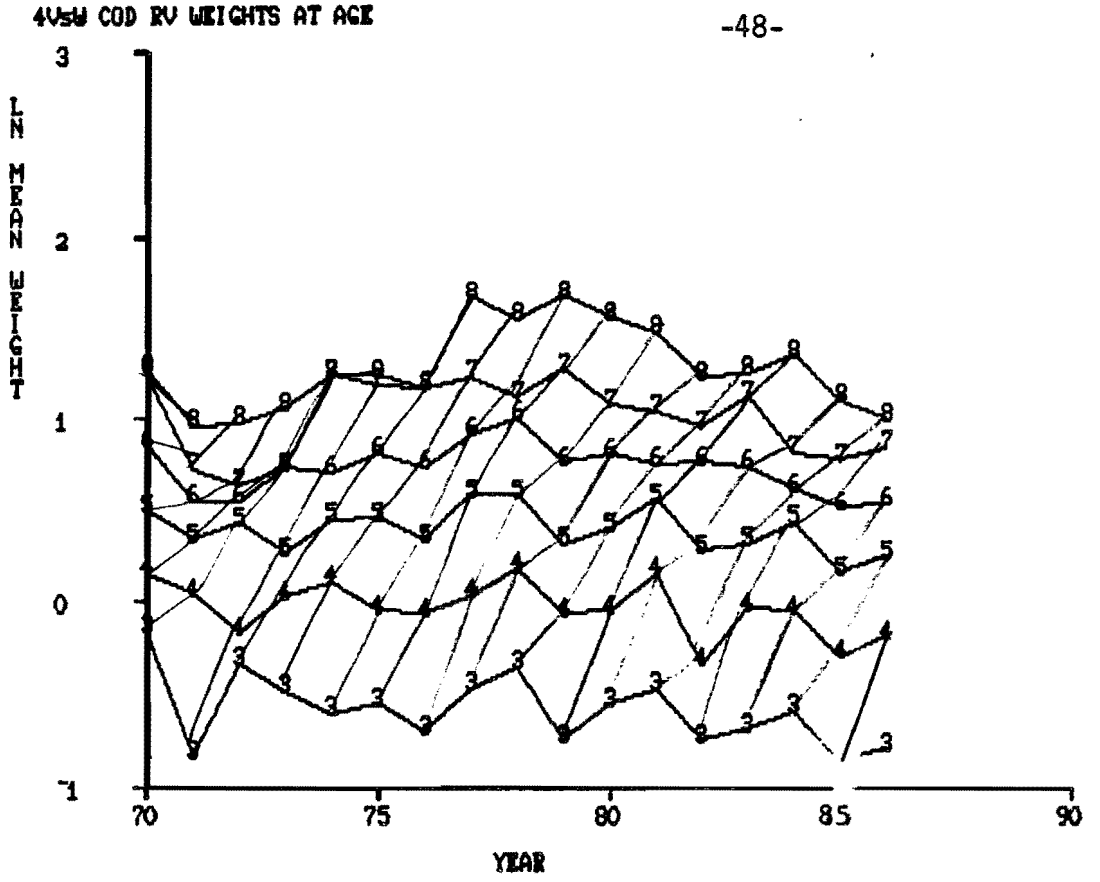


Figure 10: Age 5+ abundance at age from summer surveys.



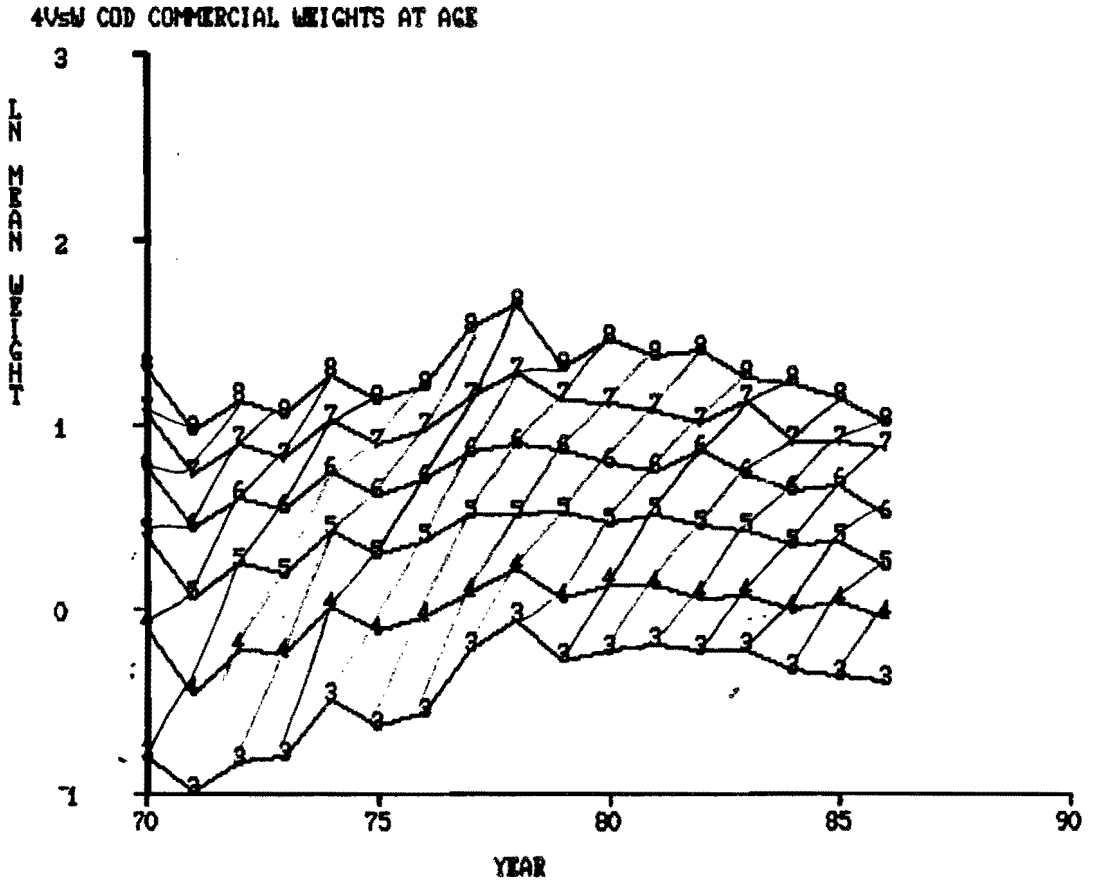


Figure 11: Comparison of mean weights at age from surveys and commercial catch.

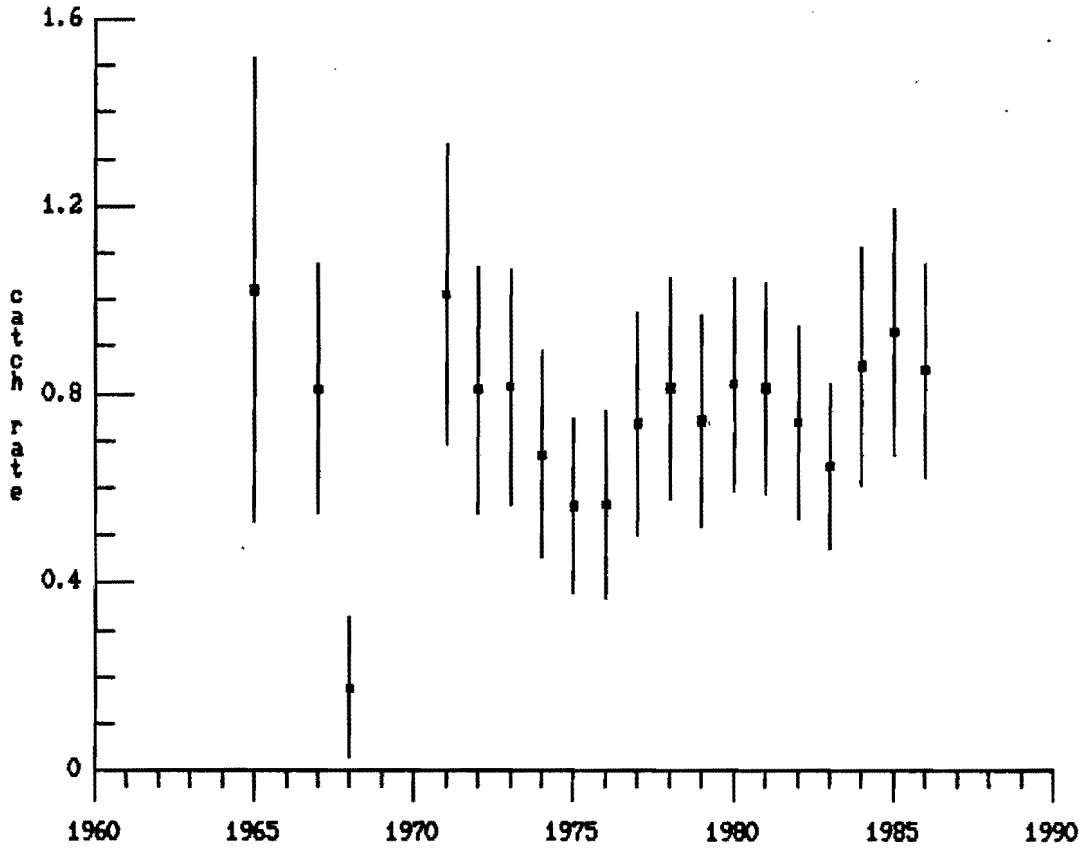


Figure 12: Standardized mean catch rate by year for longlines fishing 4VsW cod (2 s.e.).

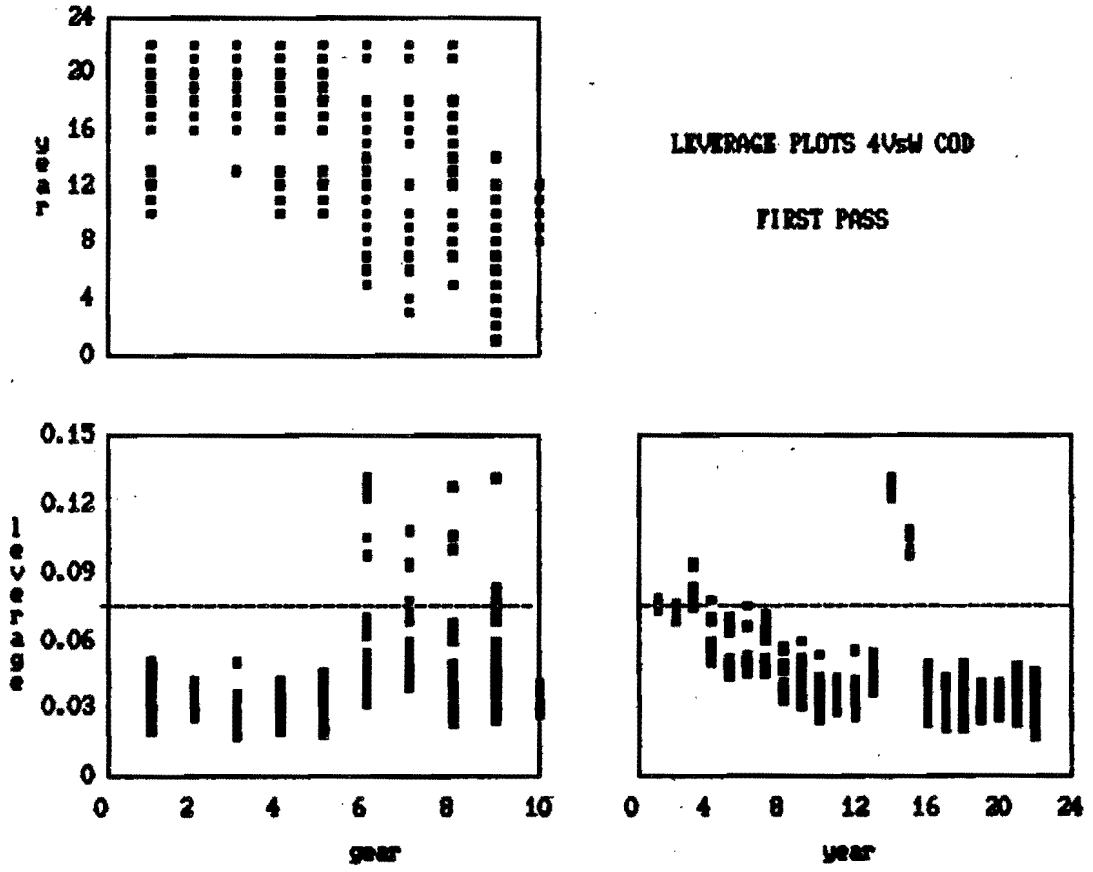


Figure 13: Leverage vs gear and year from the initial analysis of otter trawler catch rates. (See text for gear codes).

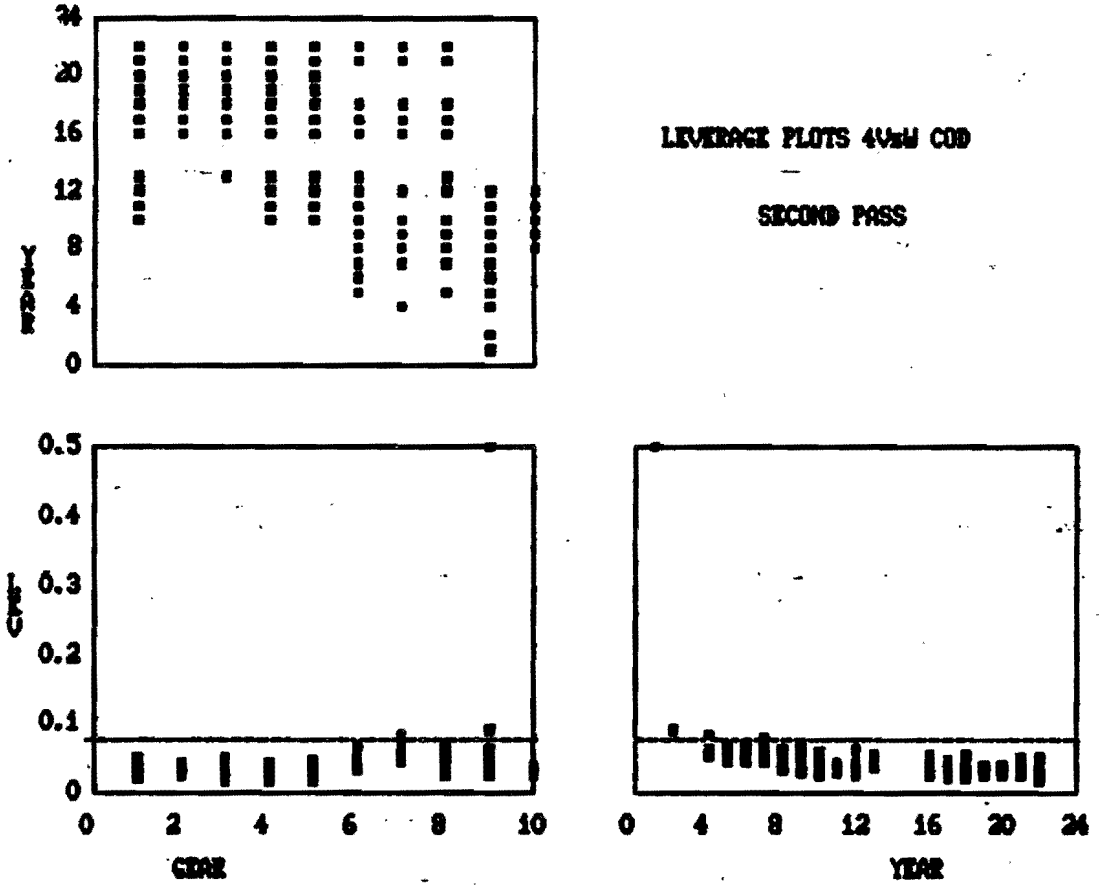


Figure 14: Leverage vs gear and year from a second analysis of otter trawler catch rates after eliminating aliased data.

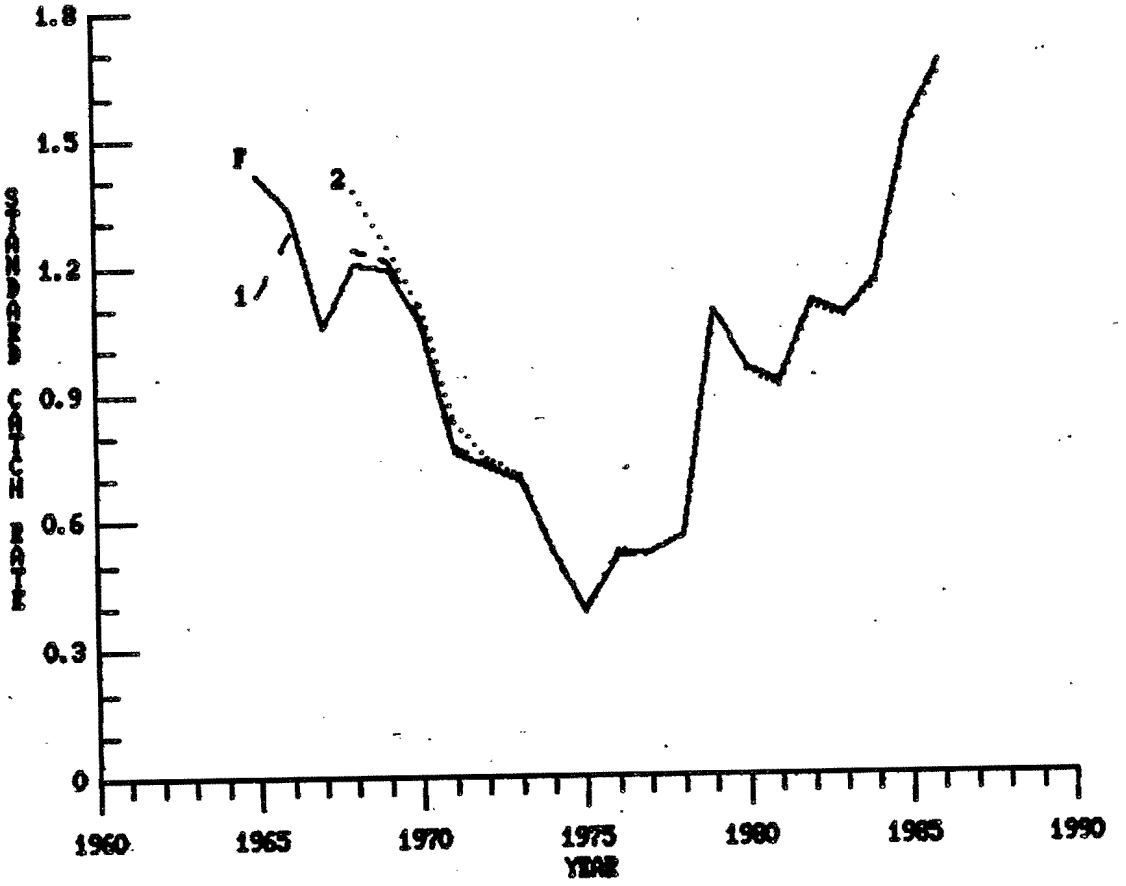


Figure 15: Comparison of mean catch rates after high leverage points were removed. F indicates the full analysis, 1 following elimination of 1967, 1978, and 1979 data, 2 following elimination of 1965 and 1966 data.

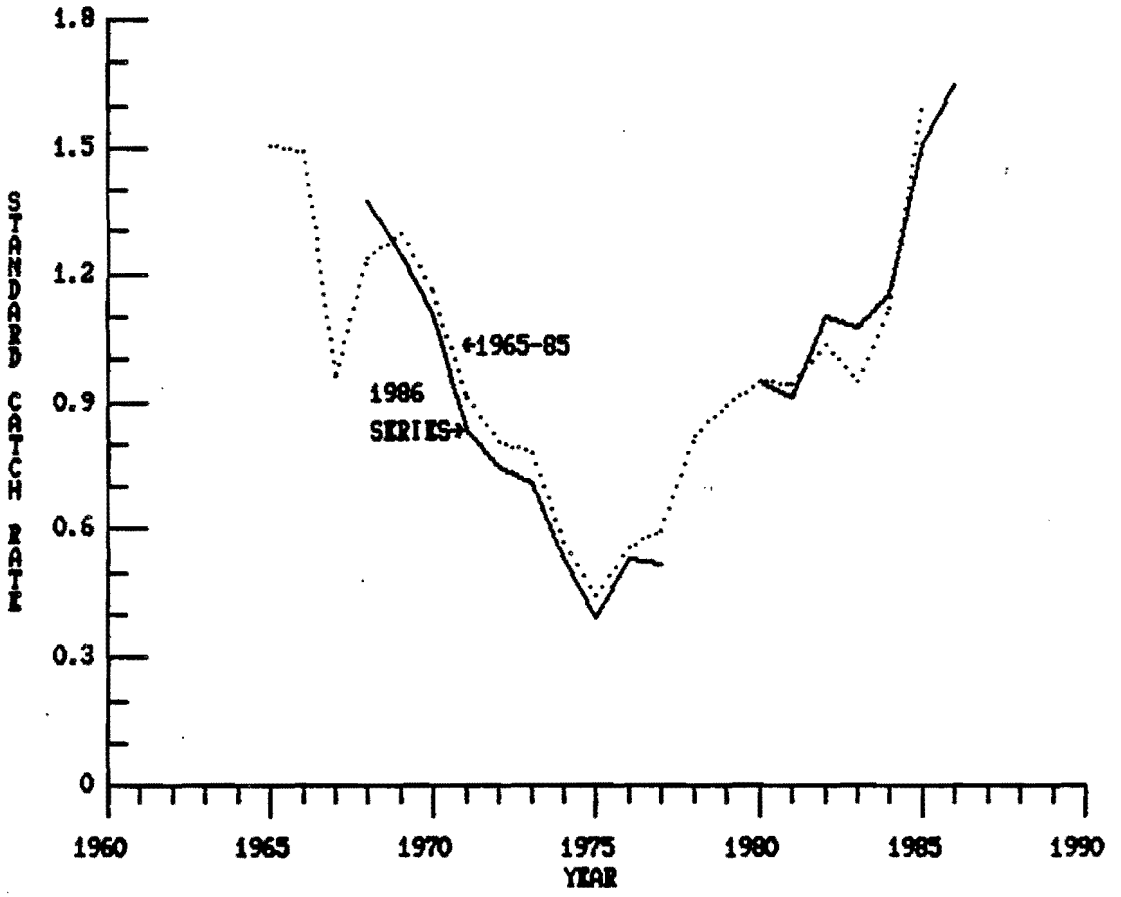


Figure 16: Comparison of the catch rate series used for calibration last year (1965-85) to the otter trawler series used this year.

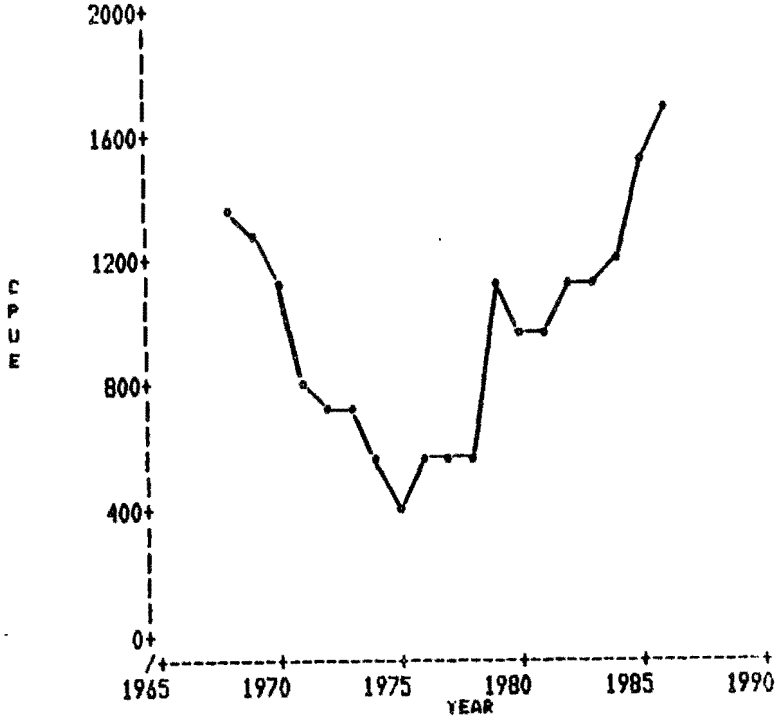


Figure 17: Standardized catch rate for otter trawlers fishing 4VsW cod.

Figure 18: Percent of nominal catch taken in Subdiv. 4Vs.

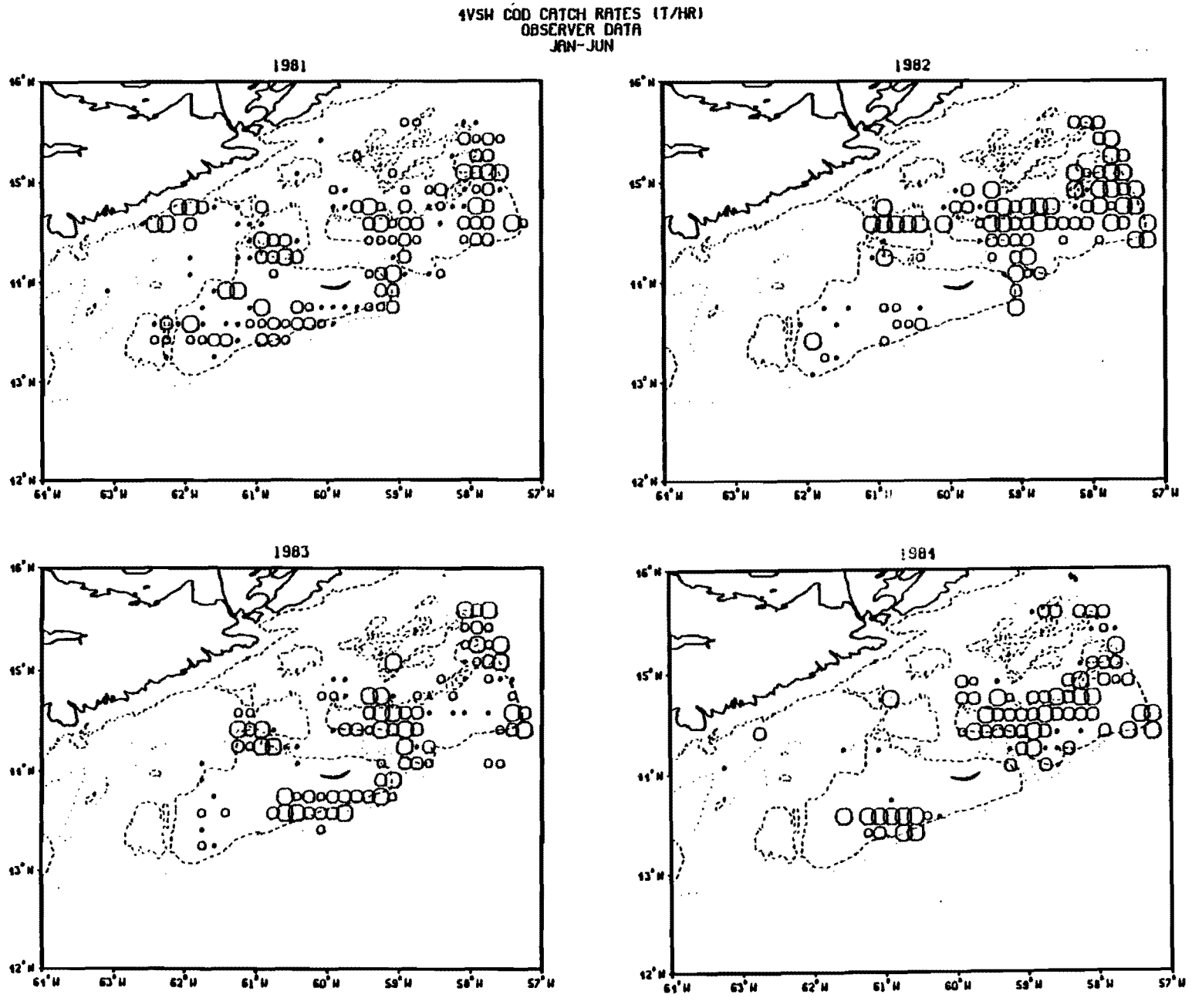


Figure 19: 4VsW cod spring offshore fishery distribution 1981-1986 from Scotia Fundy Region observer program. Symbol size indicates catch rate.

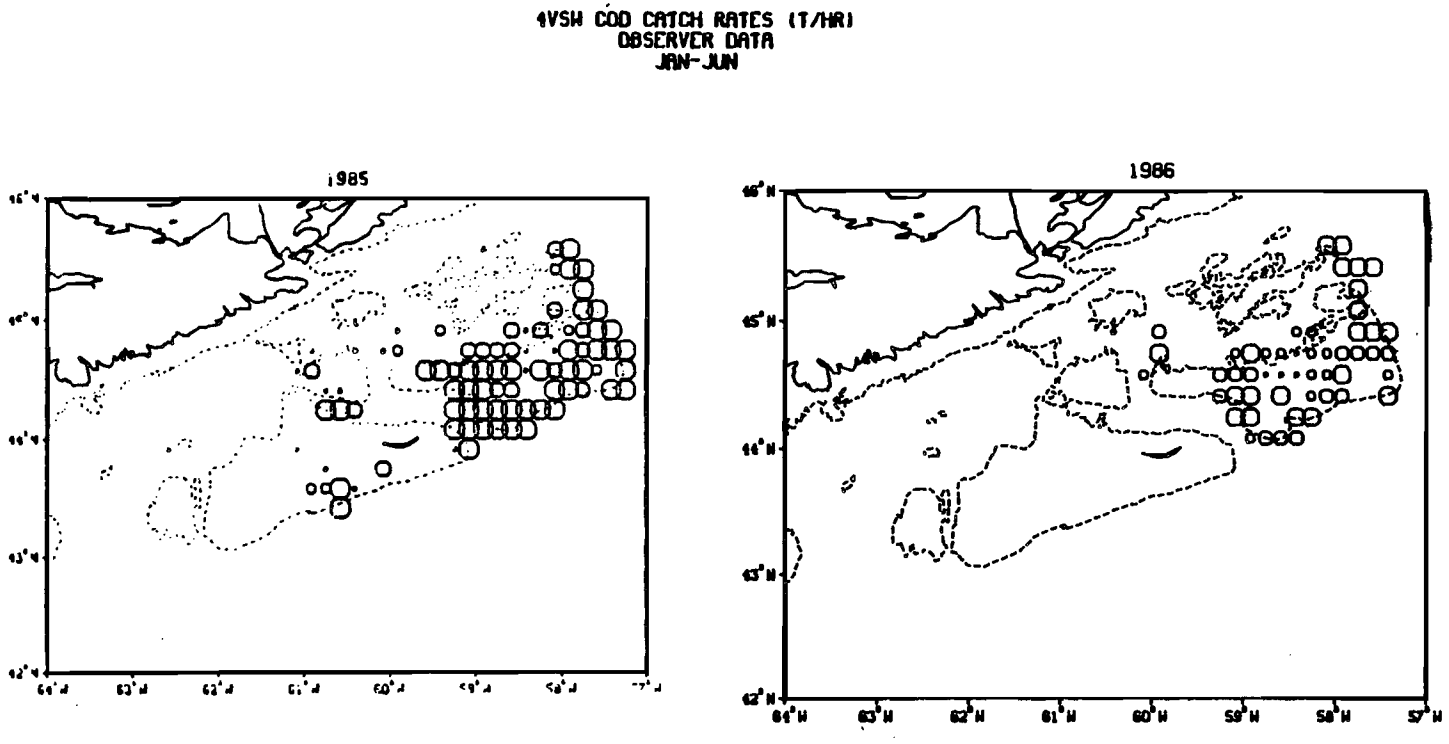


Figure 19: con't

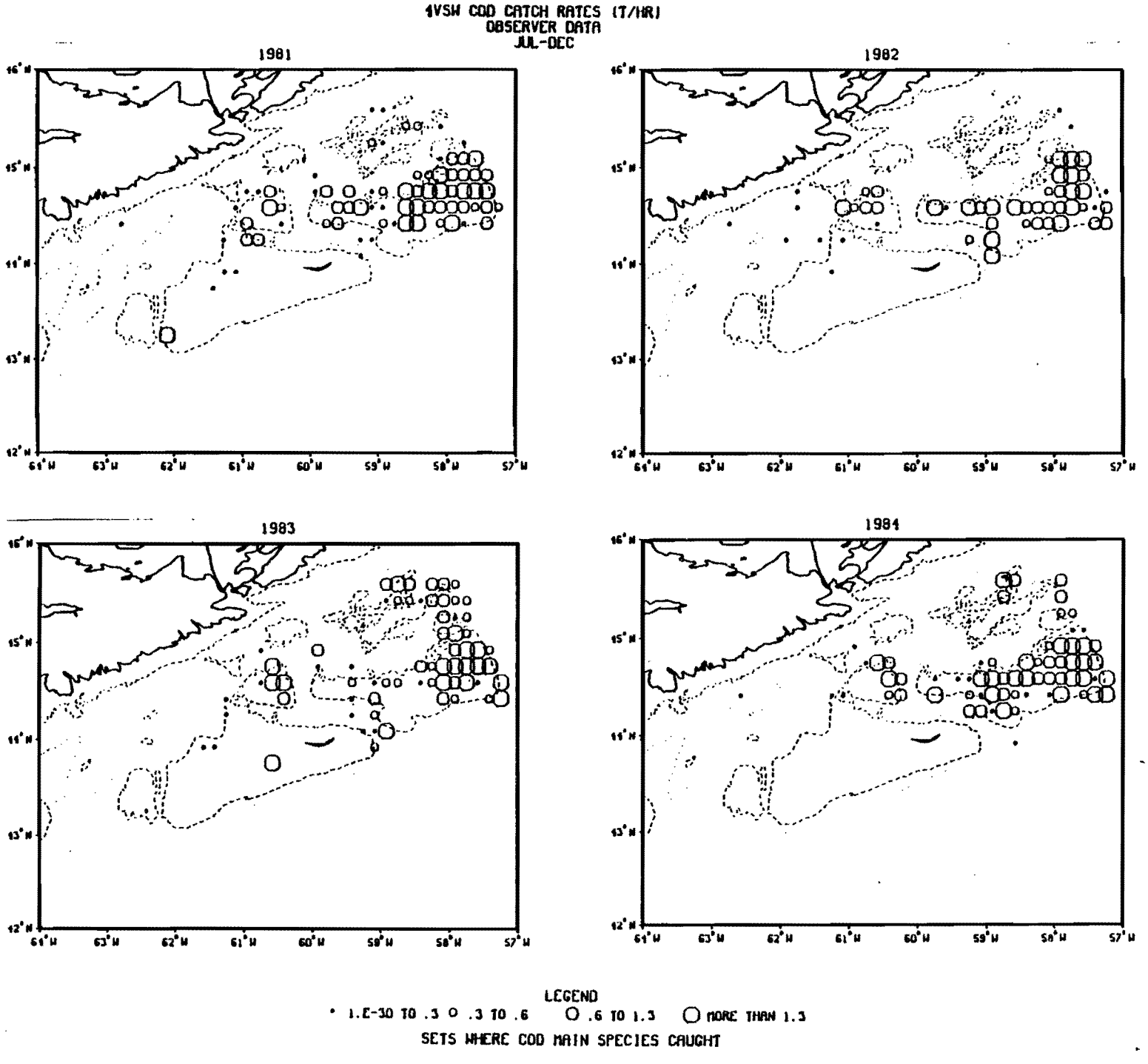


Figure 20: 4VsW cod fall offshore fishery distribution 1981-1986 from Scotia Fundy Region observer program. Symbol size indicates catch rate.

4VSW COD CATCH RATES (T/HR)
OBSERVER DATA
JUL-DEC

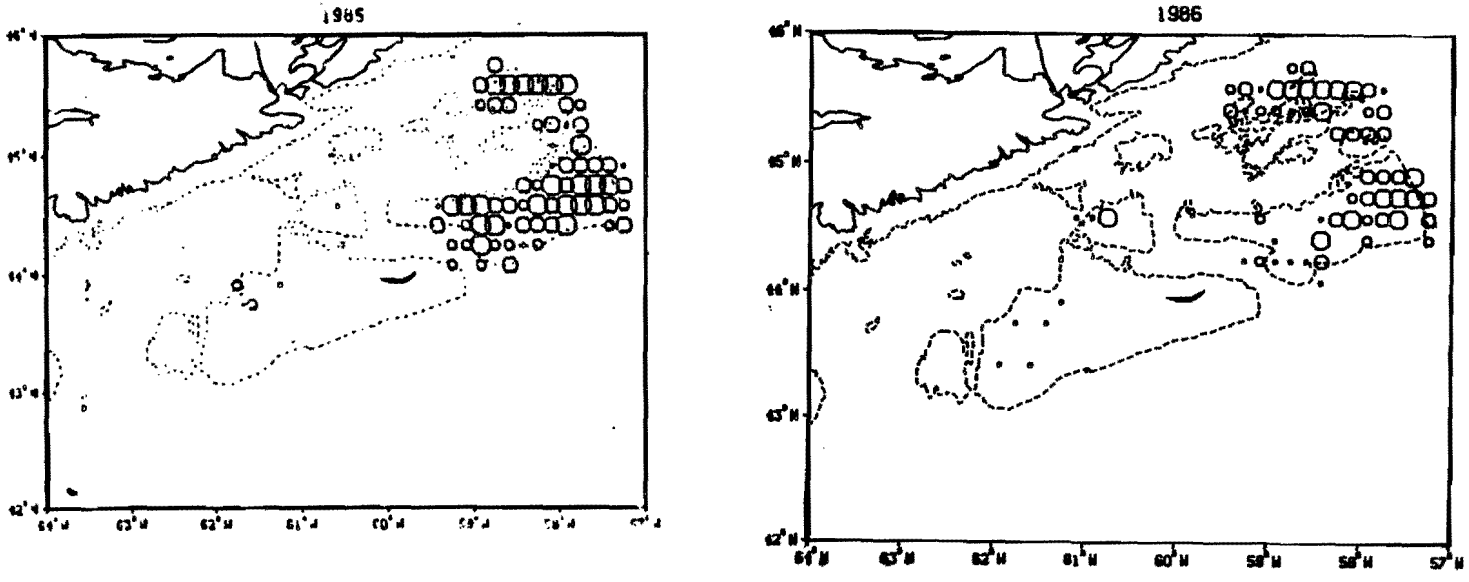
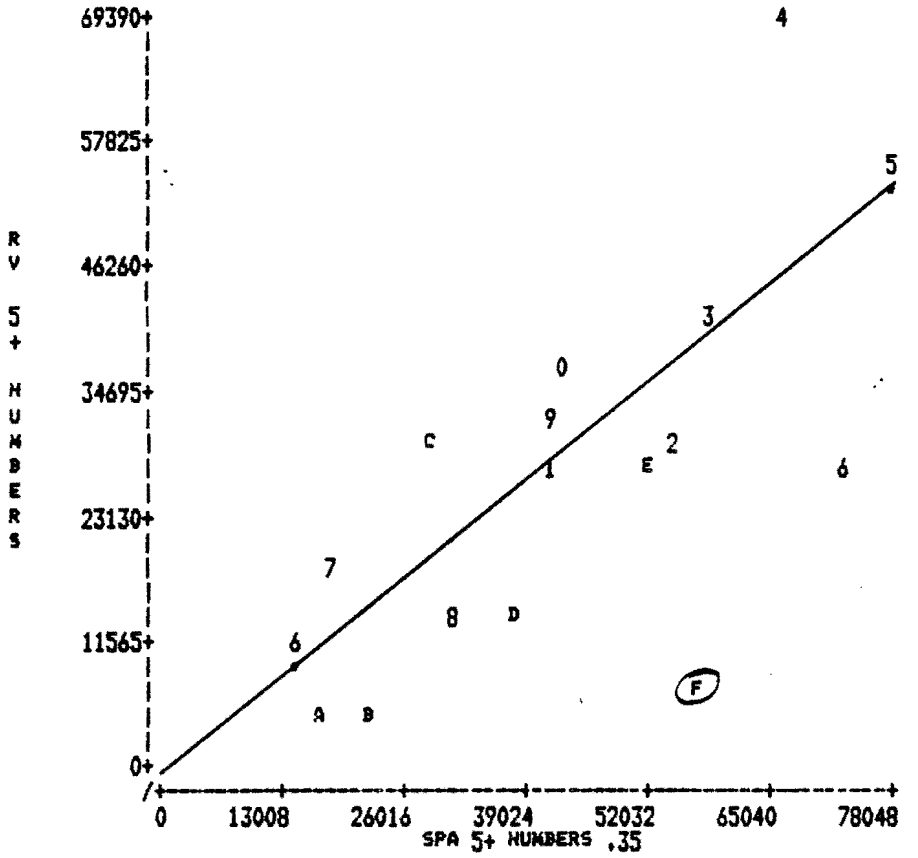
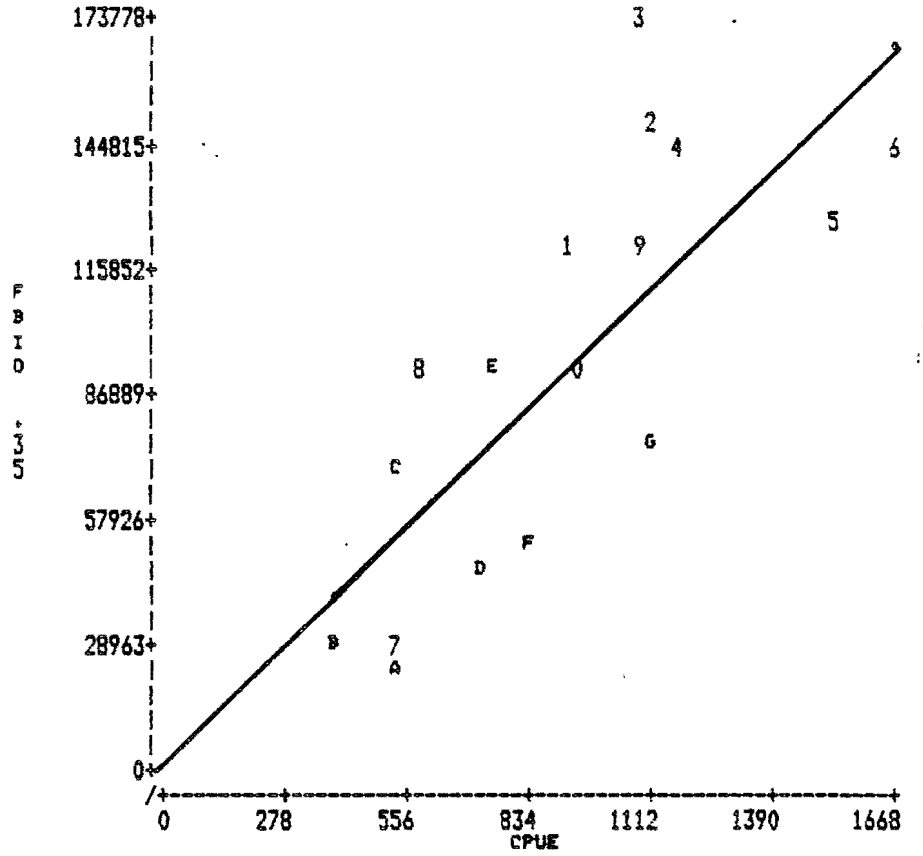


Figure 20: con't



S	YEAR	RESIDUALS	IND	DEP
F	1970	1.000	57722	7631
E	1971	-0.676	52462	27415
D	1972	-0.897	37108	14617
C	1973	0.998	28394	29273
B	1974	-0.786	22032	5603
A	1975	-0.491	16800	5260
6	1976	0.173	14363	10816
7	1977	0.694	17617	18672
8	1978	-0.536	30815	14273
9	1979	0.362	41686	31377
0	1980	0.744	42762	36256
1	1981	0.027	42063	28004
2	1982	-0.530	54052	30077
3	1983	0.221	58102	40971
4	1984	2.354	65852	69385
5	1985	0.210	78047	54377
6	1986	-1.367	72772	28254

Figure 21: Calibration plot for 4VsW cod using RV survey 5+ numbers vs SPA 5+ mean numbers.



S	YEAR	RESIDUALS	IND	DEP
G	1970	-1.209	1103	74315
F	1971	-0.990	828	53299
E	1972	0.586	745	94803
D	1973	-0.903	711	44165
C	1974	0.452	532	68916
B	1975	-0.448	396	26579
A	1976	-0.943	528	24307
7	1977	-0.864	526	26601
8	1978	1.136	575	94945
9	1979	0.328	1081	120756
0	1980	-0.188	953	91404
1	1981	0.801	922	119584
2	1982	1.161	1112	150303
3	1983	1.996	1083	173775
4	1984	0.748	1165	142594
5	1985	-0.890	1524	127186
6	1986	-0.773	1665	145206

Figure 22: Calibration plot for 4VsW cod using otter trawl fishable biomass vs catch rate.

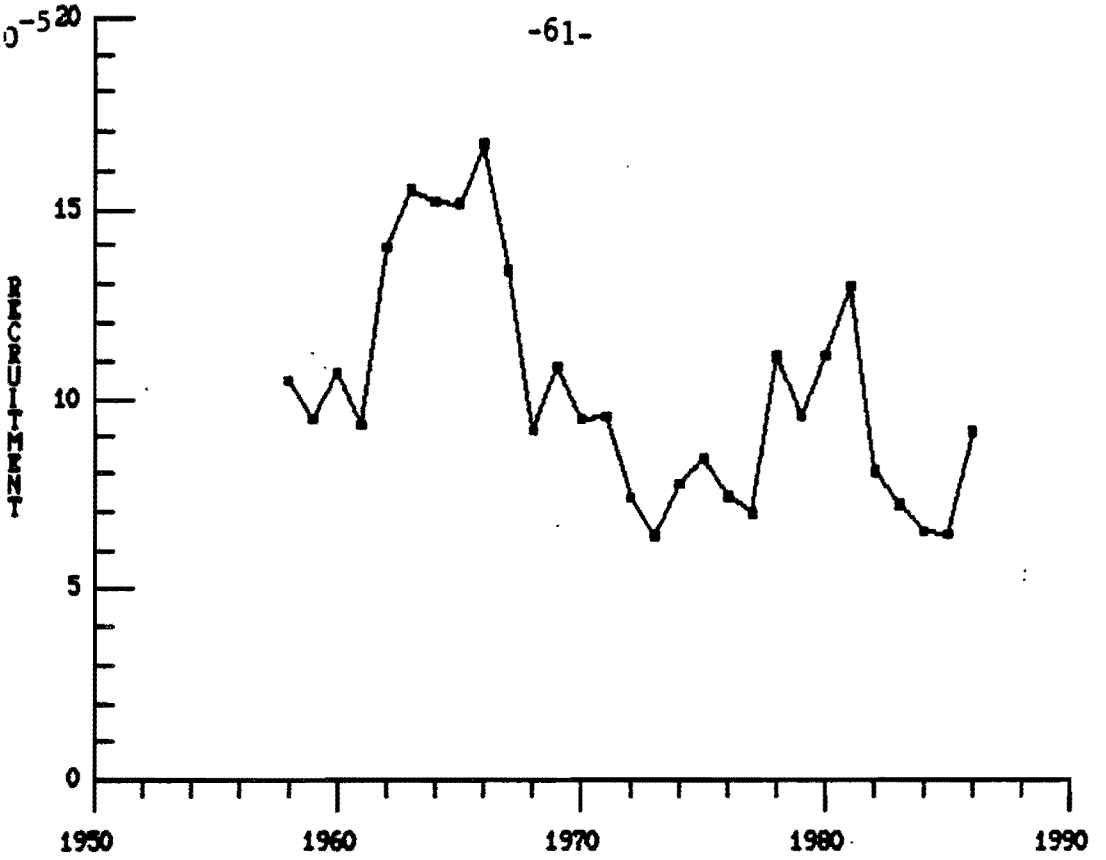


Figure 23: 4VsW cod age 1 recruitment. Year is indicated on x axis.

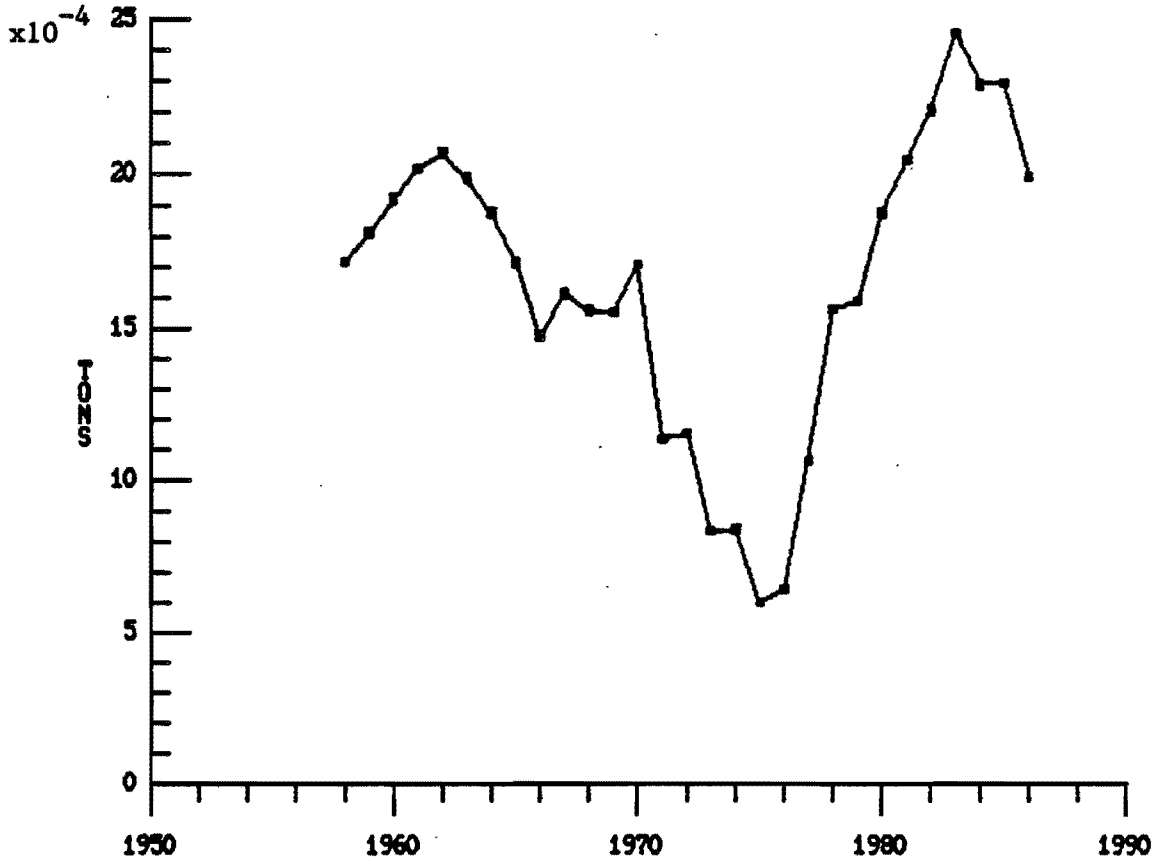
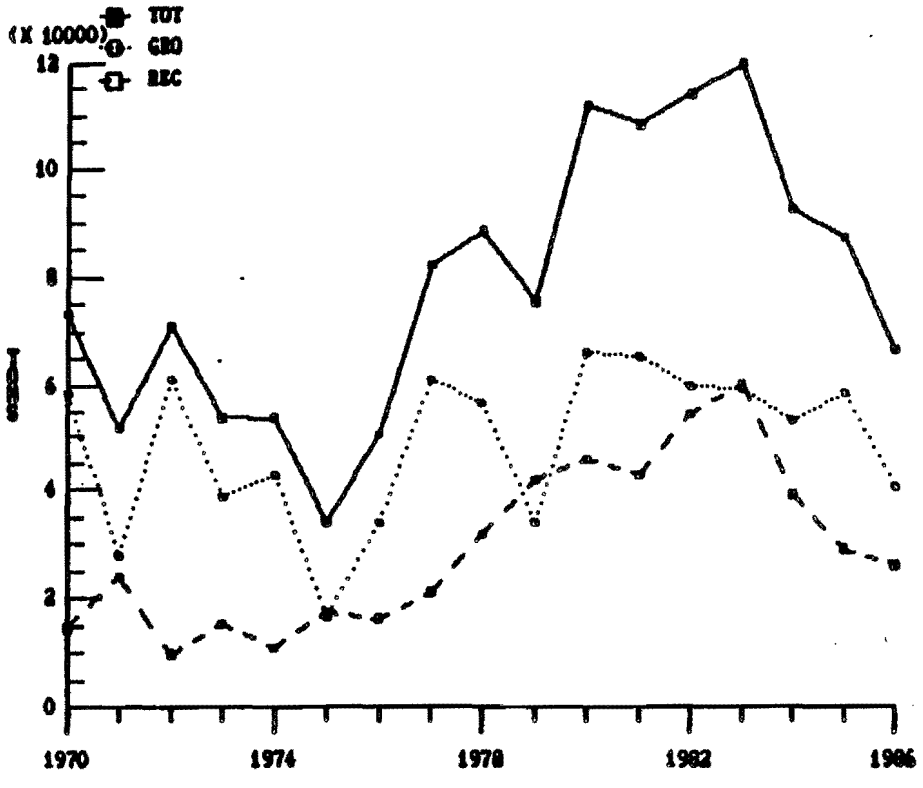


Figure 24: 4VsW cod age 3+ mean population biomass.



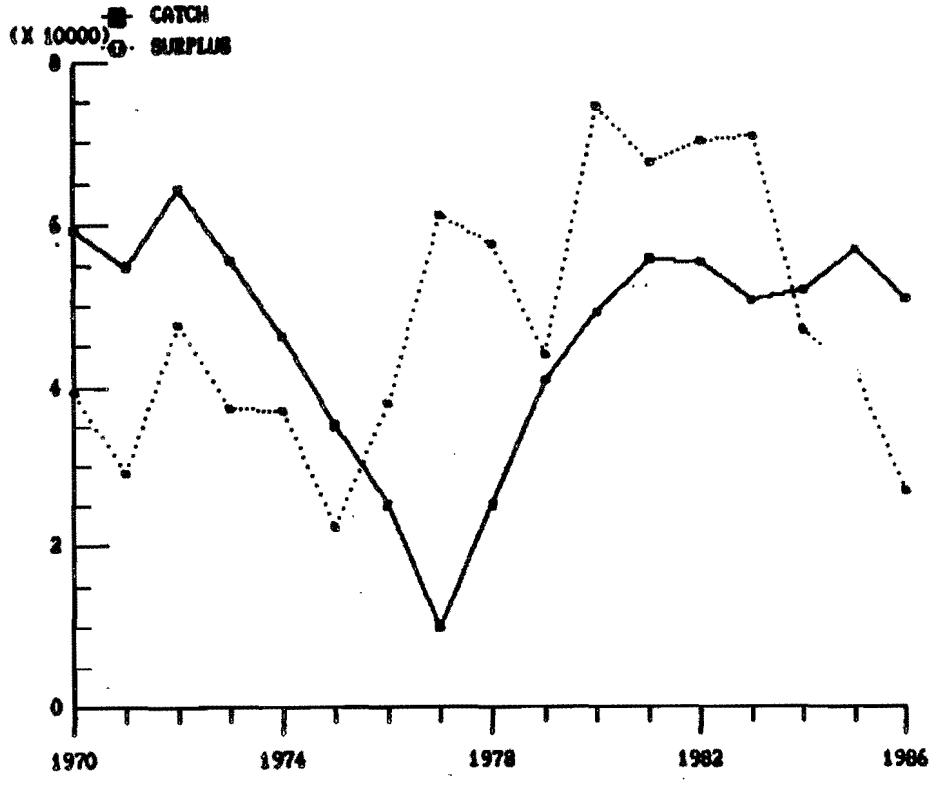


Figure 25: Production history of 4VsW cod. A) Production due to growth and recruitment, B) Comparison of surplus production (total production less natural mortality) and catch biomass. Stock biomass increases when surplus production exceeds catch.