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# Assessment of 4VsW Cod in 1987

by

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## Abstract

The 1987 catch fell almost 6,000 t below that of 1986 to 45,372 t. The movement of the population from 4W to 4Vs seen in the fishery and in the research vessel survey since 1983 has continued in 1987. The research vessel numbers indicate that while the age 5+ population abundance remains large the population at younger ages appears no better than average with 2 year classes (1983 and 1984) very small. The standardized trawler catch rate remains high although lower than in 1985 and 1986. Both the research vessel (RV) population numbers at age and commercial CPUE were used to calibrate the cohort analysis. The RV calibration used age by age non-linear least squares to estimate fishing mortalities (F) in 1987. The average fully recruited F was 0.30. Conventional age aggregated calibration indicated fully recruited F to be 0.26. The average value of 0.28 was selected as the terminal F in 1987. Catch projections indicated that if the 1988 TAC of 38,000 t were taken it would produce an $F_{0.1}$ TAC of 33,200 t in 1989. Application of the 50% rule yields a 1989 TAC of 35,200 t.



## Résumé

Les prises de 1987, de 45 372 t, ont été inférieures de près de 6 000 t à celles de 1986. Le déplacement de la population de 4W vers 4Vs indiqué par les résultats de la pêche et ceux des relevés par navires de recherche depuis 1983 s'est poursuivi en 1987. Selon les données des relevés de recherche, la population d'âge 5+ demeure importante, celle des poissons plus jeunes n'est pas supérieure à la moyenne et deux classes annuelles (1983 et 1984) sont très faibles. Le taux de prises au chalut normalisé demeure élevé bien qu'inférieur à ceux de 1985 et 1986. Les effectifs selon l'âge déterminés par navires de recherche et les PUE de la pêche commerciale ont servi à l'étalonnage de l'analyse des cohortes. La valeur de F de 1987 a été estimée par étalonnage par méthode des moindres carrées non linéaire âge par âge des résultats NR. La valeur moyenne du F de plein recrutement était de 0,30. Un étalonnage classique par regroupement des âges donnait cependant une valeur de F de plein recrutement de 0,26. La valeur moyenne de 0,28 F de dernière année en 1987. Selon les prévisions des prises, l'atteinte du TPA de 1988, de 38 000 t, se traduirait par un TPA ($F_{0,1}$) de 33 200 t en 1989. L'application de la règle du rendement de 50 % donne un TPA de 35 200 t en 1989.

## Introduction

The preliminary catch in 1987 was 45,372 t, a drop of almost 6,000 t from 1986 (Table 1, Figure 1). The only foreign catch was 80 t total bycatch in the silver hake and redfish (Japan) fisheries.

The catch declined proportionately in both Division 4W and Subdivision 4Vs (Figure 2). The Canadian catch is broken down by gears and areas in Table 2. The total catches by the different Canadian gears all decreased to some degree (Figure 3) however, unlike 1986 the longliner catch fell proportionately more than did that of the trawlers (Figure 4).

The 1987 TAC was 44,000 t which was exceeded by 1,372 t. All gear sectors except the fixed gear between 65' and 100' exceeded their final allocations (Table 3a). The history of management variation orders pertaining to the stock in 1987 is in Table 3b.

## Catch at Age

The catch at age prior to 1987 was taken from Sinclair and Smith (1987). The 1987 commercial catch at age was estimated using 5 age length keys (Table 4). The pair trawl, seine and otter trawl landings were grouped into the otter trawl keys. The longline and handline landings were grouped in the longline keys. The resulting catch at age by key is given in Table 5. There were no large shifts between quarters in the numbers at age for trawlers. The trawlers caught proportionately much more at ages 4 and 5 than did the longliners.

The catch in the keys for 1987 was 96% of the total (43,754 t out of 45,372 t). The catch at age was pro-rated to the total catch and appended to the catch at age matrix for 1970 to 1986 (Table 6).

The observed catch at age for 1987 was compared to that projected in the 1987 assessment (Figure 5). The catches of the 1981 and 1982 year classes were higher than projected and the 1980 year class at age 7 was much larger than projected, and conversely, the catch of the 1983 year class at age 4 was much smaller.

The decline in commercial mean weights at age (Table 7, Figure 6) noted in the previous assessment continues, particularly at older ages (6, 7, and 8).

## Indices of Abundance

### Commercial Catch Rates

Catch and effort data from the previous assessment were updated using NAFO statistics for 1984 and 1985. The Atlantic zone data was

obtained from the ZIFF dataset for 1986 and 1987. Only otter trawler catch and effort was utilized as the longline catch rates have been found to poorly represent population abundance (Sinclair and Smith, 1987). The resulting catch rate series, from 1968 to 1987 was standardized using a multiplicative model.

The gear categories were defined by Sinclair and Smith (1987) and are:

| Category | Gear | TC | Country |
|---|---|---|---|
| 1 | OTB1 | 4 | Maritime |
| 2 | OTB2 | 2 | Maritime |
| 3 | OTB2 | 3 | Maritime |
| 4 | OTB2 | 4 | Maritime |
| 5 | OTB2 | 5 | Maritime |
| 6 | OTB1 | 4 | Nfld. |
| 7 | OTB2 | 4 | Nfld. |
| 8 | OTB2 | 5 | Nfld. |
| 9 | PTB | 4 | Spain |
| 10 | PTB | 5 | Spain |

An additional category examined this year is:

| | | | |
|---|---|---|---|
| 11 | OTB2 | 6 | Maritime |

The analysis of the catch rate data for this assessment was done in the same manner as was described in Sinclair and Smith (MS 1987). The statistical package GLIM (Payne, 1986) was again used for the modelling of the data and applying diagnostics to the resultant models. Estimated annual standard catch rates and standard errors were initially verified with results obtained from the STSC-APL workspace STANDARD (Anon. MS 1986).

The catch and effort data for 1965-1987 for otter trawlers and Spanish pair trawlers were fitted by the full model,

$$\ln(\text{catch/effort}) = \text{mean} + \text{gear} + \text{month} + \text{year}.$$

The factor for area was found to make a marginally nonsignificant contribution to the model in last year's analysis and this factor was tested and removed again this year (P-level = 0.09265).

As was the case last year, the influence or leverage that each observation has on the fitted value was measured via the diagonal elements of the Hat-matrix. These elements and associated information on the temporal distribution of gear types are presented in the draftsman plot in Figure 7a. The critical value for evaluating the

leverage values indicated on the lower two plots was 0.0746. The gear codes are as defined above. In the analysis presented last year many of the observations in the years 1965-1967 and all of the 1978 and 1979 points were identified as having higher than expected influence on these fitted values. This is also true in the current analysis. Additionally the new gear category examined (TC 6 Maritimes) also had higher influences and these observations were removed and the analysis was run again. There was some doubt regarding the identification of observations of this gear category in previous years and evaluation of the value of having this gear type in the model depends on resolving this problem.

The leverage plots for the second run are given in Figure 7b where 1965-1967, 1978-1979 points still stand out. Removal of the 1965-1967 points resulted in changes for the estimates for 1979-1986 in last year's analysis while the presence or absence of the 1978-1979 had little impact. Therefore the final series used for this assessment used the data for 1968-1987 with gear type 11 removed.

The estimates for the parameters for the final model are in Table 9, the estimated annual catch rates with standard errors are in Table 10 and the catch rate series is plotted in Figure 8.

The International Observer Program (IOP) observed 2000 trawl sets from domestic TC5 stern trawlers during the 1987 Scotian Shelf 4VsW cod fishery. Deployments were highest in the second half of the year. The yearly coverage level was 7% of the total catch for OTB's (table below). Directed catch rates were observed to be higher in the first half of the year (Figures 9a, 9b). The concentration of the catch in the Banquereau area noted in the last assessment continued in 1987. The highest catch rates in the first half of 1987 were along the Laurentian Channel. During the second half of the year the highest catch rates were more to the west, on Banquereau and Misaine Banks.

| | Reported Catch | Observed Catch | Observed Directed Catch | Observed Directed Effort | Observed Directed CPUE |
|---|---|---|---|---|---|
| Jan-Jun | | 802 | 509 | 200 | 2.542 |
| Jul-Dec | | 1536 | 1527 | 1560 | 0.978 |
| Total | 34107 | 2338 | 2036 | 1760 | 1.369* |

*Weighted by catch

Research Vessel Surveys

The July research survey conducted in Scotia-Fundy Region from 1970 to 1987 was used to evaluate the status of the resource. The estimated numbers at age from these surveys are in Table 11 and the

total abundance and ages 4 to 7 abundance are plotted in Figure 10. The RV indicates that the 1985 and 1986 year classes are small, however this indication must be interpreted with caution. The total abundance indicates a small increase over the estimates in 1986 however both the total and ages 4-7 abundance are low, similar to the middle 1970's. The distribution of the survey abundance reflects the same trend as the commercial fishery. The age 5+ abundance in 4Vs is increasing with respect that in 4W and currently the relative difference is at the most extreme seen in the survey series (Table 12, Figure 11).

The percent at age in the July RV survey has shown an increasing proportion of older fish since 1983 (Table 13). This corresponds well with the passage through the population of the large 1980-81 year classes.

The mean weight at age in the RV surveys have also followed that same trend as the commercial in that the mean weights in the older age groups (6, 7, and 8) have been declining since 1979 or 1980 (Table 14, Figure 12). The biomass at age, based on numbers at age and mean weights at age, in the RV survey is given in Table 15.

## Sequential Population Analysis

Input Partial Recruitment

Partial recruitment was estimated from the ratio of F's at younger ages to fully recruited F's in the last 3 years of an initial COHORT run. The input PR and $F_t$ were from last year's assessment. It was assumed that ages 7 to 10 were fully recruited. The F's on the younger ages were divided by the average fully recruited F (ages 7-10) weighted by population numbers within each year. The 3 annual PR vectors were then averaged across years and the resulting PR vector was adjusted to make the mean of ages 7-10 equal to 1.0. Values at ages 7 to 10 were set to 1.0 and the resulting average PR was then input into a COHORT run and a new F matrix generated. The procedure was iterated until no further change in the PR vector occurred.

Comparison of the current PR vector with that from the 1986 assessment is given in the text table below.

| | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| Year Aver. | 1 | 2 | 3 | 4 | 5 | 6 | 7+ |
| 83-85 | .005 | .005 | .060 | .350 | .800 | 1.000 | 1.000 |
| 84-86 | .001 | .001 | .021 | .271 | .695 | 1.000 | 1.000 |

The value at age 1 was set equal to age 2 (0.001) as the estimated PR was 0 due to no catch.

Calibration

Natural mortality was assumed constant at 0.2 for all ages and years. With this assumption three different calibrations of the SPA were considered in this assessment. The RV 5+ numbers were regressed on the SPA 5+ numbers excluding the 1970 point. The 1970 observation has been excluded from the calibration since 1980. The reasons given to exclude the point have usually referred to a change in the survey gear between 1970 and 1971 and to the large residual for this year. The population in the survey is too low to be consistent with a population generated from the SPA. This practice has been followed in the current assessment. The 1984 and 1986 survey estimates are high and low outliers respectively. The regressions including a fitted intercept were examined and non-significant intercepts were estimated in a range of F's (0.25-0.45) around the maximum $R^2$ (equivalent to minimum mean squared error (MSE)). The F was chosen based on the minimum MSE about the regression line when it was fitted with a zero intercept. The F estimated this way was $F_t = 0.353$.

Cohort analysis of ages 1 to 15 from 1971 to 1987 was calibrated age by age using ADAPT, an implementation of the adaptive framework of Gavaris (1988) (listing in Appendix 1). The RV numbers at ages 4 to 7 were used to estimate fishing mortality at these ages in 1987. The F's at other ages were based on the mean 84-86 PR given above and the mean F for ages 6 and 7. The ADAPT summary table is given in Table 16a. The diagnostics from initial runs indicated that intercepts were not necessary in the age-by-age relationships between RV and SPA numbers. The final estimate of mean F for ages 6+ was 0.305. The estimates of numbers in 1987 were significant at ages 5-7 and only marginally non-significant at age 4 (Table 16b). The estimated slopes were significant at all ages. The non-significant estimate at age 4 is caused by the fact that the age 4 parameter estimate only affects a single residual; that for age 4 in 1987. Because there is only a single residual for the age 4 parameter the residual is always zero i.e. the parameter is adjusted to fit the last point at age 4 on the line, and hence the parameter estimate is non-significant. There is one anomalous year class (1969) apparent in the residuals (Table 17; Figure 13). There is a large positive residual at age 4 and large negative residuals at ages 5 and 6 associated with the 1969 year class. This year class is fully converged and hence adjustment of the F's in the final year will not affect the estimates pertaining to the 1969 year class.

Although the adaptive framework makes it possible to incorporate more than one index series in a single calibration this requires a means of assigning the appropriate relative weights to the residuals. As survey standard errors were not available the CPUE series was analysed as a separate calibration. The standard formulation of fishable biomass on standardized CPUE aggregated across ages was chosen. Since the CPUE series is for otter trawlers only, the fishable biomass was calculated from annual PR vectors for otter trawlers although commercial weights at age were for all gears

combined. Review of initial calibration plots indicated that non-significant intercepts occurred over a wide range of F's (0.25-0.45). For this reason a terminal F of 0.26 was selected based on minimum mean squared error (eqivalent to maximizing $R^2$) for regressions through the origin of CPUE on OTB fishable biomass.

The estimate of F from ADAPT was considered the best estimate available from the survey data. It was averaged with the estimate from conventional tuning of CPUE on fishable biomass to produce a final estimate of F = 0.28. The average was used because the lack of survey variance estimates makes it impossible to properly weight both indices in ADAPT. The average implicitly gives equal weight to the two estimates of F. It is anticipated that the average used will have little impact on the conclusions of the assessment relative to a weighted analysis.

The fishing mortality matrix, beginning of year population numbers, and mean population biomass are given in Tables 18, 19, and 20 respectively.

## Assessment Results

To put the current view of the resource status in perspective the long-term (1958-87) age 1 recruitment and mean 3+ biomass are given in Figures 14 and 15. The recruitment at age 1 was at a peak in 1981 (1980 year class) second only to that in 1965 (1964 year class). Since 1981 the recruitment has plunged to the lowest values since 1958.

The 3+ population biomass reached a high plateau from 1983 to 1985 and has declined in 1986 and 1987. In spite of the decline the 1987 biomass is still approximately equal to the previous peak which was in 1962. The early 80's peak is the result of 2 very large year classes (1979 and 1980) passing through the population at the same time.

Specific details of the conclusions regarding the population trends in the last few years (84-87) will depend on the estimates of population size in 1987. In spite of this, the indications of low recruitment from the 1983 and 1984 year classes and declining stock biomass must be taken as real.

## Prognosis

Catch projections from the beginning of year 1988 numbers, average weights from 1985-87 and final PR in 1987 from ADAPT were made to 1989. The recruitment to the population was determined by setting the apparently small 1984 year class equal to the smallest previously observed which was 1983. The 1985 year class was also set to the smallest previously observed which was also the 1983 year class. There is only 1 previous observation in the fishery of the 1985 year class

however, the survey also indicates that it is small. The 1986-88 year classes at age 1 were set equal to the geometric mean recruitment at age 1 from 1970-83 (86.8 million).

The input data are:

| Age | Numbers in 1988 | Mean Weight | Recruitment |
|---|---|---|---|
| 1 | 86802* | 0.065 | 0.001 |
| 2 | 71067* | 0.367 | 0.001 |
| 3 | 31485* | 0.629 | 0.02 |
| 4 | 25742* | 0.986 | 0.13 |
| 5 | 20262 | 1.353 | 0.67 |
| 6 | 23513 | 1.758 | 1.0 |
| 7 | 15538 | 2.293 | 1.0 |
| 8 | 15911 | 2.900 | 1.0 |
| 9 | 7193 | 3.802 | 1.0 |
| 10 | 2936 | 4.815 | 1.0 |
| 11 | 1617 | 6.136 | 1.0 |
| 12 | 634 | 6.534 | 1.0 |
| 13 | 359 | 9.175 | 1.0 |
| 14 | 167 | 11.059 | 1.0 |
| 15 | 28 | 12.030 | 1.0 |

* set as described in text.

If the 1988 TAC of 38,000 t is taken it would generate an F of 0.225 and the projected $F_{0.1}$ catch in 1989 would be 33,200 t. Application of the 50% rule would set the target F in 1989 to be 0.213 (i.e. midway between the estimated F in 1988 of 0.225 and $F_{0.1}$ which is 0.20) which would imply a catch in 1989 of 35,200 t.

## Retrospective

The assessment results regarding terminal F and age 3 recruitment in the last 5 assessments are summarized below:

| Assessment Year | $F_t$ | Year class at age 3 (millions) 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|
| 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 | |
| 1988 | .28 | 85 | 101 | 62 | 57 | 31 | (31) |

* numbers in parentheses were assumed.

Although the 1987 fishery produced the lowest $F_t$ in the past 5 years (0.28) it remains well above $F_{0.1}$ (0.20).

In each of the last 2 assessments the perception of the 1980-82 year classes has increased however the 1983 year class has become smaller. The 1979 year class now is estimated at a value intermediate to the last two assessments.

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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 | 19610 | 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 | 51765 | - | 303 | - | 110 | 30 | 52546 | 42578 | 9968 | 55000 |
| 1985 | 56553 | - | 870 | - | 21 | 11 | 57455 | 48189 | 9266 | 55000 |
| 1986[1] | 51248 | - | - | - | 28 | 34 | 51306 | 43819 | 7487 | 48000 |
| 1987[1] | 45292 | - | - | - | 35[2] | 45[2] | 45372 | 39647 | 5725 | 44000 |
| 1988 | | | | | | | | | | 38000 |

[1] Preliminary interzonal

[2] IOP

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 | 38533 | 7449 | 718 | 609 | 47309 | 3035 | 2758 | 1229 | 2222 | 9244 | 41568 | 10207 | 1947 | 2831 | 56553 |
| 1986[1] | 34515 | 8145 | 250 | 880 | 43791 | 2206 | 2700 | 626 | 1925 | 7457 | 36721 | 10845 | 875 | 2807 | 51248 |
| 1987[1] | 32770 | 6218 | 254 | 385 | 39627 | 1337 | 2404 | 542 | 1382 | 5665 | 34107 | 8622 | 796 | 1767 | 45292 |

[1] Preliminary Interzonal

Table 3a. 4VsW Cod - 1987 Allocations & Catches.

| Gear Sector | Initial Allocation | Final Allocation | Catch (Quota Report)* |
|---|---|---|---|
| Vessels >100' | 28955 | 28955 | 29071 |
| fg 65 - 100' | 850 | 410 | 245 |
| mg 65 - 100' | 585 | 1025 | 1201 |
| fg<65' | 8550[t] | 8550 | 8814 |
| mg<65' | 5060[v] | 5060 | 5390 |
| Total | 44000 | 44000 | 44721 |

* Preliminary

Table 3b. 4VsW Cod - 1987 Management Variation Orders.

| Gear Sector | Allocations | Initial Closures | Final Closures |
|---|---|---|---|
| FG<65' | 455 | Jan. 1 - Mar. 31 | |
| | 840 | Apr. 1 - May 31 | Apr.1 (4500 kg Trip Limit (T.L.)) |
| | 5520 | June 1 - Aug. 31 | June 1 (18000 kg T.L.) |
| | | | July 23 (9000 kg T.L.) |
| | | | Aug. 13 (13600 kg T.L.) |
| | 1735 | Sept. 1 - Dec. 31 | Sept. 1 (13600 kg T.L.) |
| | | | Sept. 14 (4530 kg T.L.) |
| | | | Nov. 20 (1500 kg T.L.) |
| MG<65' | 1285 | Jan. 1 - Mar. 31 | Jan. 1 (13500 kg T.L.) |
| | 2535 | Apr. 1 - Aug. 31 | Apr. 1 (13500 kg T.L.) |
| | | | Apr. 16 (0 kg T.L. 10% Bycatch (BC)) |
| | | | May 2 (7000 kg T.L.) |
| | | | May 22 (1500 kg T.L. 10% BC) |
| | | | July 7 (0 kg T.L. 10% BC) |
| | | | Aug. 6 (3400 kg T.L.) |
| | 1240 | Sept. 1 - Dec. 31 | Sept. 1 (9000 kg T.L.) |
| | | | Sept. 26 (3400 kg T.L.) |
| | | | Nov. 27 (1500 kg T.L.) |
| All gear >65' | | | April 9 (New Brunswick only) |
| FG >65' | | | December 14 |
| MG >65-100' | | | Feb. 25 (revoked March 7) |
| | | | Mar. 14 (revoked Nov. 8) |
| | | | Nov. 22 (revoked Nov. 26) |
| | | | Dec. 14 |

Table 4. Data used to generate 1987 age length keys for 4VsW cod.

| Key | Gear | Period Covered | Length-Weight Coeff* a | b | No. Measured | No. Aged | Catch |
|---|---|---|---|---|---|---|---|
| 1 | OTB, OTM, PTB | Q1-Jan.-Mar. | .0084 | 3.021 | 7083 | 576 | 10598 |
| 2 | OTB, OTM, PTB | Q2-Apr.-Jun. | .0084 | 3.021 | 5163 | 349 | 6635 |
| 3 | OTB, OTM, PTB | Q3-Jul.-Sept. | .0084 | 3.021 | 5733 | 330 | 9803 |
| 4 | OTB, OTM, PTB | Q4-Oct.-Dec. | .0084 | 3.021 | 2458 | 356 | 7812 |
| 5 | LL, LH | Jan.-Dec. | .0084 | 3.021 | 3369 | 547 | 8906 |

* 1987 July Groundfish Survey

Table 5. 4VsW cod catch at age ('000) by key in 1987.

| Age | OTB, OTM, PTB | | | | LL, LHP | Total |
|---|---|---|---|---|---|---|
| | $Q_1$ | $Q_2$ | $Q_3$ | $Q_4$ | Combined | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 28 | 3 | 2 | 2 | 0 | 35 |
| 4 | 254 | 111 | 240 | 192 | 5 | 802 |
| 5 | 1705 | 784 | 1614 | 913 | 180 | 5196 |
| 6 | 1498 | 676 | 1656 | 1212 | 343 | 5385 |
| 7 | 1971 | 826 | 1295 | 817 | 605 | 5514 |
| 8 | 772 | 415 | 440 | 414 | 452 | 2493 |
| 9 | 276 | 120 | 172 | 108 | 341 | 1017 |
| 10 | 141 | 51 | 21 | 81 | 266 | 560 |
| 11 | 29 | 7 | 3 | 21 | 160 | 220 |
| 12 | 25 | 1 | 28 | 5 | 65 | 124 |
| 13 | 10 | 2 | 0 | 1 | 45 | 58 |
| 14 | 3 | 0 | 0 | 4 | 3 | 10 |
| 15 | 0 | 4 | 0 | 0 | 10 | 14 |
| 16 | 1 | 2 | 0 | 0 | 9 | 12 |
| Total | 6713 | 3002 | 5471 | 3770 | 2482 | 21440 |

Table 6. 4VsW cod commercial removals at age.

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1293 | 2311 | 2383 | 1418 | 1482 | 1792 | 728 | 2 | 177 | 12 | 31 | 3 | 5 | 0 | 0 | 0 | 0 | 0 |
| 2 | 8631 | 15218 | 17738 | 12142 | 8451 | 9979 | 4061 | 24 | 153 | 81 | 152 | 348 | 149 | 0 | 2 | 4 | 2 | 0 |
| 3 | 8886 | 12582 | 14227 | 14881 | 12885 | 9485 | 3587 | 386 | 1004 | 1629 | 2034 | 3742 | 2500 | 3048 | 378 | 154 | 121 | 36 |
| 4 | 14802 | 9146 | 13361 | 7507 | 9947 | 4341 | 3713 | 1073 | 3650 | 6164 | 5119 | 9724 | 7664 | 8251 | 6034 | 2323 | 4121 | 832 |
| 5 | 13673 | 8809 | 9661 | 9755 | 7130 | 4549 | 4818 | 1559 | 4621 | 9145 | 7112 | 7276 | 9953 | 7368 | 9434 | 8353 | 7506 | 5388 |
| 6 | 4539 | 10262 | 8780 | 3823 | 2766 | 2594 | 2412 | 871 | 2441 | 4871 | 6147 | 4852 | 3449 | 5967 | 6141 | 7782 | 9026 | 5584 |
| 7 | 1942 | 5160 | 3432 | 2996 | 944 | 2627 | 1426 | 501 | 768 | 1162 | 2929 | 2991 | 2408 | 1938 | 4192 | 3922 | 3527 | 5718 |
| 8 | 759 | 1849 | 1919 | 3724 | 1323 | 612 | 611 | 220 | 213 | 371 | 1066 | 1455 | 1273 | 999 | 1318 | 2224 | 1518 | 2585 |
| 9 | 236 | 496 | 358 | 1166 | 413 | 497 | 184 | 128 | 112 | 76 | 319 | 393 | 674 | 576 | 579 | 978 | 1105 | 1055 |
| 10 | 72 | 114 | 393 | 273 | 369 | 660 | 49 | 35 | 80 | 23 | 88 | 126 | 304 | 229 | 297 | 427 | 437 | 581 |
| 11 | 137 | 131 | 79 | 299 | 15 | 153 | 22 | 44 | 26 | 10 | 47 | 62 | 156 | 140 | 156 | 274 | 282 | 228 |
| 12 | 56 | 72 | 2 | 3 | 5 | 126 | 107 | 55 | 28 | 5 | 26 | 32 | 67 | 50 | 63 | 168 | 106 | 129 |
| 13 | 9 | 98 | 37 | 7 | 0 | 36 | 1 | 11 | 26 | 4 | 4 | 21 | 57 | 22 | 34 | 65 | 65 | 60 |
| 14 | 12 | 12 | 0 | 5 | 0 | 9 | 4 | 3 | 9 | 1 | 1 | 2 | 51 | 16 | 17 | 19 | 11 | 10 |
| 15 | 4 | 51 | 1 | 5 | 0 | 9 | 1 | 2 | 4 | 0 | 4 | 6 | 19 | 6 | 2 | 16 | 19 | 15 |

Table 7. 4VsW cod mean weights at age in the commercial catch

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .02 | .01 | .05 | .08 | .13 | .10 | .10 | .10 | .20 | .07 | .07 | .07 | .07 | .12 | .07 | .07 | .07 | .07 |
| 2 | .15 | .11 | .18 | .22 | .33 | .27 | .28 | .28 | .62 | .53 | .57 | .62 | .58 | .39 | .56 | .64 | .26 | .21 |
| 3 | .45 | .32 | .44 | .45 | .62 | .53 | .57 | .81 | .95 | .76 | .80 | .83 | .81 | .81 | .72 | .70 | .69 | .50 |
| 4 | .91 | .64 | .81 | .79 | 1.02 | .89 | .96 | 1.09 | 1.25 | 1.06 | 1.15 | 1.14 | 1.07 | 1.08 | 1.00 | 1.04 | .96 | .95 |
| 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 | 1.33 |
| 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 | 1.61 |
| 7 | 2.94 | 2.09 | 2.48 | 2.28 | 2.82 | 2.47 | 2.66 | 3.17 | 3.61 | 3.13 | 3.08 | 2.97 | 2.78 | 3.10 | 2.49 | 2.49 | 2.42 | 1.97 |
| 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 | 2.76 |
| 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 | 3.40 | 4.07 |
| 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 | 5.11 | 5.02 | 4.32 |
| 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 | 6.75 |
| 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 | 6.64 |
| 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 | 8.95 | 9.94 | 10.05 | 7.54 |
| 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 | 12.59 |
| 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 | 11.26 | 11.73 | 13.11 |

Table 8. Data selection in recent years for standardization of 4VsW cod OTB 1, 2 catch rates.

**1984 - CAFSAC Res. Doc. 84/78**

Included: 1968-76 Spanish PTB TC 4, TC 5
1968-83 Canadian (M&Q) LLS TC 2-4
1974-77, 1980-83 Canadian (M&Q) OTB 1 TC 4
1974-77, 1980-83 Canadian (M&Q) OTB 2 TC 5

Excluded: 1968-73 Canadian (M&Q) (OTB 1, TC 4), (OTB 2, TC 5)
- these two series indicated stable or increasing biomass when other indications were that there was a substantial decline in biomass.

1978-79 Canadian (M&Q) (OTB 1, TC 4), (OTB 2, TC 5)
- removed because the possibility of substantial misreporting of catch and effort.

**1985 - CAFSAC Res. Doc. 85/39**

Included: 1965-76 Spanish PTB TC 4, TC 5
1965-84 Canadian (M&Q) LLS TC 2-4
1965-84 Canadian (N) OTB 1 TC 4
1965-84 Canadian (N) OTB 2 TC 4, TC 5
1965-84 Canadian (M&Q) OTB 1 TC 4
1965-84 Canadian (M&Q) OTB 2 TC 2, TC 3, TC 4, TC 5

Excluded: All observations where catch or effort was less than 10 units.

1965-74 Canadian (M&Q) OTB 1-2 and 1978-79 Canadian (M&Q) OTB 1-2
- as 1984

7 individual points associated with abnormally large residuals were eliminated.

**1986 - CAFSAC Res. Doc. 86/46**

Included: As in 1985 with the addition of 1985 catch and effort for Canadian (M) and Canadian (N).

Excluded: As in 1985 with the addition of 1985 Canadian (M) OTB 2 TC 5
- due to biased catch rates caused by company imposed trip limits on cod.

**1987 - CAFSAC Res. Doc. 87/72**

Included: 1968-76 Spanish PTB TC 4, TC 5
1968-86 Canadian (M) OTB 1 TC 4
1968-86 Canadian (M) OTB 2 TC 2, TC 3, TC4, TC5
1968-86 Canadian (N) OTB 1 TC 4
1968-86 Canadian (N) OTB 2 TC 4, TC 5

Excluded: All observations of catch or effort less than 10.
All longliners.

**1988 - This assessment**

Included: As in 1987 with the addition of 1987 catch and effort for Canadian (M) and Canadian (N).

Excluded: As in 1987 with the addition of all OTB 2 TC 6

Table 9. Estimated parameters and standard errors of 4VsW cod trawler catch rate final model.

d.f. = 1089 from 1129 observations

| number | estimate | s.e. | parameter |
|---|---|---|---|
| 1 | 0.1669 | 0.1001 | 1 - mean over standards |
| 2 | -0.6049 | 0.08425 | GEAR(2) |
| 3 | -0.02000 | 0.07018 | GEAR(3) |
| 4 | 0.05957 | 0.06720 | GEAR(4) |
| 5 | 0.2182 | 0.06141 | GEAR(5) |
| 6 | -0.1427 | 0.08600 | GEAR(6) |
| 7 | 0.01945 | 0.1050 | GEAR(7) |
| 8 | 0.1950 | 0.07806 | GEAR(8) |
| 9 | 0.4943 | 0.07933 | GEAR(9) |
| 10 | 0.8921 | 0.08631 | GEAR(10) |
| 11 | 0.000 | Deleted | GEAR(11) |
| 12 | 0.08436 | 0.08185 | MONT(2) |
| 13 | 0.03431 | 0.07836 | MONT(3) |
| 14 | -0.1838 | 0.07995 | MONT(4) |
| 15 | -0.3603 | 0.08202 | MONT(5) |
| 16 | -0.4705 | 0.08929 | MONT(6) |
| 17 | -0.5289 | 0.09687 | MONT(7) |
| 18 | -0.3550 | 0.08975 | MONT(8) |
| 19 | -0.3072 | 0.08889 | MONT(9) |
| 20 | -0.3192 | 0.08564 | MONT(10) |
| 21 | 0.0007900 | 0.08718 | MONT(11) |
| 22 | 0.02152 | 0.09202 | MONT(12) |
| 23 | 0.000 | Deleted | YEAR(2) |
| 24 | 0.000 | Deleted | YEAR(3) |
| 25 | -0.06681 | 0.1423 | YEAR(4) |
| 26 | -0.08999 | 0.1383 | YEAR(5) |
| 27 | -0.1976 | 0.1407 | YEAR(6) |
| 28 | -0.5455 | 0.1367 | YEAR(7) |
| 29 | -0.5914 | 0.1178 | YEAR(8) |
| 30 | -0.6359 | 0.1127 | YEAR(9) |
| 31 | -0.9359 | 0.09739 | YEAR(10) |
| 32 | -1.233 | 0.1035 | YEAR(11) |
| 33 | -0.9494 | 0.09888 | YEAR(12) |
| 34 | -0.9587 | 0.1150 | YEAR(13) |
| 35 | -0.8368 | 0.1984 | YEAR(14) |
| 36 | -0.1320 | 0.1779 | YEAR(15) |
| 37 | -0.3627 | 0.09057 | YEAR(16) |
| 38 | -0.4074 | 0.08560 | YEAR(17) |
| 39 | -0.2176 | 0.08377 | YEAR(18) |
| 40 | -0.2547 | 0.09118 | YEAR(19) |
| 41 | -0.1411 | 0.08941 | YEAR(20) |
| 42 | 0.08912 | 0.08930 | YEAR(21) |
| 43 | 0.2943 | 0.08873 | YEAR(22) |
| 44 | 0.000 | Standard | YEAR(23) |

scale parameter taken as 0.2995

Table 10. 4VsW cod final standardized catch rate series.

| Year | CPUE | Std. Error | Effort |
|---|---|---|---|
| 1968 | 1.2705 | 0.18370 | 14058 |
| 1969 | 1.2425 | 0.17250 | 6628 |
| 1970 | 1.1152 | 0.15833 | 5968 |
| 1971 | 0.7880 | 0.10887 | 13445 |
| 1972 | 0.7544 | 0.09060 | 19337 |
| 1973 | 0.7221 | 0.08215 | 15392 |
| 1974 | 0.5358 | 0.05270 | 11159 |
| 1975 | 0.3977 | 0.04086 | 13553 |
| 1976 | 0.5286 | 0.05197 | 8876 |
| 1977 | 0.5228 | 0.06017 | 8844 |
| 1978 | 0.5826 | 0.11625 | 30137 |
| 1979 | 1.1826 | 0.21695 | 24215 |
| 1980 | 0.9505 | 0.09393 | 37074 |
| 1981 | 0.9092 | 0.08681 | 40486 |
| 1982 | 1.0994 | 0.10363 | 35109 |
| 1983 | 1.0588 | 0.10498 | 35981 |
| 1984 | 1.1864 | 0.11577 | 34343 |
| 1985 | 1.4933 | 0.14871 | 27836 |
| 1986 | 1.8334 | 0.18107 | 20028 |
| 1987 | 1.3659 | 0.13645 | 24970 |

Table 11. Research vessel survey (July) population numbers (000's).

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1478 | 1539 | 6210 | 6430 | 5174 | 3372 | 2242 | 808 | 3033 | 1213 |
| 2 | 16388 | 7680 | 9674 | 43907 | 32961 | 8412 | 14066 | 10145 | 13065 | 10612 |
| 3 | 5250 | 35664 | 11881 | 69024 | 19246 | 13000 | 16098 | 26372 | 31245 | 16044 |
| 4 | 7714 | 8027 | 31536 | 56081 | 5623 | 6171 | 10187 | 17059 | 34205 | 16595 |
| 5 | 3742 | 15803 | 5812 | 22484 | 2017 | 2959 | 6621 | 11353 | 9461 | 18075 |
| 6 | 1228 | 5775 | 5989 | 1870 | 2244 | 675 | 1264 | 4893 | 3490 | 9053 |
| 7 | 1532 | 3459 | 1621 | 2907 | 372 | 867 | 656 | 1081 | 889 | 2696 |
| 8 | 466 | 1475 | 547 | 901 | 463 | 235 | 1308 | 878 | 185 | 1009 |
| 9 | 104 | 638 | 495 | 431 | 224 | 433 | 0 | 244 | 90 | 411 |
| 10 | 249 | 70 | 153 | 514 | 161 | 23 | 929 | 0 | 79 | 83 |
| 11 | 209 | 137 | 0 | 166 | 63 | 0 | 38 | 161 | 0 | 45 |
| 12 | 101 | 58 | 0 | 0 | 59 | 68 | 0 | 62 | 79 | 5 |
| 1+ | 38461 | 80325 | 73918 | 204715 | 68607 | 36215 | 53409 | 73056 | 95821 | 75841 |
| 2+ | 36983 | 78786 | 67708 | 198285 | 63433 | 32843 | 51167 | 72248 | 92788 | 74628 |
| 3+ | 20595 | 71106 | 58034 | 154378 | 30472 | 24431 | 37101 | 62103 | 79723 | 64016 |
| 4+ | 15345 | 35442 | 46153 | 85354 | 11226 | 11431 | 21003 | 35731 | 48478 | 47972 |
| 5+ | 7631 | 27415 | 14617 | 29273 | 5603 | 5260 | 10816 | 18672 | 14273 | 31377 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|---|
| 1 | 690 | 4589 | 2633 | 39572 | 1165 | 3697 | 1026 | 1853 |
| 2 | 7064 | 12770 | 226028 | 37813 | 20894 | 4834 | 3791 | 4325 |
| 3 | 18488 | 18936 | 188892 | 120818 | 36823 | 22643 | 4368 | 14291 |
| 4 | 10260 | 30753 | 65976 | 48451 | 54858 | 27478 | 16126 | 13866 |
| 5 | 17365 | 12057 | 14824 | 24808 | 37171 | 26772 | 10552 | 25450 |
| 6 | 12099 | 8570 | 8020 | 11398 | 17253 | 14701 | 11462 | 10366 |
| 7 | 4794 | 4404 | 4325 | 2611 | 11861 | 7358 | 3339 | 7791 |
| 8 | 1302 | 1553 | 1850 | 1444 | 1170 | 2896 | 1678 | 4235 |
| 9 | 338 | 533 | 413 | 395 | 955 | 1391 | 679 | 979 |
| 10 | 265 | 650 | 419 | 222 | 284 | 330 | 443 | 69 |
| 11 | 93 | 163 | 226 | 64 | 674 | 319 | 101 | 229 |
| 12 | 0 | 74 | 0 | 29 | 17 | 610 | 0 | 124 |
| 1+ | 72758 | 95052 | 513606 | 287625 | 183125 | 113029 | 53565 | 83578 |
| 2+ | 72068 | 90463 | 510973 | 248053 | 181960 | 109332 | 52539 | 81725 |
| 3+ | 65004 | 77693 | 284945 | 210240 | 161066 | 104498 | 48748 | 77400 |
| 4+ | 46516 | 58757 | 96053 | 89422 | 124243 | 81855 | 44380 | 63109 |
| 5+ | 36256 | 28004 | 30077 | 40971 | 69385 | 54377 | 28254 | 49243 |

Table 12. 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 | 1987 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4Vs | <50 FM | 43 | 421 | 943 | 362 | 597 | 146 | 397 | 92 | 81 | 50 | 464 | 3188 | 1323 | 1229 | 5446 | 30937 | 17494 | 3156 | 733 |
| | | 47 | 175 | 0 | 74 | 155 | 96 | 939 | 36 | 275 | 480 | 1592 | 10139 | 2386 | 1492 | 6444 | 512 | 3732 | 5618 | 1487 |
| | | 48 | 90 | 216 | 94 | 397 | 27 | 11 | 17 | 445 | 401 | 4233 | 192 | 354 | 254 | 92 | 268 | 2038 | 288 | 348 |
| | 50-100 FM | 44 | 4219 | 16132 | 11436 | 4068 | 2969 | 1671 | 4374 | 7572 | 528 | 5250 | 4971 | 12332 | 11015 | 7499 | 16361 | 11031 | 14003 | 30771 |
| | | 49 | 5 | 17 | 6 | 39 | 0 | 10 | 0 | 5 | 0 | 57 | 34 | 0 | 39 | 58 | 2 | 22 | 4 | 6 |
| | | 50 | 12 | 3 | 37 | 11 | 30 | 0 | 6 | 81 | 1 | 13 | 0 | 86 | 99 | 77 | 93 | 171 | 46 | 227 |
| | >100 FM | 45 | 86 | 2397 | 332 | 964 | 77 | 242 | 143 | 1081 | 264 | 203 | 4902 | 2150 | 4431 | 1754 | 2526 | 6681 | 1625 | 4661 |
| | | 46 | 60 | 65 | 81 | 36 | 39 | 4 | 169 | 6 | 0 | 68 | 280 | 562 | 1029 | 319 | 486 | 1162 | 350 | 154 |
| | | 51 | 0 | 17 | 29 | 0 | 7 | 31 | 0 | 0 | 0 | 73 | 15 | 32 | 133 | 175 | 102 | 49 | 0 | 176 |
| | | 52 | 0 | 13 | 0 | 0 | 139 | 157 | 57 | 89 | 0 | 383 | 12 | 0 | 293 | 568 | 277 | 72 | 64 | 143 |
| TOTAL 4Vs | | | 5068 | 19803 | 12451 | 6267 | 3530 | 3462 | 4894 | 9635 | 1724 | 12336 | 23733 | 19225 | 20014 | 22432 | 51564 | 42452 | 25154 | 38706 |
| 4W | <50 FM | 55 | 21 | 78 | 599 | 44 | 195 | 109 | 508 | 752 | 728 | 4278 | 3834 | 2022 | 7436 | 5622 | 1184 | 773 | 288 | 562 |
| | | 56 | 25 | 483 | 125 | 517 | 66 | 98 | 703 | 287 | 204 | 5628 | 1047 | 797 | 175 | 487 | 767 | 495 | 100 | 223 |
| | | 58 | 119 | 377 | 264 | 17 | 57 | 89 | 157 | 991 | 173 | 2482 | 2797 | 1017 | 627 | 1305 | 2698 | 1549 | 379 | 107 |
| | | 63 | 0 | 54 | 46 | 0 | 71 | 161 | 67 | 78 | 57 | 103 | 64 | 127 | 27 | 0 | 171 | 60 | 27 | 31 |
| | | 64 | 280 | 316 | 199 | 1674 | 818 | 341 | 893 | 160 | 518 | 2910 | 2011 | 1005 | 1168 | 439 | 934 | 310 | 150 | 321 |
| | 50-100 FM | 54 | 0 | 0 | 37 | 1 | 0 | 0 | 23 | 27 | 1 | 288 | 44 | 123 | 94 | 169 | 0 | 87 | 0 | 39 |
| | | 57 | 1 | 36 | 0 | 0 | 24 | 0 | 0 | 0 | 9690 | 0 | 1905 | 41 | 72 | 54 | 112 | 96 | 287 | 13 |
| | | 60 | 330 | 209 | 0 | 1 | 0 | 131 | 0 | 0 | 106 | 0 | 146 | 65 | 67 | 118 | 0 | 0 | 10 | 0 |
| | | 62 | 10 | 148 | 74 | 0 | 51 | 55 | 387 | 79 | 0 | 55 | 0 | 0 | 59 | 106 | 0 | 208 | 0 | 0 |
| | | 65 | 238 | 245 | 46 | 43 | 103 | 106 | 128 | 46 | 481 | 231 | 436 | 37 | 187 | 118 | 202 | 95 | 77 | 243 |
| | >100 FM | 53 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 64 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 61 | 0 | 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 | 0 | 9 | 0 | 5 | 0 | 0 | 7 | 0 | 0 |
| | | 59 | 1926 | 5766 | 749 | 20707 | 690 | 703 | 3051 | 6613 | 585 | 3065 | 225 | 3418 | 111 | 10013 | 11750 | 7869 | 1639 | 676 |
| TOTAL 4W | | | 2950 | 7712 | 2139 | 23004 | 2075 | 1793 | 5917 | 9033 | 12543 | 19040 | 12518 | 8716 | 10028 | 18431 | 17818 | 11549 | 2957 | 2215 |

Table 13. Percent at age in July RV survey of 4VsW cod. 28/ 4/88

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 4 | 2 | 8 | 3 | 8 | 9 | 4 | 1 | 3 | 2 | 1 | 5 | 1 | 14 | 1 | 3 | 2 | 2 |
| 2 | 43 | 10 | 13 | 21 | 48 | 23 | 26 | 14 | 14 | 14 | 10 | 13 | 44 | 13 | 11 | 4 | 7 | 5 |
| 3 | 14 | 44 | 16 | 34 | 28 | 36 | 30 | 36 | 33 | 21 | 25 | 20 | 37 | 42 | 20 | 20 | 8 | 17 |
| 4 | 20 | 10 | 43 | 27 | 8 | 17 | 19 | 23 | 36 | 22 | 14 | 32 | 13 | 17 | 30 | 24 | 30 | 17 |
| 5 | 10 | 20 | 8 | 11 | 3 | 8 | 12 | 16 | 10 | 24 | 24 | 13 | 3 | 9 | 20 | 24 | 20 | 30 |
| 6 | 3 | 7 | 8 | 1 | 3 | 2 | 2 | 7 | 4 | 12 | 17 | 9 | 2 | 4 | 9 | 13 | 21 | 12 |
| 7 | 4 | 4 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 4 | 7 | 5 | 1 | 1 | 6 | 7 | 6 | 9 |
| 8 | 1 | 2 | 1 | 0 | 1 | 1 | 2 | 1 | 0 | 1 | 2 | 2 | 0 | 1 | 1 | 3 | 3 | 5 |
| 9 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| 10 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 11 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

Table 14. Research vessel survey (July) mean weight at age (kg.).

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .07 | .05 | .07 | .09 | .13 | .09 | .08 | .14 | .08 | .05 | .07 |
| 2 | .24 | .19 | .31 | .25 | .31 | .28 | .26 | .28 | .40 | .26 | .29 |
| 3 | .86 | .44 | .72 | .62 | .55 | .58 | .50 | .63 | .71 | .48 | .58 |
| 4 | 1.17 | 1.05 | .85 | 1.03 | 1.12 | .96 | .94 | 1.04 | 1.20 | .94 | .96 |
| 5 | 1.65 | 1.40 | 1.54 | 1.30 | 1.57 | 1.58 | 1.41 | 1.80 | 1.81 | 1.37 | 1.49 |
| 6 | 2.39 | 1.74 | 1.74 | 2.10 | 2.05 | 2.27 | 2.11 | 2.52 | 2.74 | 2.15 | 2.26 |
| 7 | 3.44 | 2.08 | 1.90 | 2.10 | 3.45 | 3.28 | 3.22 | 3.42 | 3.06 | 3.55 | 2.93 |
| 8 | 3.55 | 2.63 | 2.67 | 2.89 | 3.46 | 3.46 | 3.24 | 5.29 | 4.68 | 5.28 | 4.72 |
| 9 | 5.31 | 3.56 | 7.62 | 2.24 | 2.71 | 4.77 | .00 | 5.09 | 6.47 | 5.59 | 7.70 |
| 10 | 5.68 | 3.10 | 2.34 | 7.96 | 4.01 | 6.17 | 4.99 | .00 | 11.96 | 8.26 | 8.33 |
| 11 | 3.13 | 2.72 | .00 | 4.57 | 8.27 | .00 | 6.17 | 5.42 | .00 | 7.54 | 10.65 |
| 12 | 12.74 | 9.06 | .00 | .00 | 6.17 | 9.06 | .00 | 3.97 | .00 | 12.74 | .00 |

| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|
| 1 | .08 | .06 | .07 | .08 | .06 | .08 | .06 |
| 2 | .34 | .29 | .24 | .28 | .14 | .26 | .18 |
| 3 | .63 | .48 | .51 | .56 | .43 | .46 | .44 |
| 4 | 1.17 | .72 | .97 | .96 | .75 | .84 | .77 |
| 5 | 1.76 | 1.33 | 1.37 | 1.55 | 1.18 | 1.29 | 1.26 |
| 6 | 2.14 | 2.15 | 2.11 | 1.86 | 1.67 | 1.71 | 1.48 |
| 7 | 2.83 | 2.60 | 3.07 | 2.27 | 2.18 | 2.33 | 1.83 |
| 8 | 4.34 | 3.41 | 3.48 | 3.83 | 3.01 | 2.73 | 2.36 |
| 9 | 6.55 | 4.33 | 4.95 | 3.04 | 3.79 | 3.97 | 3.48 |
| 10 | 8.79 | 6.17 | 4.83 | 3.33 | 4.34 | 4.93 | 4.30 |
| 11 | 8.42 | 8.16 | 8.17 | 7.60 | 7.08 | 7.18 | 6.10 |
| 12 | 12.74 | .00 | 11.74 | 13.80 | 4.46 | .00 | 7.80 |

Table 15. Research vessel survey (July) population biomass (mt.).

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 103 | 77 | 435 | 579 | 673 | 303 | 179 | 113 | 243 | 61 |
| 2 | 3933 | 1459 | 2999 | 10977 | 10218 | 2355 | 3657 | 2841 | 5226 | 2759 |
| 3 | 4515 | 15692 | 8554 | 42795 | 10585 | 7540 | 8049 | 16614 | 22184 | 7701 |
| 4 | 9025 | 8428 | 26806 | 57763 | 6298 | 5924 | 9576 | 17741 | 41046 | 15599 |
| 5 | 6174 | 22124 | 8950 | 29229 | 3167 | 4675 | 9336 | 20435 | 17124 | 24763 |
| 6 | 2935 | 10049 | 10421 | 3927 | 4600 | 1532 | 2667 | 12330 | 9563 | 19464 |
| 7 | 5270 | 7195 | 3080 | 6105 | 1283 | 2844 | 2112 | 3697 | 2720 | 9571 |
| 8 | 1654 | 3879 | 1460 | 2604 | 1602 | 813 | 4238 | 4645 | 866 | 5328 |
| 9 | 552 | 2271 | 3772 | 965 | 607 | 2065 | 0 | 1242 | 582 | 2297 |
| 10 | 1414 | 217 | 358 | 4091 | 646 | 142 | 4636 | 0 | 945 | 686 |
| 11 | 654 | 373 | 0 | 759 | 521 | 0 | 234 | 873 | 0 | 339 |
| 12 | 1287 | 525 | 0 | 0 | 364 | 616 | 0 | 246 | 0 | 64 |
| 1+ | 37518 | 72290 | 66835 | 159794 | 40564 | 28811 | 44684 | 80778 | 100499 | 88631 |
| 2+ | 37415 | 72213 | 66401 | 159215 | 39891 | 28507 | 44505 | 80664 | 100256 | 88571 |
| 3+ | 33481 | 70754 | 63402 | 148239 | 29673 | 26152 | 40848 | 77824 | 95030 | 85812 |
| 4+ | 28966 | 55061 | 54847 | 105444 | 19088 | 18612 | 32799 | 61209 | 72846 | 78110 |
| 5+ | 19941 | 46633 | 28042 | 47680 | 12790 | 12688 | 23223 | 43468 | 31800 | 62511 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|---|
| 1 | 48 | 367 | 158 | 2770 | 93 | 222 | 82 | 104 |
| 2 | 2049 | 4342 | 65548 | 9075 | 5850 | 677 | 986 | 793 |
| 3 | 10723 | 11930 | 90668 | 61617 | 20621 | 9736 | 2009 | 6284 |
| 4 | 9850 | 35981 | 47503 | 46997 | 52664 | 20609 | 13546 | 10703 |
| 5 | 25874 | 21220 | 19716 | 33987 | 57615 | 31591 | 13612 | 32023 |
| 6 | 27344 | 18340 | 17243 | 24050 | 32091 | 24551 | 19600 | 15364 |
| 7 | 14046 | 12463 | 11245 | 8016 | 26924 | 16040 | 7780 | 14287 |
| 8 | 6145 | 6740 | 6309 | 5025 | 4481 | 8717 | 4581 | 10015 |
| 9 | 2603 | 3491 | 1788 | 1955 | 2903 | 5272 | 2696 | 3403 |
| 10 | 2207 | 5713 | 2585 | 1072 | 946 | 1432 | 2184 | 297 |
| 11 | 990 | 1372 | 1844 | 523 | 5122 | 2259 | 725 | 1396 |
| 12 | 0 | 943 | 0 | 340 | 235 | 2721 | 0 | 968 |
| 1+ | 101879 | 122903 | 264607 | 195428 | 209545 | 123826 | 67801 | 95637 |
| 2+ | 101831 | 122536 | 264449 | 192658 | 209452 | 123604 | 67718 | 95533 |
| 3+ | 99783 | 118194 | 198901 | 183583 | 203602 | 122927 | 66733 | 94739 |
| 4+ | 89060 | 106264 | 108233 | 121966 | 182981 | 113191 | 64724 | 88456 |
| 5+ | 79210 | 70283 | 60730 | 74968 | 130317 | 92582 | 51178 | 77752 |

Table 16a. ADAPT input summary for 4VsW cod.

Parameters:

Year-class estimates

$N_{i,1987}$ i = 4 to 7

Calibration constants for mid-year RV numbers

$K_i$ i = 4 to 7

Structure imposed:

- error for catch assumed negligible
- partial recruitment vector fixed for ages 1, 2, 3, 8-11, calculated as mean of 1984-86, assuming flat-top recruitment for ages 6 and older.
- F for oldest age group calculated as a weighted F for ages 7, 8, 9, and 10.
- model did not include an intercept term.
- M = 0.2

Input:

$C_{i,t}$, i = 1 t 10; t = 1971-1987

$RV_{i,t}$ (numbers), i = 4, 5, 6, 7, ; t = 1971-1987

Objective function:

- log transformation

Summary:

- Number of observations: 68
- Number of parameters: 8

Table 16b. Final parameter estimates and significance statistics for age 4-7 numbers and corresponding slopes from ADAPT. The correlation matrix pertains to the correlations between the estimated parameters.

PARASE
APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.007788
MEAN SQUARE RESIDUALS ..... 0.288307

| PAR. EST. | STD. ERR. | T-STATISTIC |
|---|---|---|
| 2.29387E0004 | 1.24863E0004 | 1.83710E0000 |
| 3.20939E0004 | 1.20738E0004 | 2.65814E0000 |
| 2.33229E0004 | 7.32510E0003 | 3.18397E0000 |
| 2.41745E0004 | 7.47446E0003 | 3.23428E0000 |
| 6.97335E-001 | 9.87724E-002 | 7.06002E0000 |
| 6.88899E-001 | 9.63972E-002 | 7.14647E0000 |
| 5.91930E-001 | 8.39741E-002 | 7.04896E0000 |
| 5.18642E-001 | 7.40474E-002 | 7.00419E0000 |

Correlation Matrix 4VsW Cod 4-7 no intercept

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.000 | .047 | .049 | .044 | -.254 | -.027 | -.025 | -.025 |
| 2 | .047 | 1.000 | .075 | .067 | -.184 | -.209 | -.039 | -.038 |
| 3 | .049 | .075 | 1.000 | -.013 | -.193 | -.227 | -.288 | -.184 |
| 4 | .044 | .067 | -.013 | 1.000 | -.173 | -.202 | -.253 | -.352 |
| 5 | -.254 | -.184 | -.193 | -.173 | 1.000 | .108 | .100 | .098 |
| 6 | -.027 | -.209 | -.227 | -.202 | .108 | 1.000 | .118 | .114 |
| 7 | -.025 | -.039 | -.288 | -.253 | .100 | .118 | 1.000 | .144 |
| 8 | -.025 | -.038 | -.184 | -.352 | .098 | .114 | .144 | 1.000 |

Table 17. Residuals between the observed RV (log transformed) and the predicted RV by age and year.

| | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | -.773 | .478 | 1.423 | -.655 | -.460 | -.037 | -.069 | .336 | -.264 | -.700 | -.063 | .816 |
| 5 | .035 | -.287 | .946 | -1.116 | -.490 | .313 | .467 | -.288 | .183 | .281 | -.035 | -.308 |
| 6 | -.473 | .049 | -.264 | -.463 | -1.186 | -.299 | .749 | -.091 | .375 | .595 | .330 | .249 |
| 7 | -.060 | -.919 | .431 | -.913 | -.325 | -.084 | .388 | -.360 | .301 | .552 | .420 | .397 |

| | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|
| 4 | .258 | .197 | -.033 | -.452 | .000 |
| 5 | -.175 | .416 | -.168 | -.604 | .382 |
| 6 | .107 | .579 | .147 | -.421 | .016 |
| 7 | -.242 | .853 | .445 | -.708 | -.176 |

Table 18. Fishing mortality matrix for 4VsW cod

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .02 | .03 | .04 | .02 | .02 | .02 | .01 | .00 | .00 | .00 | .00 | .00 | .00 |
| 2 | .12 | .25 | .30 | .26 | .20 | .20 | .07 | .00 | .00 | .00 | .00 | .00 | .00 |
| 3 | .21 | .25 | .39 | .44 | .48 | .37 | .10 | .01 | .02 | .04 | .03 | .06 | .03 |
| 4 | .36 | .35 | .45 | .37 | .59 | .30 | .24 | .04 | .10 | .19 | .17 | .20 | .17 |
| 5 | .40 | .38 | .77 | .70 | .72 | .60 | .63 | .15 | .24 | .39 | .35 | .38 | .32 |
| 6 | .30 | .60 | .81 | .83 | .43 | .64 | .75 | .21 | .36 | .44 | .51 | .43 | .31 |
| 7 | .42 | .67 | .41 | .74 | .49 | .99 | .91 | .34 | .30 | .29 | .51 | .50 | .40 |
| 8 | .34 | .92 | .56 | 1.13 | .90 | .70 | .65 | .33 | .23 | .23 | .48 | .52 | .41 |
| 9 | .59 | .39 | .44 | .82 | .34 | 1.11 | .47 | .27 | .28 | .12 | .31 | .33 | .49 |
| 10 | .28 | .64 | .61 | .73 | .67 | 1.51 | .28 | .15 | .27 | .08 | .20 | .20 | .45 |
| 11 | .64 | 1.32 | 1.45 | 1.50 | .08 | .66 | .16 | .44 | .16 | .05 | .25 | .21 | .39 |
| 12 | .35 | .86 | .05 | .16 | .07 | 1.61 | 1.61 | .72 | .57 | .04 | .17 | .26 | .37 |
| 13 | .41 | 2.17 | 1.95 | .26 | .00 | 1.11 | .04 | .69 | .94 | .14 | .04 | .20 | 1.08 |
| 14 | .09 | 1.72 | .00 | 7.38 | .00 | 1.59 | .32 | .16 | 7.72 | .07 | .05 | .03 | 1.05 |
| 15 | .33 | .64 | .62 | .88 | .49 | .82 | .74 | .26 | .33 | .36 | .48 | .44 | .36 |

| | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|
| 1 | .00 | .00 | .00 | . 0 | .00 |
| 2 | .00 | .00 | .00 | .00 | .00 |
| 3 | .03 | .01 | .00 | .00 | .01 |
| 4 | .14 | .09 | .05 | .10 | .04 |
| 5 | .25 | .25 | .17 | .24 | .19 |
| 6 | .32 | .35 | .33 | .28 | .28 |
| 7 | .28 | .39 | .39 | .24 | .28 |
| 8 | .29 | .32 | .38 | .25 | .28 |
| 9 | .32 | .27 | .41 | .32 | .28 |
| 10 | .30 | .28 | .32 | .33 | .28 |
| 11 | .39 | .35 | .44 | .36 | .28 |
| 12 | .21 | .30 | .79 | .30 | .28 |
| 13 | .20 | .22 | .59 | .84 | .28 |
| 14 | 1.08 | .23 | .18 | .18 | .28 |
| 15 | .31 | .35 | .36 | .27 | .28 |

Table 19. Beginning of year population numbers (000's) for 4VsW cod.

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 94619 | 95954 | 74456 | 64031 | 76015 | 84494 | 73849 | 70330 | 112850 | 103086 |
| 2 | 87582 | 76297 | 76469 | 58803 | 51141 | 60894 | 67556 | 59804 | 57580 | 92234 |
| 3 | 51758 | 63896 | 48697 | 46558 | 37158 | 34224 | 40827 | 51636 | 48941 | 47004 |
| 4 | 54237 | 34335 | 40929 | 26997 | 24653 | 18763 | 19438 | 30180 | 41926 | 39161 |
| 5 | 45680 | 31012 | 19836 | 21420 | 15310 | 11184 | 11434 | 12555 | 23739 | 31024 |
| 6 | 19352 | 25028 | 17420 | 7498 | 8711 | 6084 | 5041 | 5002 | 8868 | 15254 |
| 7 | 6292 | 11737 | 11206 | 6317 | 2680 | 4629 | 2634 | 1944 | 3307 | 5052 |
| 8 | 2932 | 3394 | 4941 | 6069 | 2461 | 1340 | 1413 | 866 | 1139 | 2013 |
| 9 | 585 | 1714 | 1106 | 2309 | 1599 | 818 | 543 | 604 | 510 | 739 |
| 10 | 321 | 265 | 955 | 581 | 835 | 936 | 220 | 278 | 379 | 316 |
| 11 | 320 | 198 | 114 | 426 | 229 | 350 | 169 | 136 | 196 | 238 |
| 12 | 211 | 138 | 43 | 22 | 78 | 174 | 148 | 118 | 71 | 137 |
| 13 | 30 | 122 | 48 | 34 | 15 | 59 | 28 | 24 | 47 | 33 |
| 14 | 157 | 16 | 11 | 6 | 21 | 13 | 16 | 22 | 10 | 15 |
| 15 | 15 | 118 | 2 | 9 | 0 | 17 | 2 | 10 | 16 | 0 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|---|
| 1 | 127904 | 150413 | 92026 | 85660 | 46970 | 10613 | | |
| 2 | 84388 | 104691 | 123145 | 75340 | 70133 | 38456 | 8689 | |
| 3 | 75441 | 68954 | 85399 | 100687 | 61683 | 57418 | 31481 | 7112 |
| 4 | 37009 | 59925 | 53069 | 67657 | 79678 | 50160 | 46870 | 25665 |
| 5 | 26485 | 25669 | 40264 | 36514 | 47927 | 59775 | 38966 | 34645 |
| 6 | 17126 | 15249 | 14432 | 23960 | 23228 | 30703 | 41381 | 25111 |
| 7 | 8082 | 8459 | 8094 | 8695 | 14217 | 13461 | 18096 | 25713 |
| 8 | 3085 | 3967 | 4219 | 4449 | 5365 | 7847 | 7472 | 11624 |
| 9 | 1312 | 1561 | 1931 | 2303 | 2738 | 3200 | 4412 | 4744 |
| 10 | 537 | 786 | 922 | 972 | 1364 | 1718 | 1735 | 2613 |
| 11 | 238 | 360 | 529 | 480 | 588 | 848 | 1020 | 1025 |
| 12 | 186 | 153 | 239 | 292 | 266 | 340 | 447 | 580 |
| 13 | 108 | 129 | 96 | 135 | 194 | 161 | 127 | 270 |
| 14 | 24 | 85 | 86 | 27 | 90 | 128 | 73 | 45 |
| 15 | 11 | 18 | 68 | 25 | 7 | 58 | 88 | 50 |

Table 20. Mean population biomass (mt.) for 4VsW cod.

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1703 | 858 | 3316 | 4588 | 8863 | 7571 | 6658 | 6374 | 20439 | 6116 |
| 2 | 11268 | 6761 | 10851 | 10374 | 13899 | 13552 | 16587 | 15174 | 32310 | 44285 |
| 3 | 19104 | 16500 | 16186 | 15504 | 16691 | 13853 | 20085 | 37756 | 41676 | 31774 |
| 4 | 37809 | 16912 | 24405 | 16277 | 17381 | 13170 | 15116 | 29246 | 45252 | 34356 |
| 5 | 51487 | 25216 | 16360 | 17092 | 15296 | 10329 | 11359 | 17710 | 32231 | 39764 |
| 6 | 33350 | 26834 | 20250 | 8055 | 13752 | 7706 | 6598 | 9667 | 16752 | 26986 |
| 7 | 13803 | 16416 | 20774 | 9327 | 5452 | 6694 | 4227 | 4773 | 9410 | 12482 |
| 8 | 8463 | 5407 | 10862 | 9719 | 5341 | 2754 | 3189 | 3079 | 4836 | 6075 |
| 9 | 1824 | 4165 | 3124 | 5130 | 5459 | 1735 | 1613 | 1998 | 2266 | 3018 |
| 10 | 1344 | 672 | 2961 | 1596 | 2944 | 2029 | 838 | 1252 | 1980 | 1884 |
| 11 | 1301 | 436 | 291 | 1005 | 1239 | 1236 | 789 | 466 | 1306 | 1676 |
| 12 | 1091 | 405 | 226 | 103 | 488 | 483 | 431 | 380 | 459 | 1147 |
| 13 | 164 | 244 | 127 | 170 | 112 | 224 | 177 | 115 | 292 | 299 |
| 14 | 1087 | 41 | 74 | 5 | 175 | 44 | 97 | 161 | 12 | 132 |
| 15 | 102 | 483 | 12 | 43 | 0 | 90 | 11 | 81 | 105 | 0 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|---|
| 1 | 7588 | 8924 | 5460 | 9317 | 2787 | 630 | | |
| 2 | 43555 | 58346 | 64835 | 26631 | 35532 | 22131 | 2047 | |
| 3 | 53909 | 50534 | 61351 | 72488 | 40344 | 36428 | 19505 | 3214 |
| 4 | 35643 | 56318 | 47489 | 61942 | 69181 | 46278 | 38994 | 21714 |
| 5 | 32564 | 33037 | 49624 | 45495 | 55000 | 72823 | 40109 | 38199 |
| 6 | 27155 | 24095 | 27089 | 39194 | 34212 | 47240 | 55418 | 32108 |
| 7 | 17810 | 18073 | 16925 | 21401 | 26668 | 25345 | 35371 | 40230 |
| 8 | 9642 | 11145 | 12895 | 12438 | 14401 | 18912 | 16641 | 25481 |
| 9 | 5400 | 6917 | 7672 | 7850 | 8264 | 9414 | 11690 | 15335 |
| 10 | 3062 | 4649 | 4794 | 4403 | 5391 | 6835 | 6772 | 8964 |
| 11 | 1454 | 2264 | 3491 | 2535 | 3098 | 3988 | 4125 | 5496 |
| 12 | 1583 | 1131 | 1652 | 2170 | 1695 | 1324 | 2401 | 3059 |
| 13 | 759 | 1257 | 620 | 1178 | 1422 | 1106 | 793 | 1616 |
| 14 | 170 | 656 | 522 | 177 | 749 | 1192 | 572 | 450 |
| 15 | 120 | 134 | 644 | 246 | 68 | 505 | 821 | 519 |

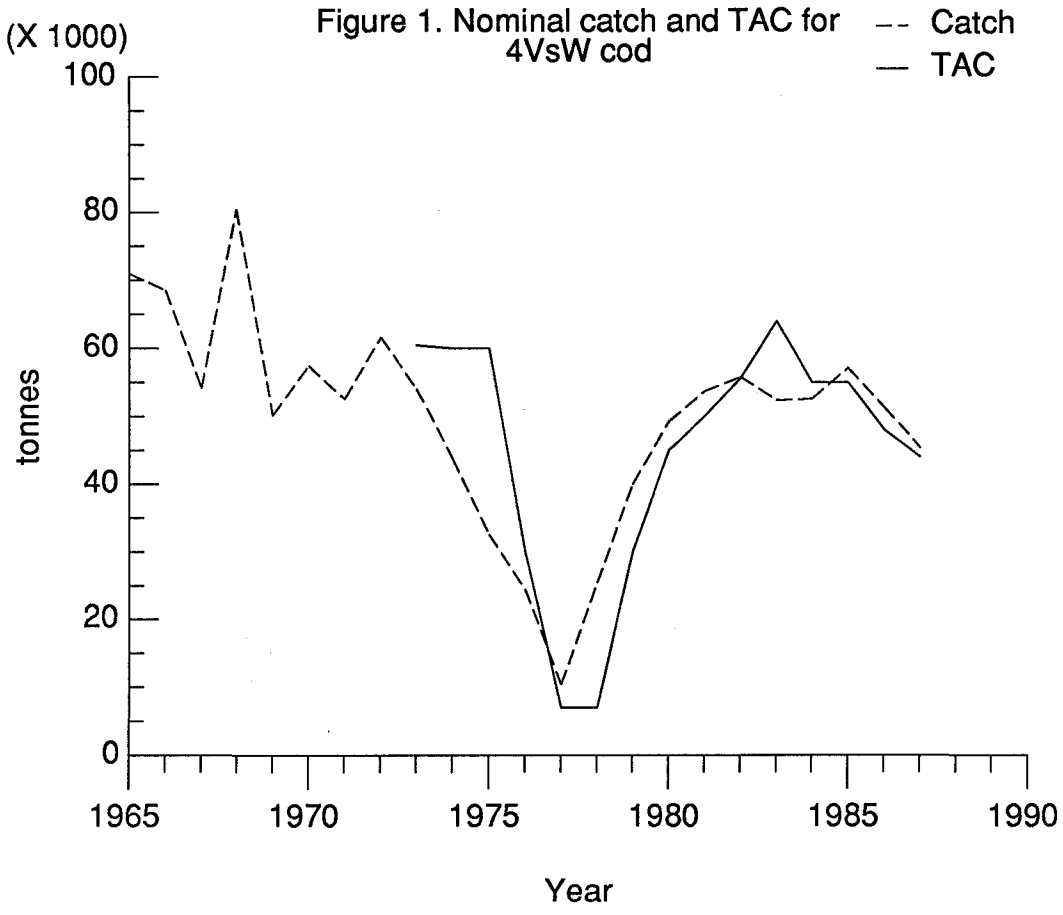



Figure 1. Nominal catch and TAC for 4VsW cod

Figure 2. Comparison of catches in areas 4Vs and 4W

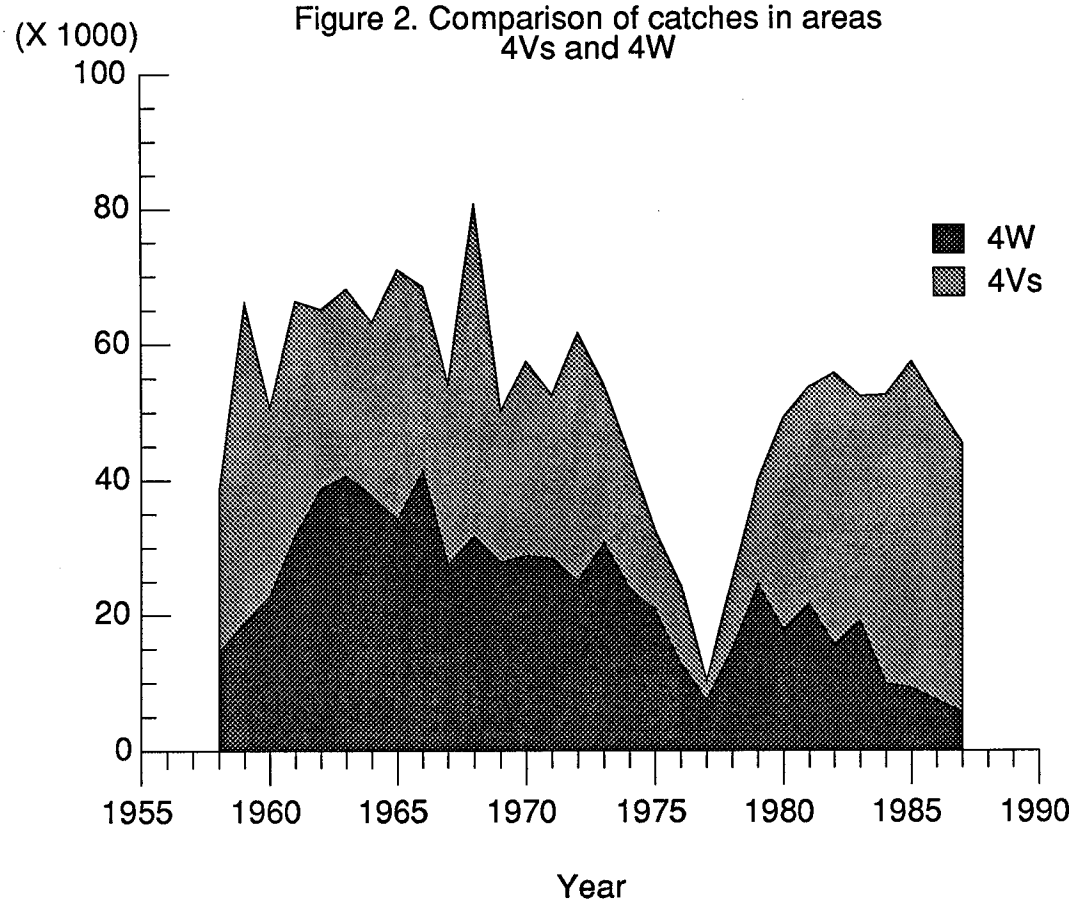


Figure 3. Comparison of Canadian catches by different gears from 4VsW cod.

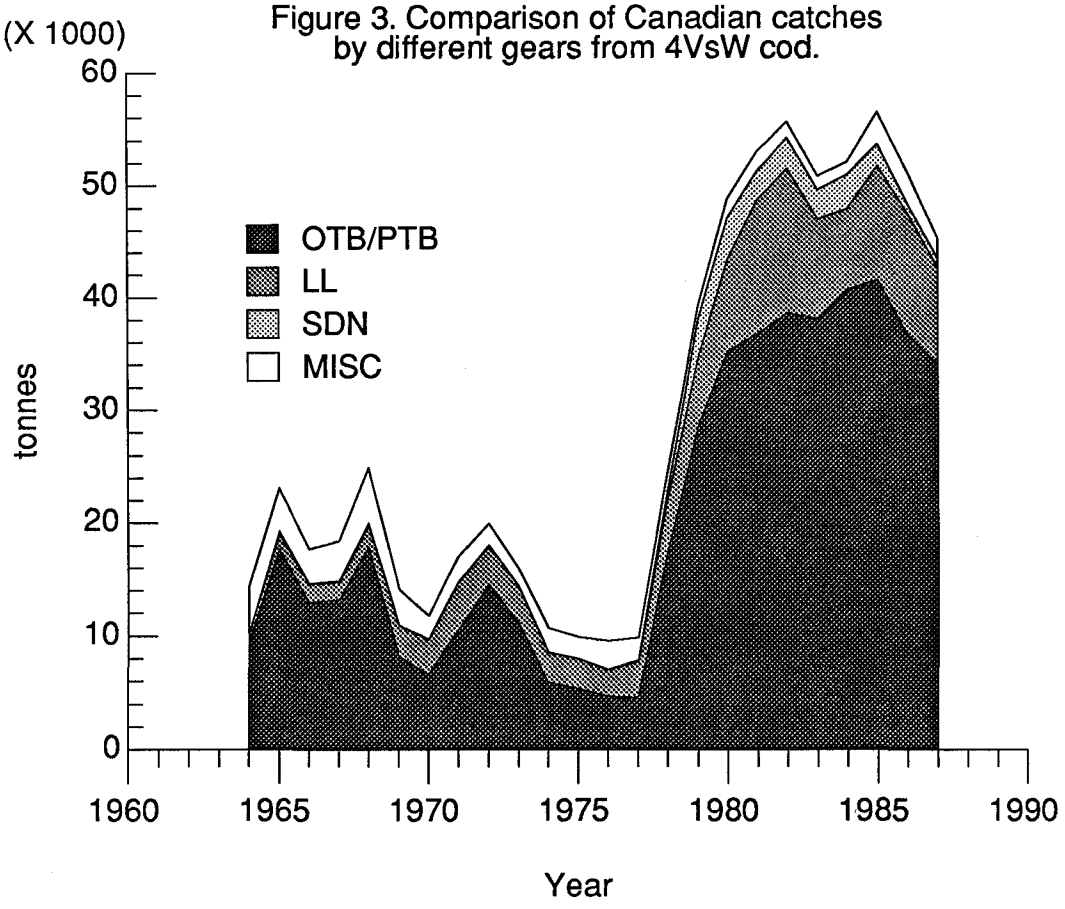


Figure 4. Comparison of relative catches by different canadian gears on 4VsW cod

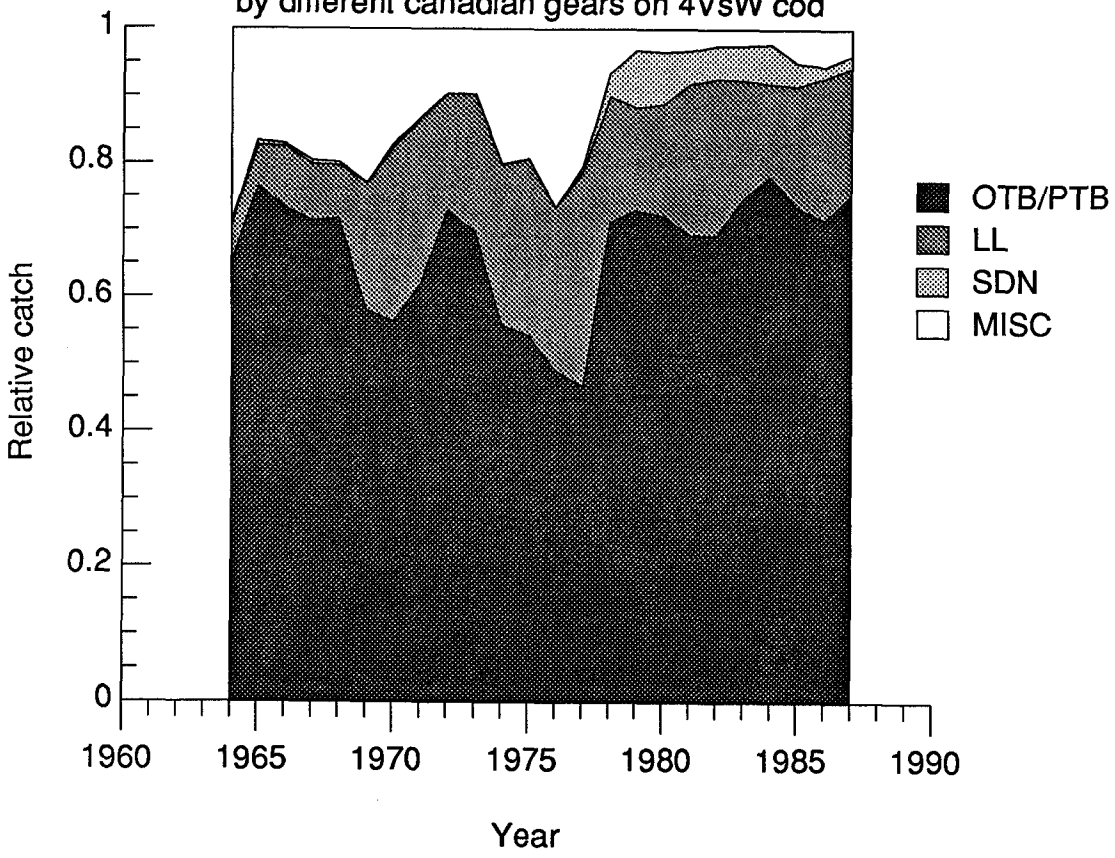


Figure 5. Projected and estimated catch at age ('000) for 1987 from 4VsW cod.

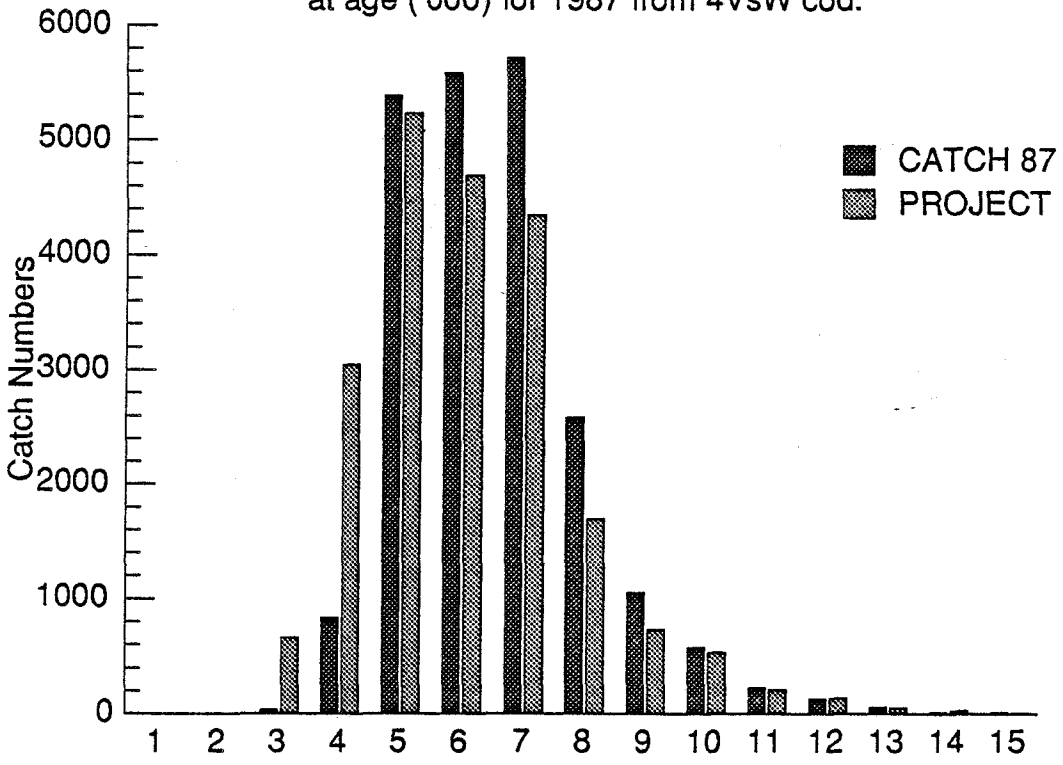


Figure 6. Commercial mean weights at age for 4VsW cod ages 3 to 8

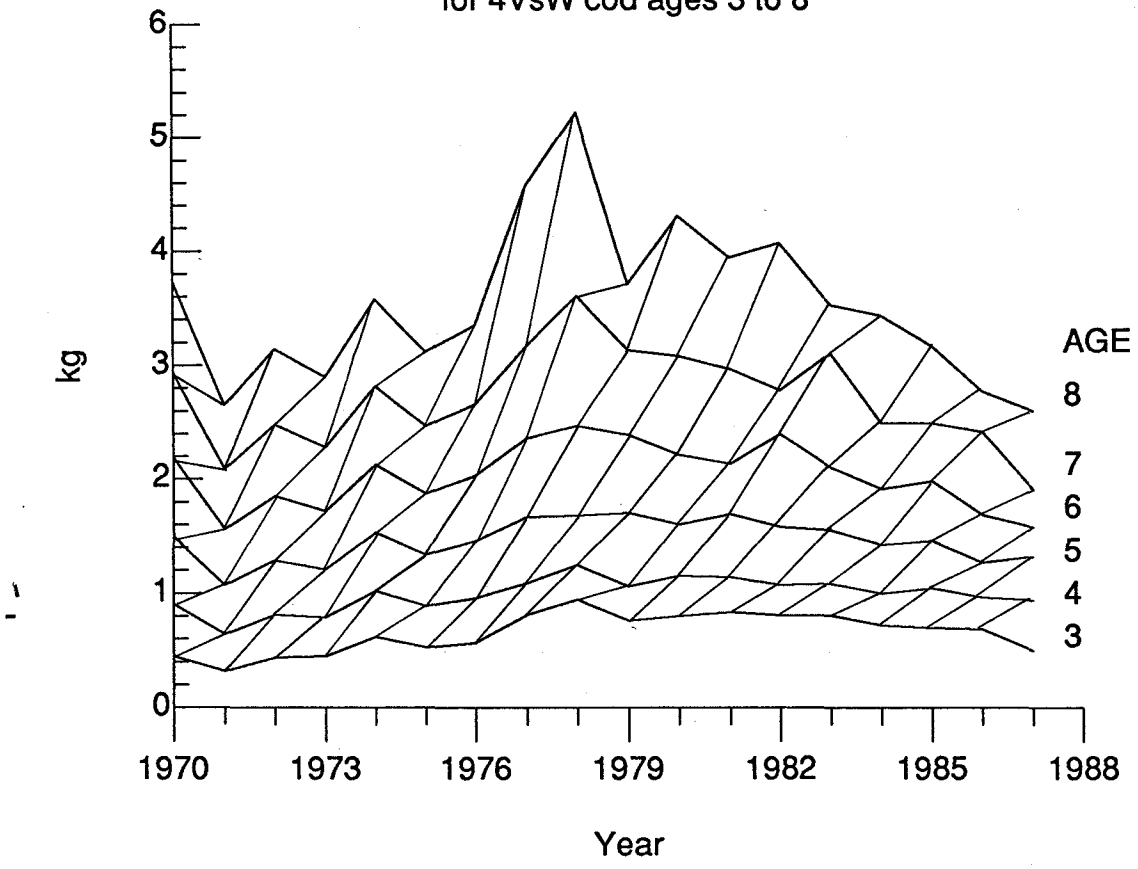


Figure 7a. Leverage plot for initial run.

1965-1987, gear 11 included; 1978, 1979 included
(NOTE: critical value = 0.0746)

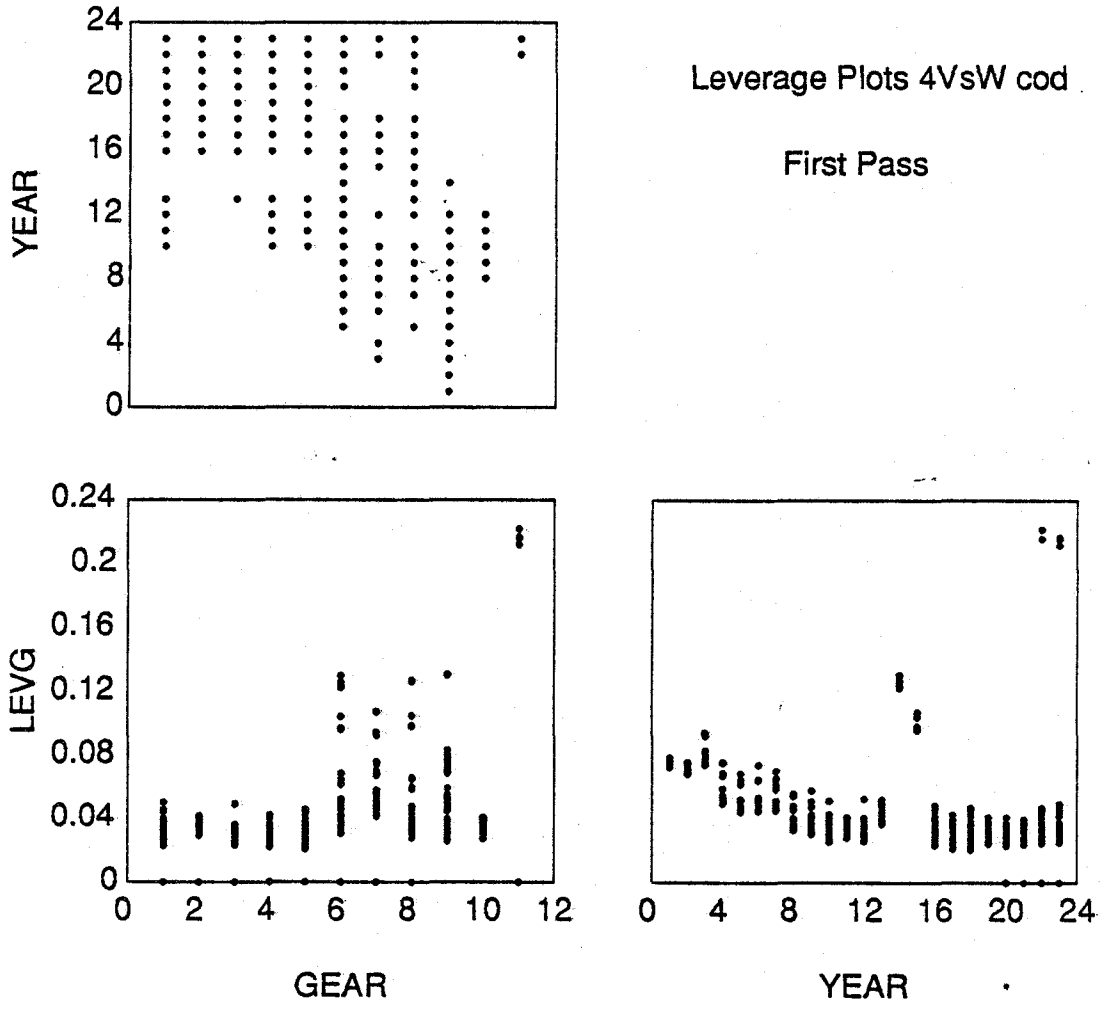


Figure 7b . Leverage plot for second run.

1965-1987, gear 11 excluded
(NOTE: critical value = 0.0749)

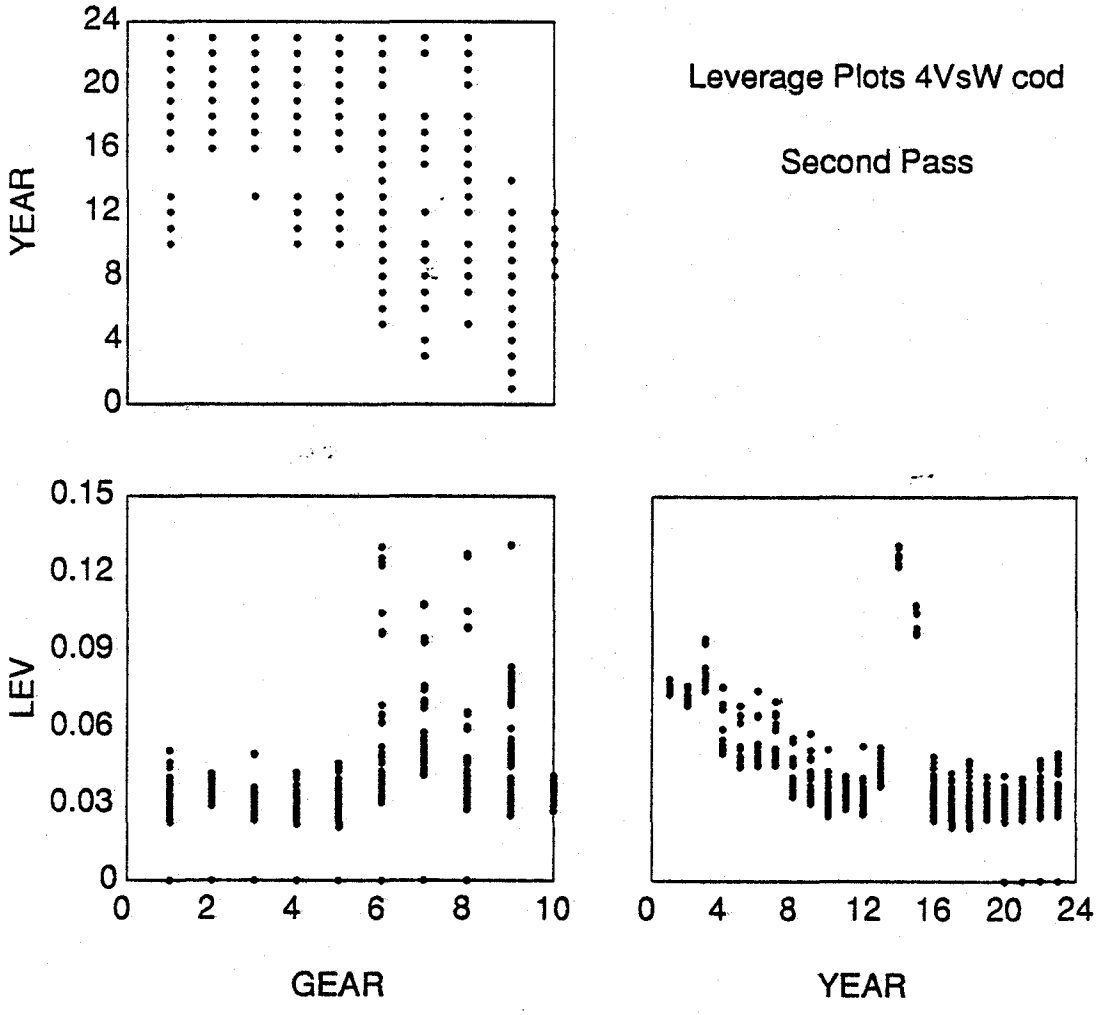
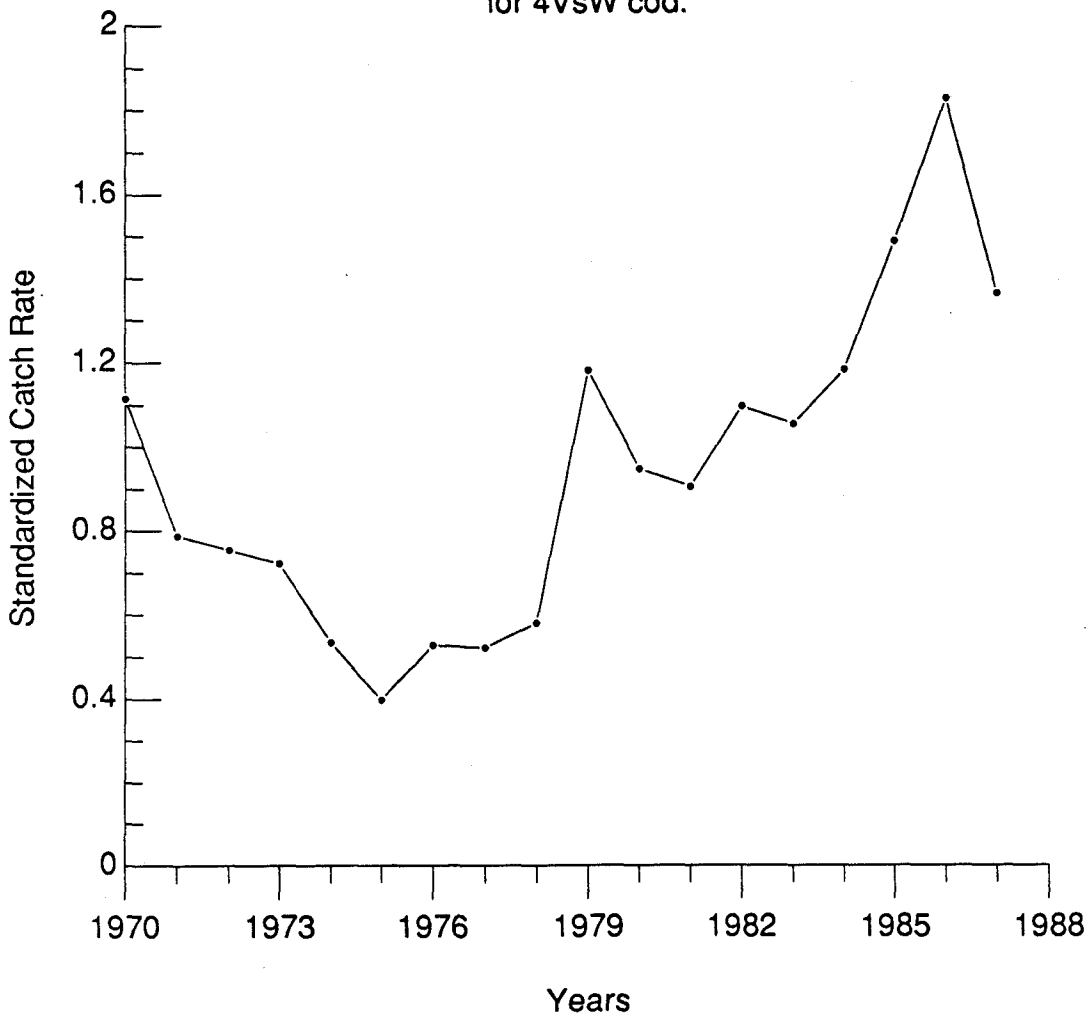


Figure 8. Standardized catch rate series for 4VsW cod.



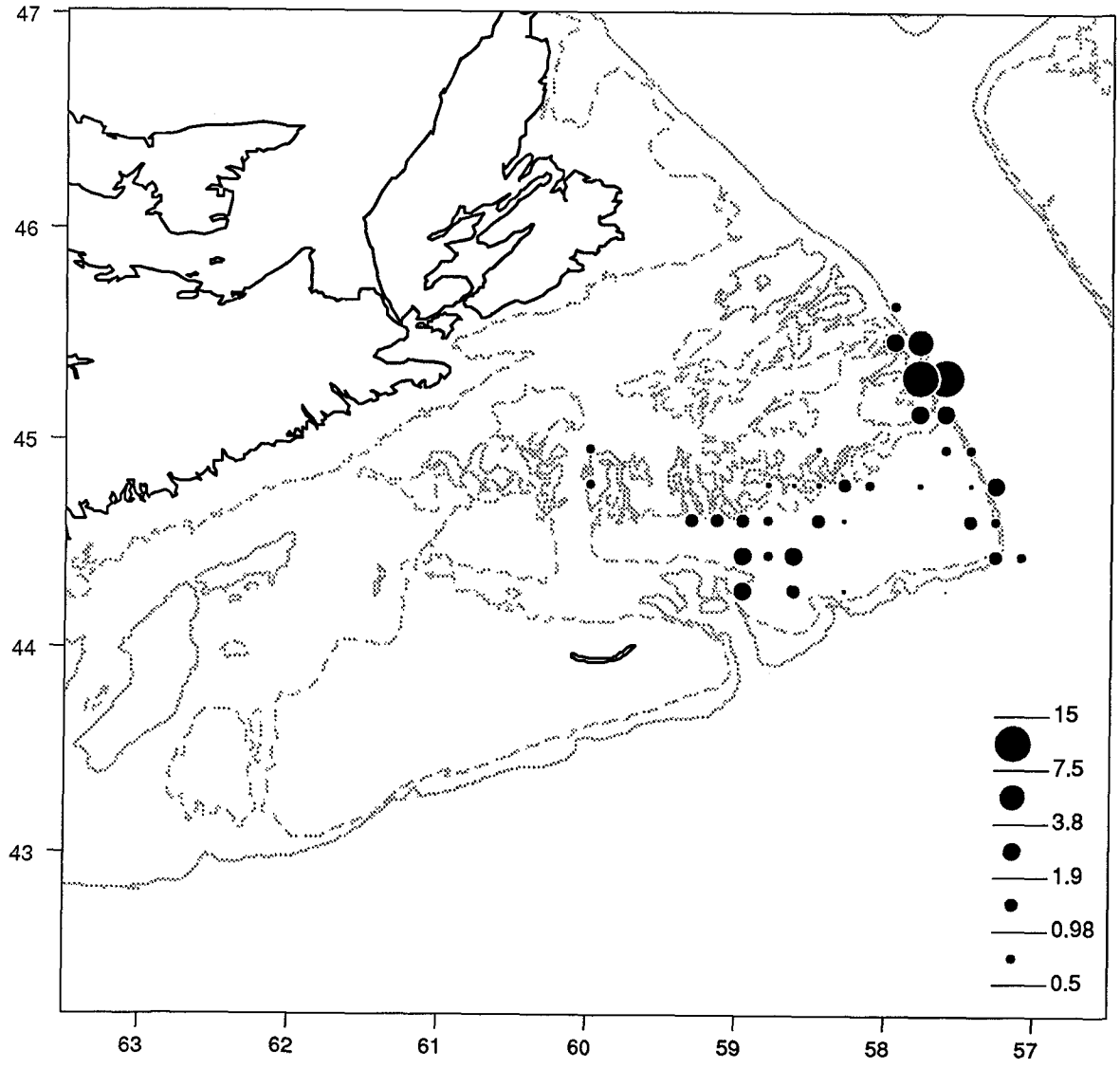



Figure 9a. January - June, 1987 IOP observations of directed cod CPUE (t/hr) from OTB-2 TC5 vessels.

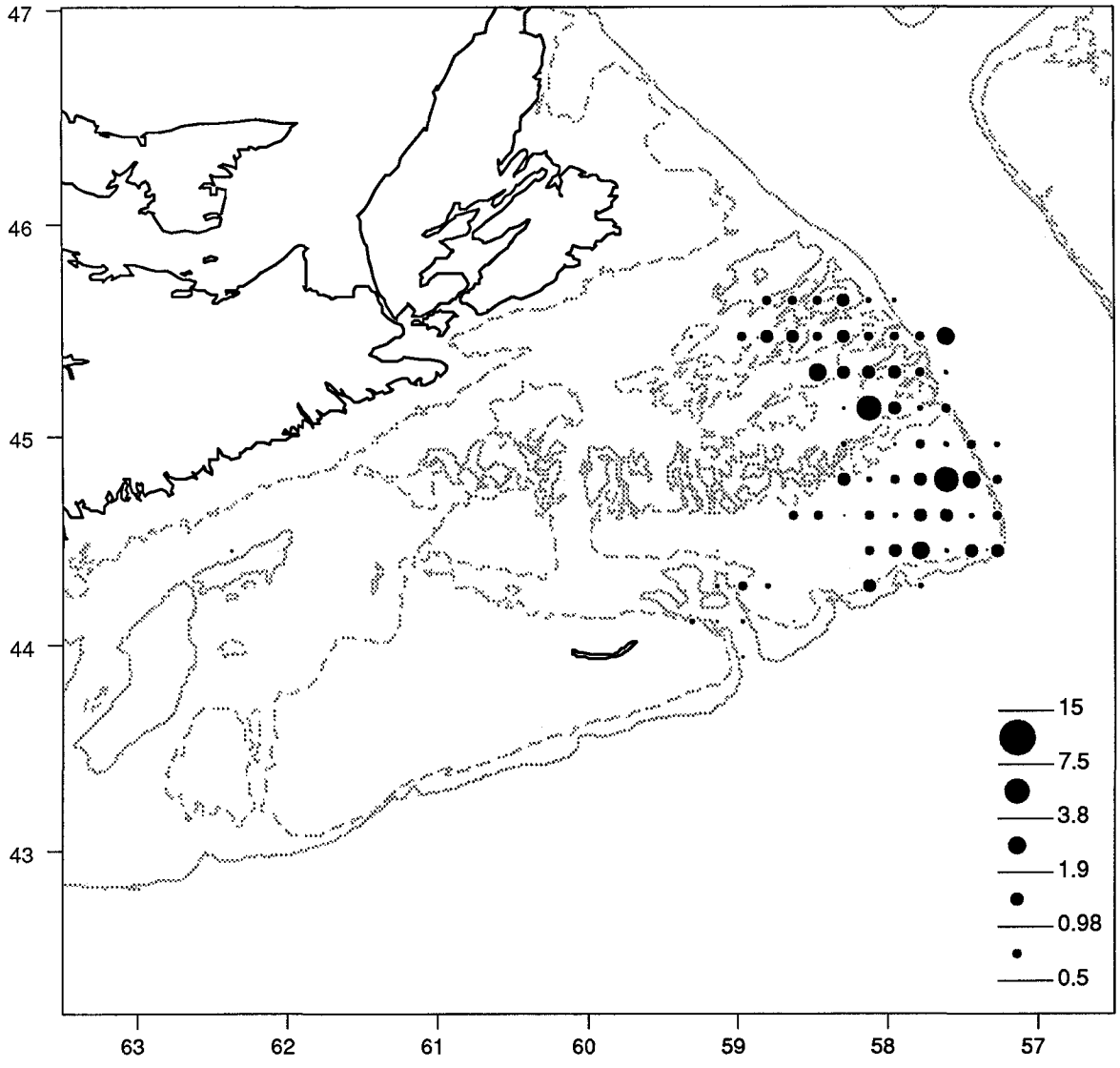



Figure 9b. July - December, 1987 IOP observations of directed cod CPUE (t/hr) from OTB-2 TC5 vessels.

Figure 10. July RV total and ages 4-7 numbers for 4VsW cod.

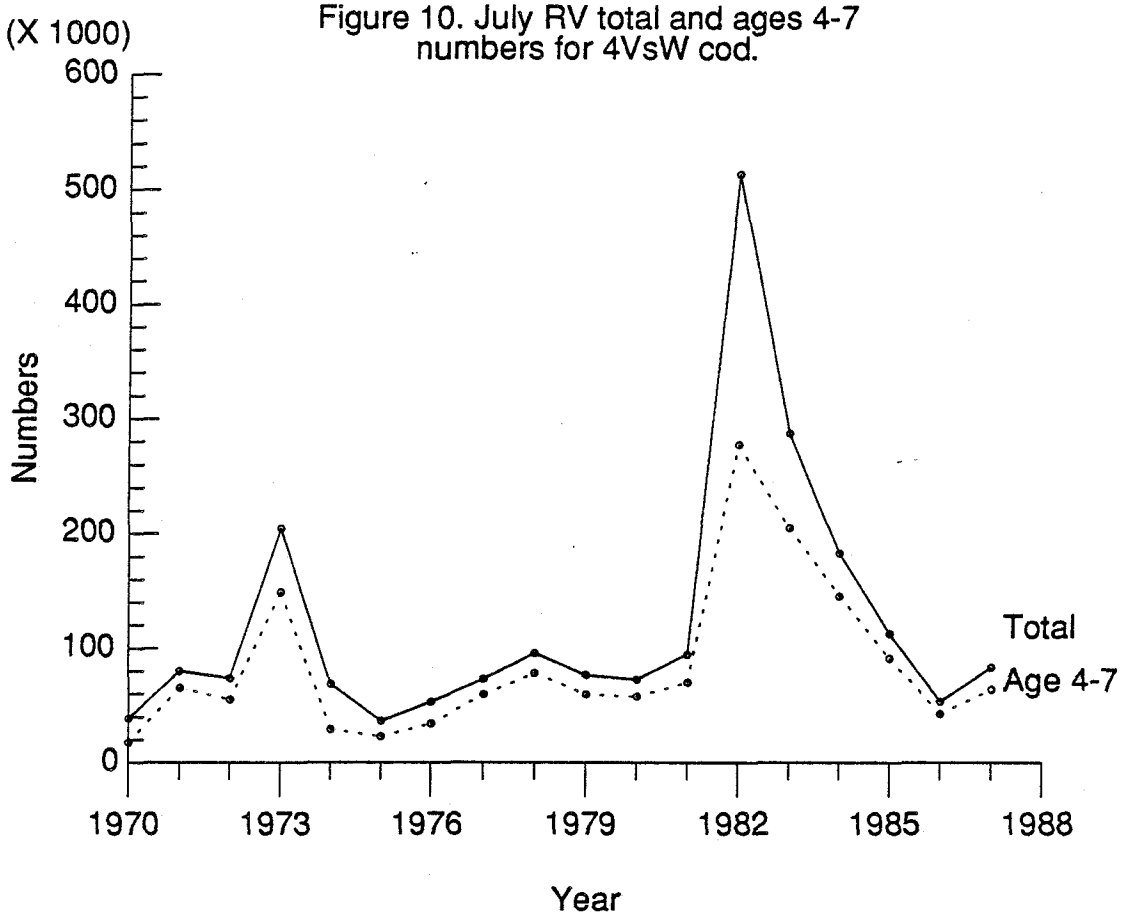


Figure 11. 4VsW cod RV survey abundance (age 5+) by area.

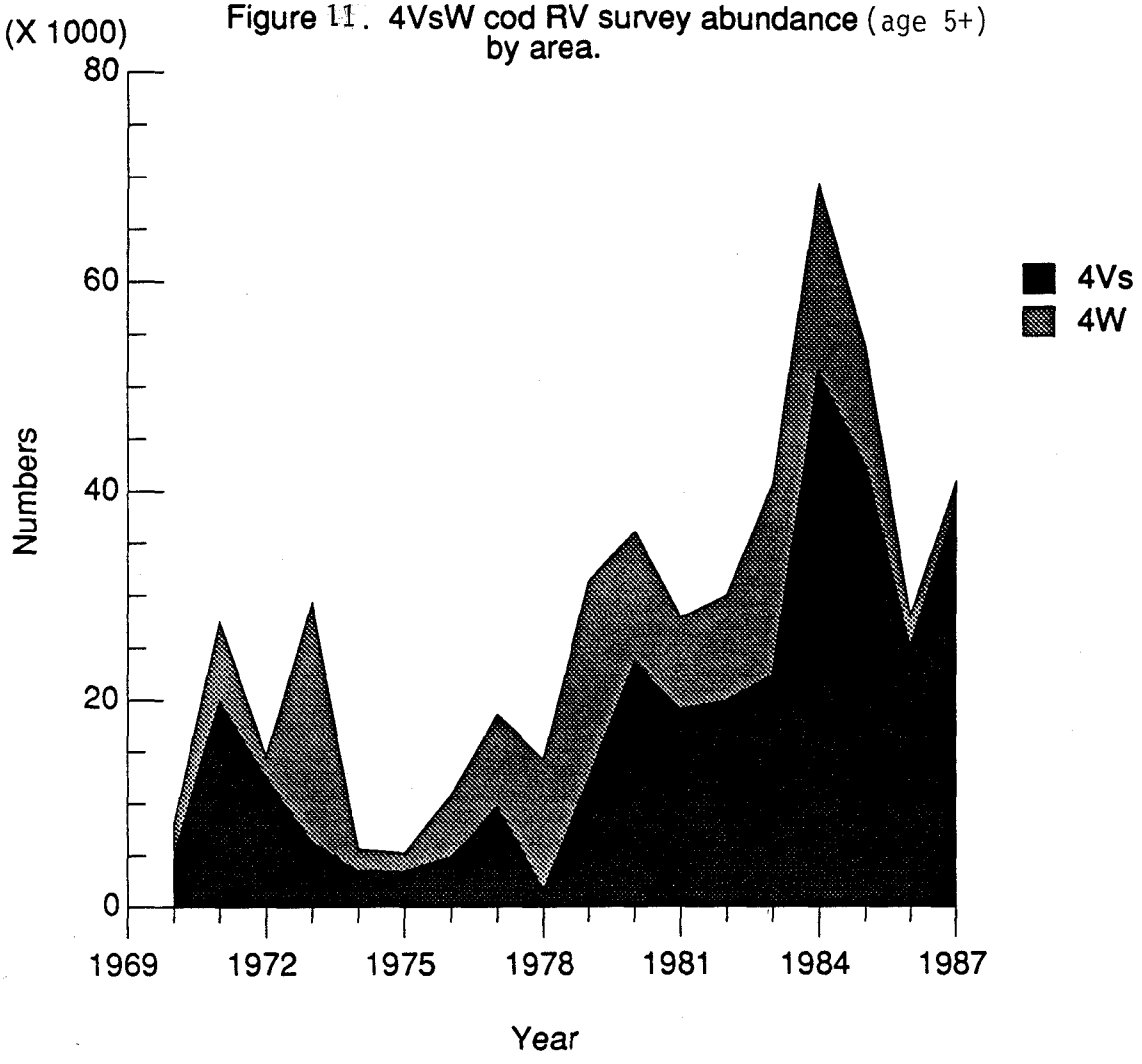


Figure 12 July RV mean weights at age
for 4VsW cod ages 2 to 8

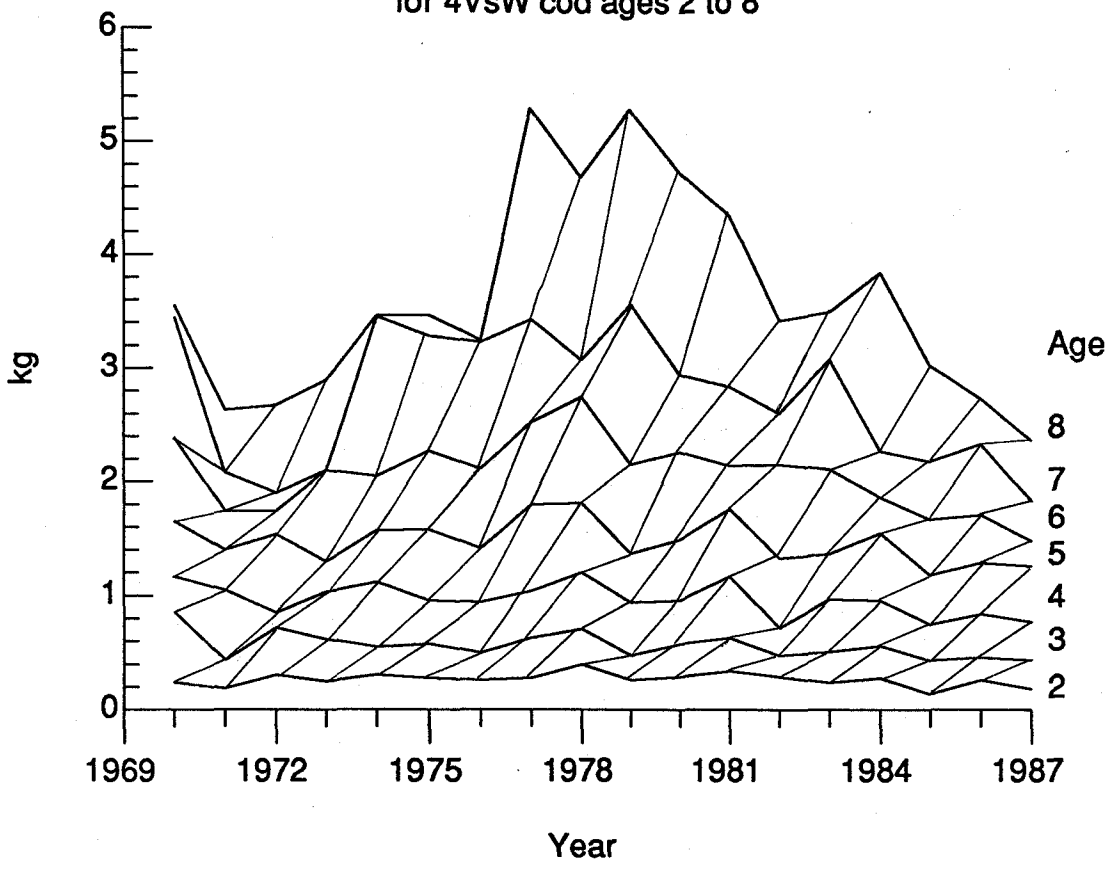


Figure 13. Age-by-age tuning plots resulting from ADAPT tuning of SPA with RV ages 4 to 7.

SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS Age 4
RESPONSE VARIABLE(S): SURVEY - o:OBSERVED, +:PREDICTED

| INDEX | CARRIER | o | + | RANK |
|---|---|---|---|---|
| 1971 | 2.493E4 | 8027 | 1.738E | 1975 |
| 1972 | 2.805E4 | 3.154E | 1.956E | 1976 |
| 1973 | 1.939E4 | 5.608E | 1.352E | 1974 |
| 1974 | 1.553E4 | 5623 | 1.083E | 1973 |
| 1975 | 1.402E4 | 6171 | 9778 | 1987 |
| 1976 | 1.517E4 | 1.019E | 1.058E | 1971 |
| 1977 | 2.622E4 | 1.706E | 1.828E | 1977 |
| 1978 | 3.507E4 | 3.421E | 2.445E | 1972 |
| 1979 | 3.099E4 | 1.66E4 | 2.161E | 1980 |
| 1980 | 2.963E4 | 1.026E | 2.066E | 1979 |
| 1981 | 4.696E4 | 3.075E | 3.275E | 1978 |
| 1982 | 4.184E4 | 6.598E | 2.918E | 1986 |
| 1983 | 5.368E4 | 4.845E | 3.743E | 1985 |
| 1984 | 6.462E4 | 5.486E | 4.506E | 1982 |
| 1985 | 4.071E4 | 2.748E | 2.839E | 1981 |
| 1986 | 3.634E4 | 1.613E | 2.534E | 1983 |
| 1987 | 1.988E4 | 1.387E | 1.387E | 1984 |

SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS Age 5
RESPONSE VARIABLE(S): SURVEY - o:OBSERVED, +:PREDICTED

| INDEX | CARRIER | o | + | RANK |
|---|---|---|---|---|
| 1971 | 2.215E | 1.58E4 | 1.526E | 1975 |
| 1972 | 1.124E | 5812 | 7745 | 1976 |
| 1973 | 1.267E | 2.248E | 8728 | 1974 |
| 1974 | 8935 | 2017 | 6155 | 1977 |
| 1975 | 7013 | 2959 | 4831 | 1972 |
| 1976 | 7031 | 6621 | 4843 | 1973 |
| 1977 | 1.033E | 1.135E | 7119 | 1981 |
| 1978 | 1.832E | 9461 | 1.262E | 1978 |
| 1979 | 2.185E | 1.808E | 1.505E | 1980 |
| 1980 | 1.904E | 1.737E | 1.312E | 1979 |
| 1981 | 1.812E | 1.206E | 1.249E | 1971 |
| 1982 | 2.929E | 1.482E | 2.018E | 1987 |
| 1983 | 2.737E | 2.481E | 1.885E | 1983 |
| 1984 | 3.56E4 | 3.717E | 2.453E | 1986 |
| 1985 | 4.597E | 2.677E | 3.167E | 1982 |
| 1986 | 2.803E | 1.055E | 1.931E | 1984 |
| 1987 | 2.521E | 2.545E | 1.737E | 1985 |

SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS Age 6
RESPONSE VARIABLE(S): SURVEY - o:OBSERVED, +:PREDICTED

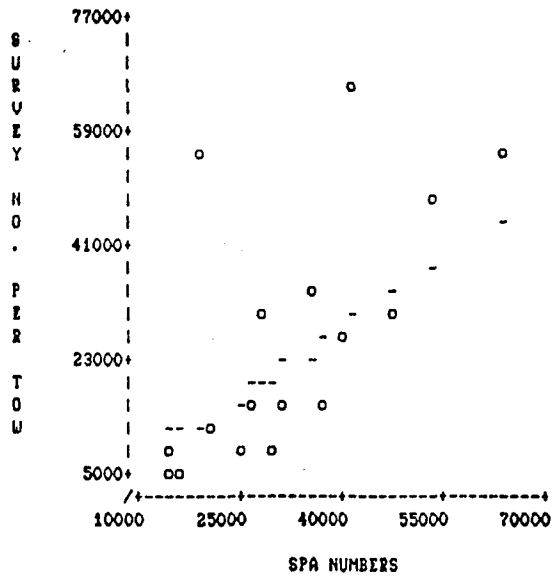
| INDEX | CARRIER | o | + | RANK |
|---|---|---|---|---|
| 1971 | 1.566E | 5775 | 9270 | 1976 |
| 1972 | 9638 | 5989 | 5705 | 1975 |
| 1973 | 4112 | 1870 | 2434 | 1977 |
| 1974 | 6022 | 2244 | 3564 | 1973 |
| 1975 | 3732 | 675 | 2209 | 1974 |
| 1976 | 2881 | 1264 | 1705 | 1978 |
| 1977 | 3907 | 4893 | 2313 | 1972 |
| 1978 | 6457 | 3490 | 3822 | 1981 |
| 1979 | 1.052E | 9053 | 6225 | 1979 |
| 1980 | 1.128E | 12099 | 6675 | 1982 |
| 1981 | 1.041E | 8570 | 6164 | 1980 |
| 1982 | 1.056E | 8020 | 6250 | 1971 |
| 1983 | 1.73E4 | 11398 | 1.024E | 1984 |
| 1984 | 1.634E | 17253 | 9670 | 1987 |
| 1985 | 2.143E | 14701 | 1.269E | 1983 |
| 1986 | 2.949E | 11462 | 1.745E | 1985 |
| 1987 | 1.723E | 10366 | 1.02E4 | 1986 |

SUMMARY OF DATA FROM PLOT

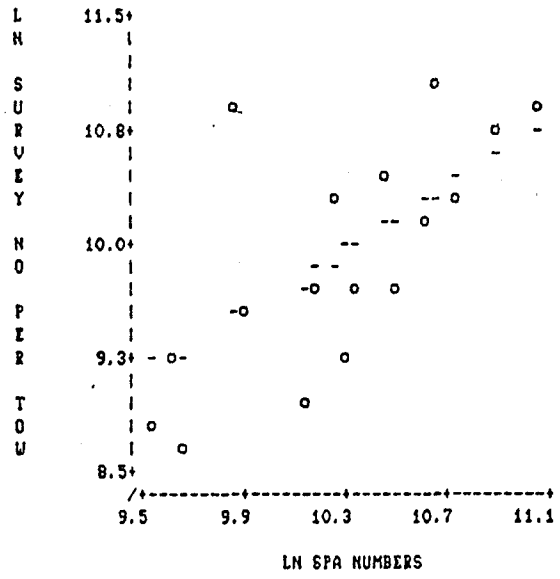
CARRIER VARIABLE: POPULATION NOS Age 7
RESPONSE VARIABLE(S): SURVEY - o:OBSERVED, +:PREDICTED

| INDEX | CARRIER | o | + | RANK |
|---|---|---|---|---|
| 1971 | 7085 | 3459 | 3675 | 1976 |
| 1972 | 7835 | 1621 | 4064 | 1977 |
| 1973 | 3644 | 2907 | 1890 | 1974 |
| 1974 | 1787 | 372 | 926.6 | 1975 |
| 1975 | 2315 | 867 | 1200 | 1978 |
| 1976 | 1375 | 656 | 713.4 | 1973 |
| 1977 | 1415 | 1081 | 733.7 | 1979 |
| 1978 | 2457 | 889 | 1274 | 1980 |
| 1979 | 3845 | 2696 | 1994 | 1981 |
| 1980 | 5324 | 4794 | 2761 | 1982 |
| 1981 | 5579 | 4404 | 2894 | 1983 |
| 1982 | 5606 | 4325 | 2908 | 1971 |
| 1983 | 6414 | 2611 | 3327 | 1972 |
| 1984 | 9742 | 11861 | 5053 | 1985 |
| 1985 | 9089 | 7358 | 4714 | 1984 |
| 1986 | 1.307E | 3339 | 6776 | 1986 |
| 1987 | 1.791E | 7791 | 9287 | 1987 |

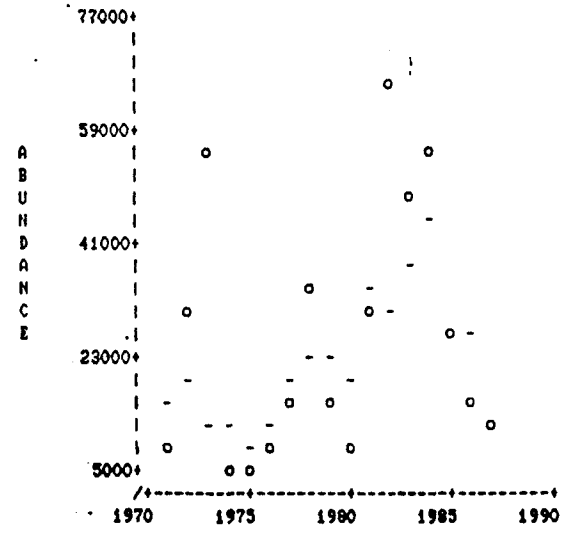
Figure 13 continued. Age 4.



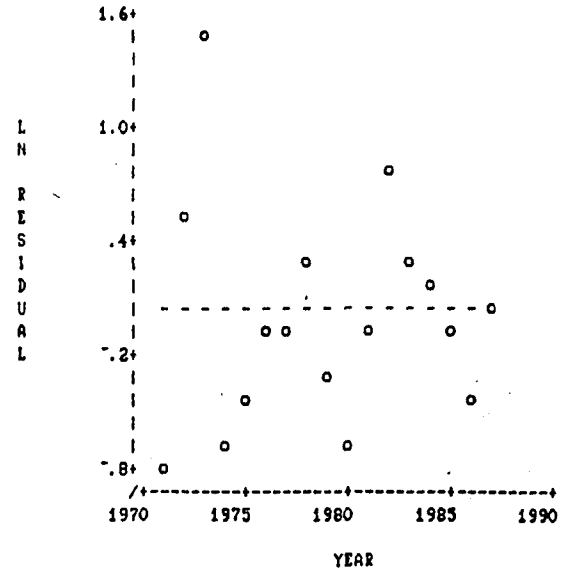

LN SURVEY NO. PER TOW VS LN SPA NUMBERS



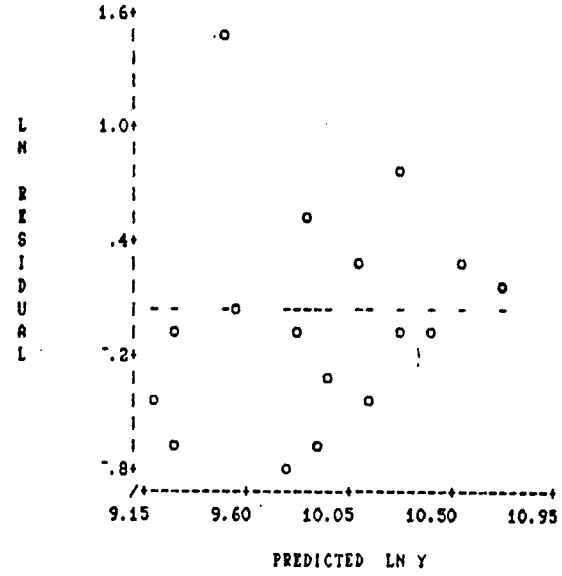

TREND IN POPULATION ABUNDANCE OVER TIME




TREND IN LN RESIDUAL OVER TIME




TREND IN LN RESIDUAL VS PREDICTED LN Y




TREND IN LN RESIDUAL VS OBSERVED LN X

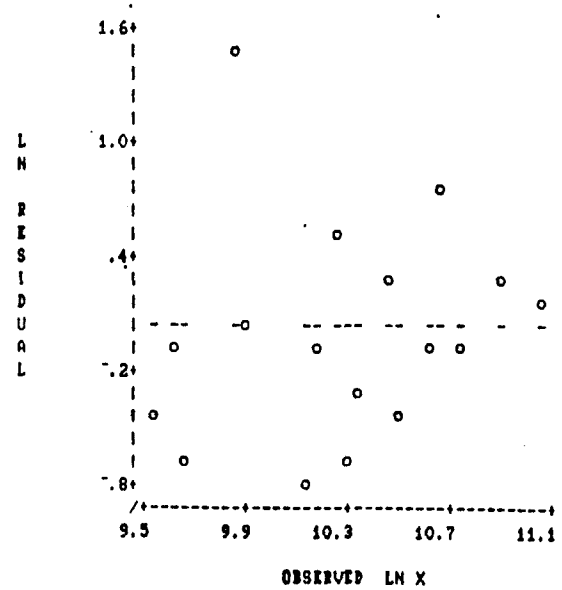
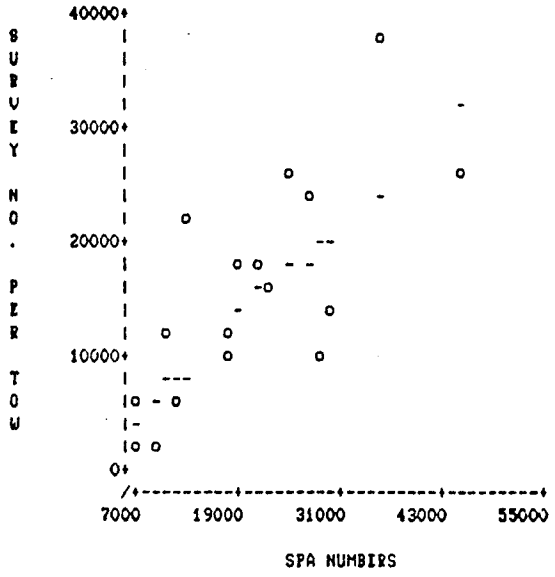


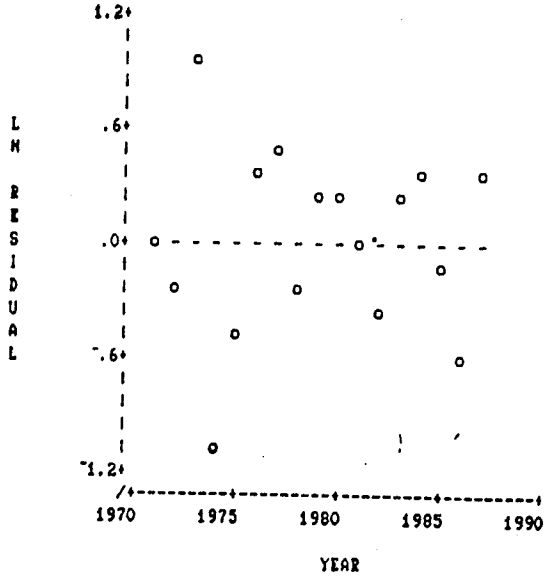
Figure 13 continued. Age 5.



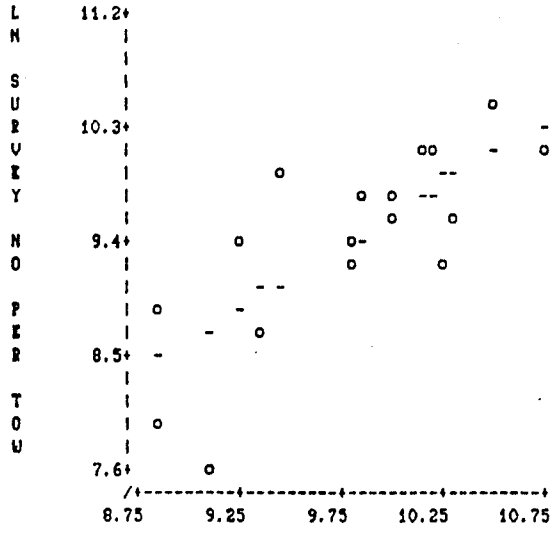
SURVEY NO. PER TOW VS SPA NUMBERS



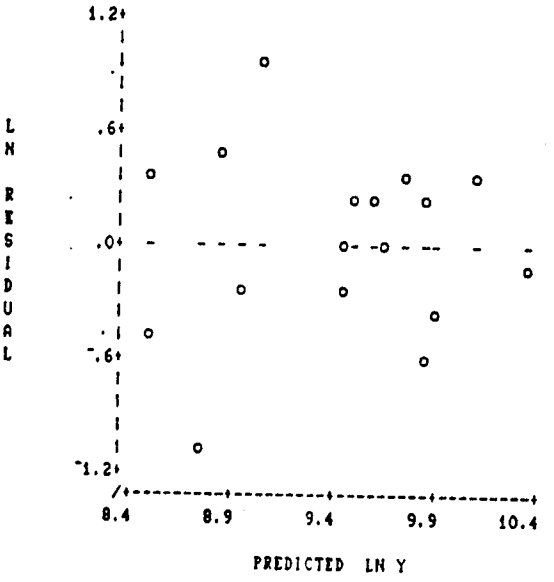

TREND IN LN RESIDUAL OVER TIME



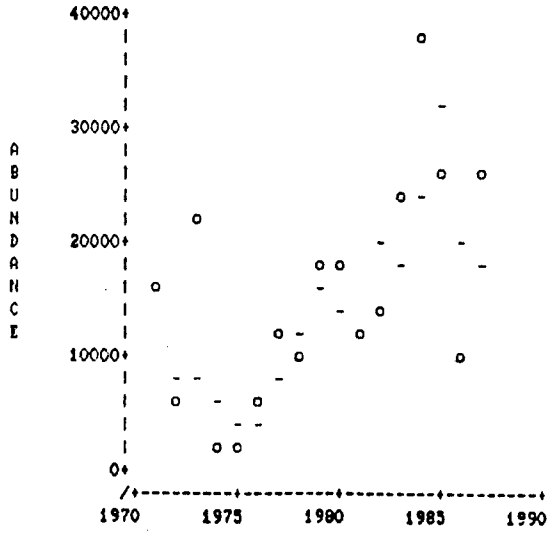

LN SURVEY NO. PER TOW VS LN SPA NUMBERS




TREND IN LN RESIDUAL VS PREDICTED LN Y




TREND IN POPULATION ABUNDANCE OVER TIME




TREND IN LN RESIDUAL VS OBSERVED LN X

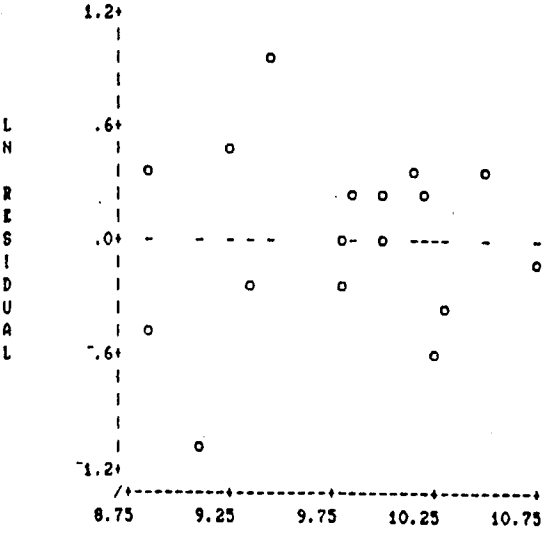
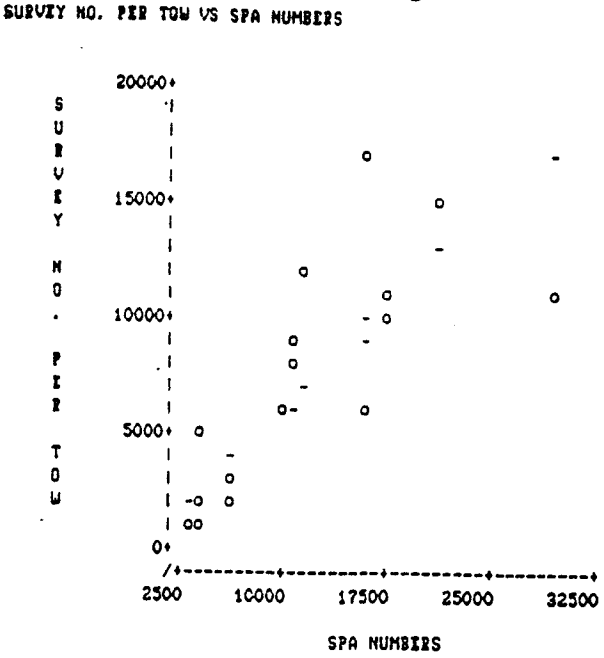
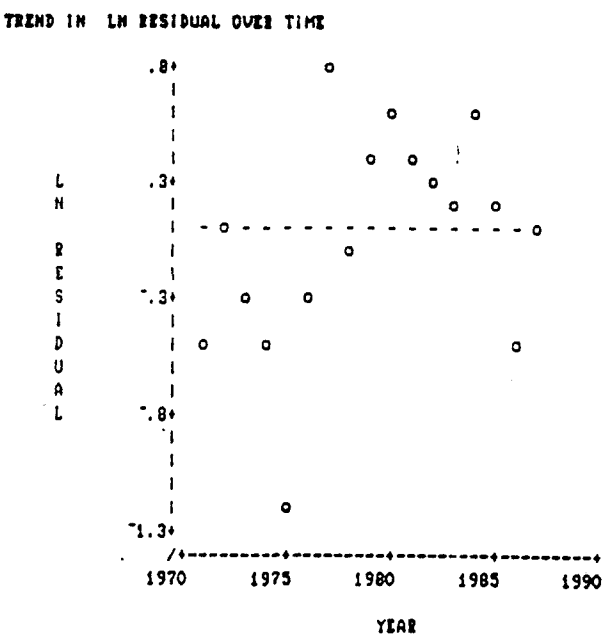
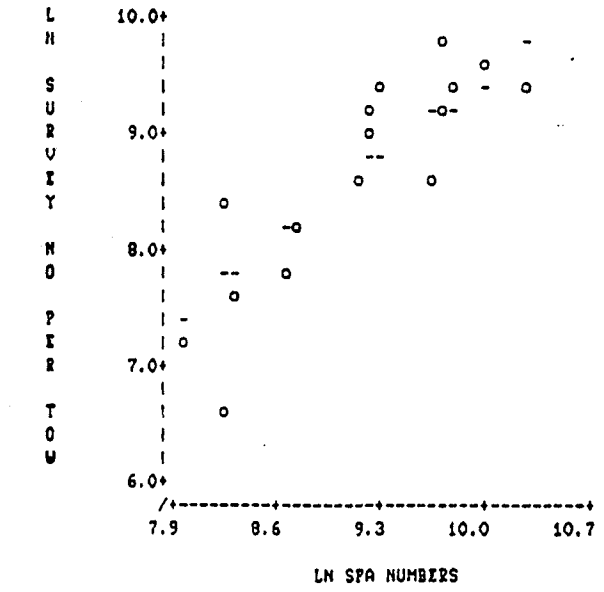


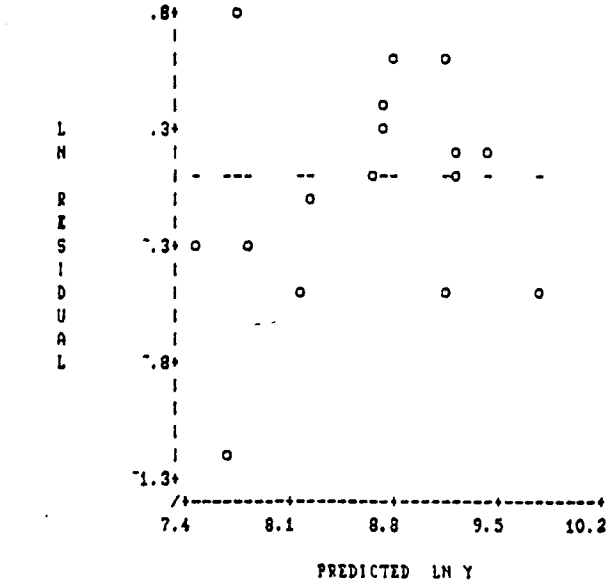
Figure 13.continued. Age 6.

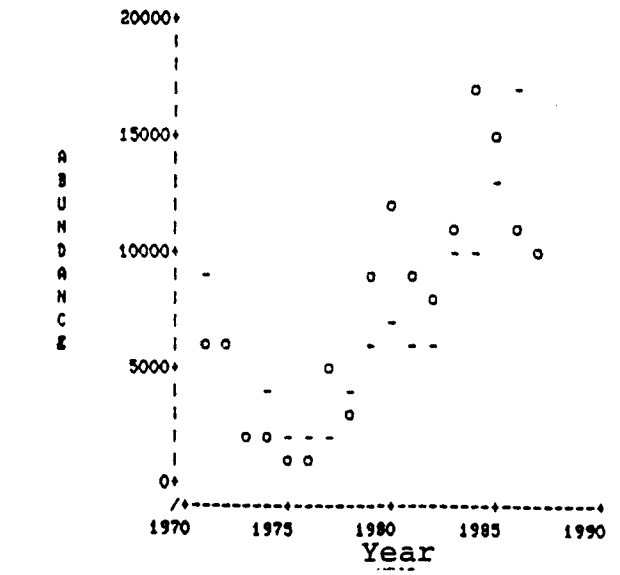




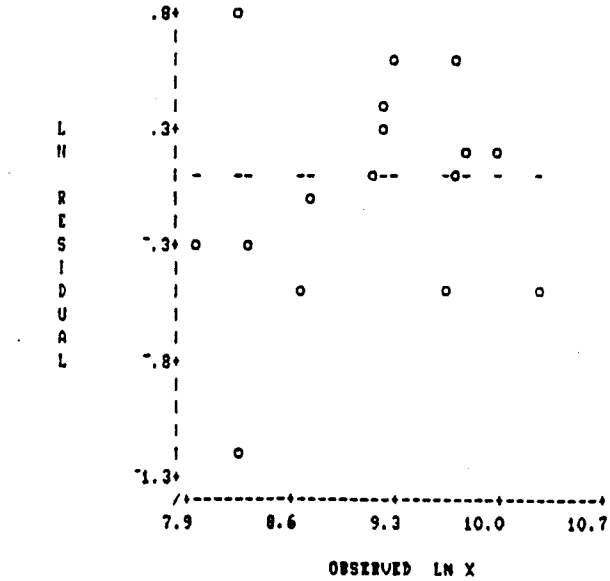
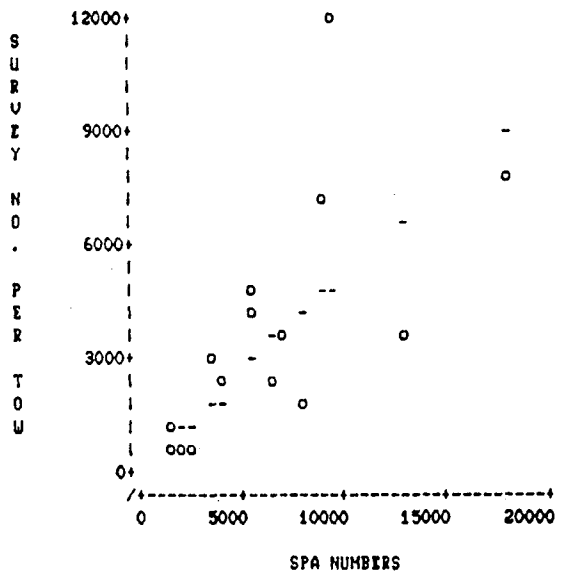



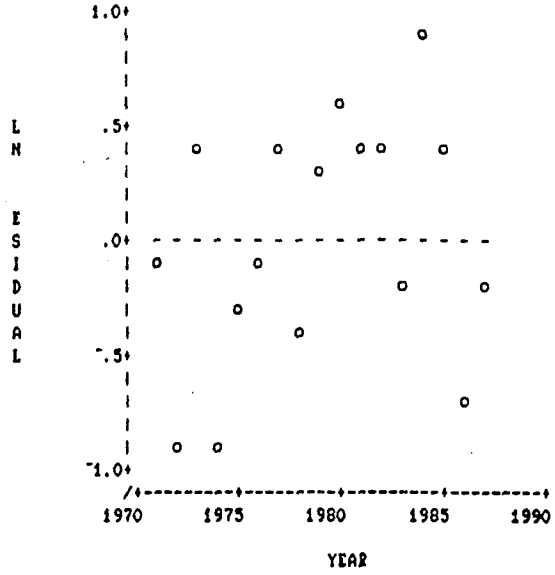
Figure 13 continued. Age 7.



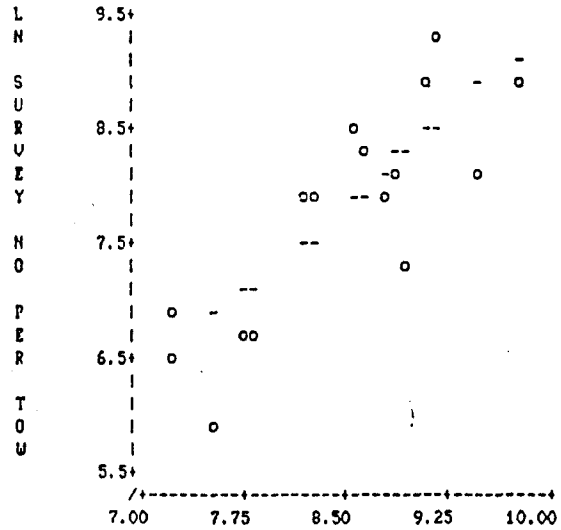
SURVEY NO. PER TOW VS SPA NUMBERS



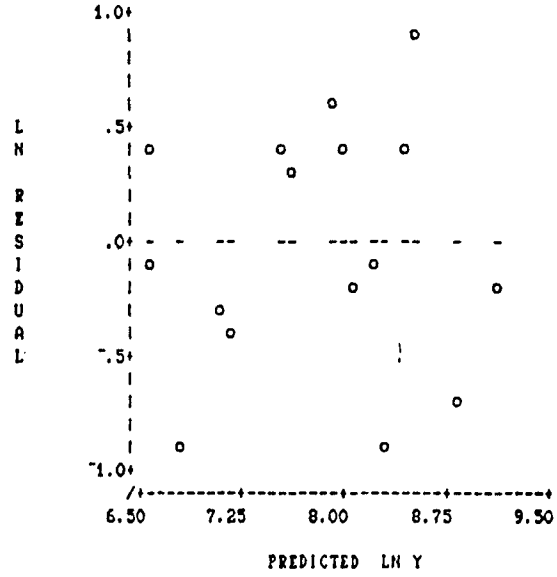

TREND IN LN RESIDUAL OVER TIME



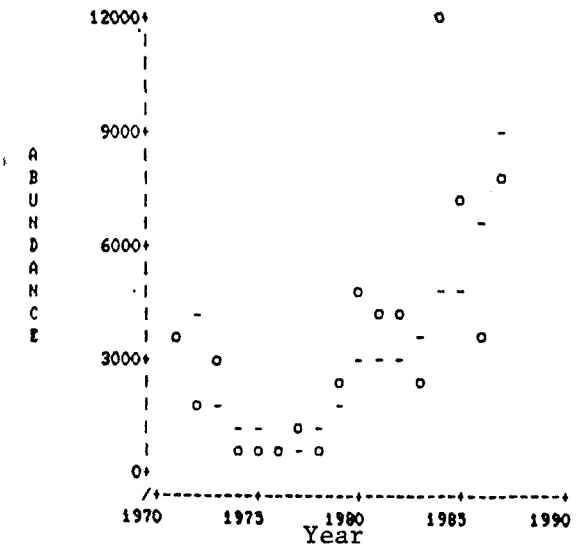

LN SURVEY NO. PER TOW VS LN SPA NUMBERS




TREND IN LN RESIDUAL VS PREDICTED LN Y




TREND IN POPULATION ABUNDANCE OVER TIME




TREND IN LN RESIDUAL VS OBSERVED LN X

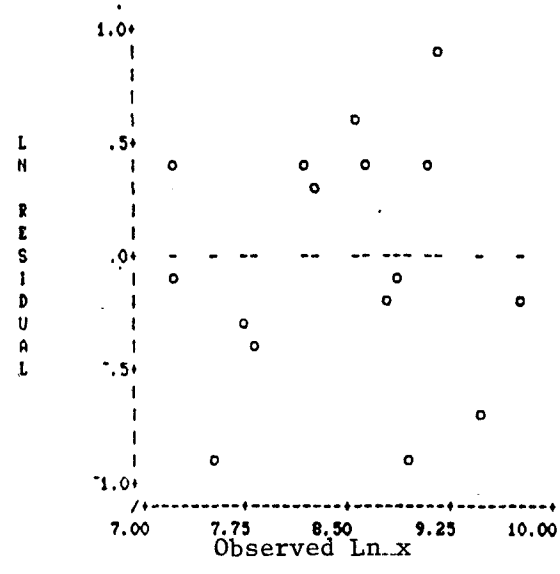


Figure 14. Mean fully recruited fishing mortality for 4VsW cod.

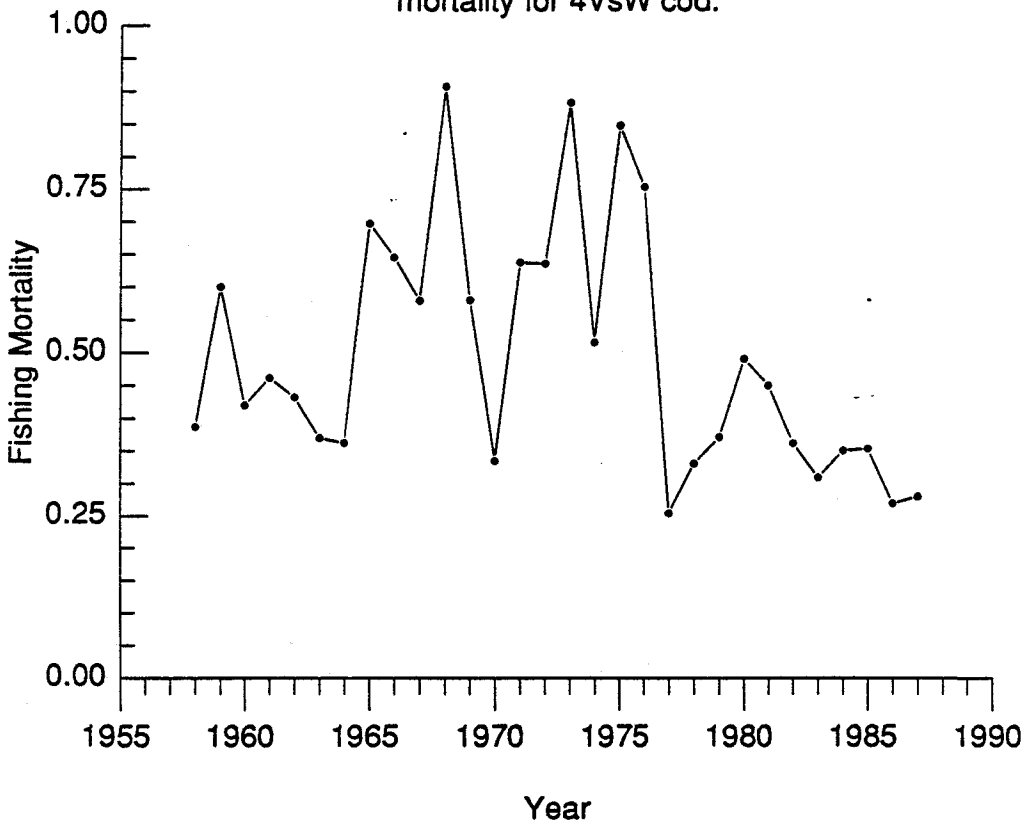


Figure 15. Number of recruits at age 1 for 4VsW cod.

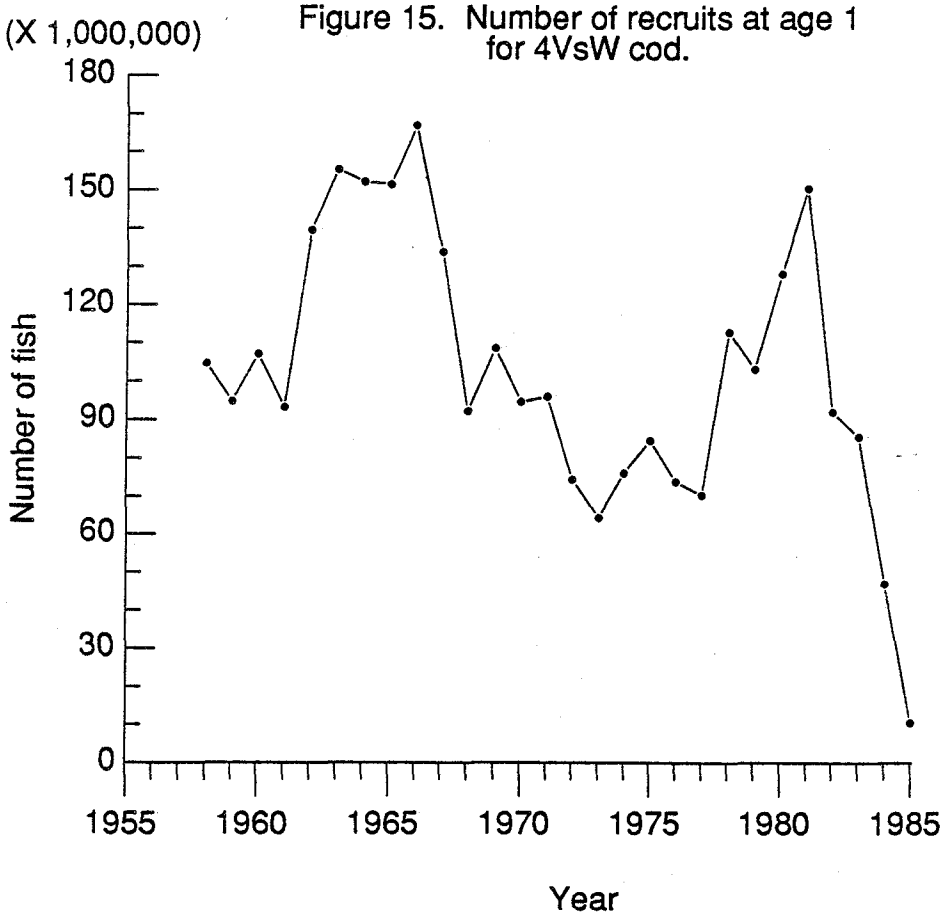
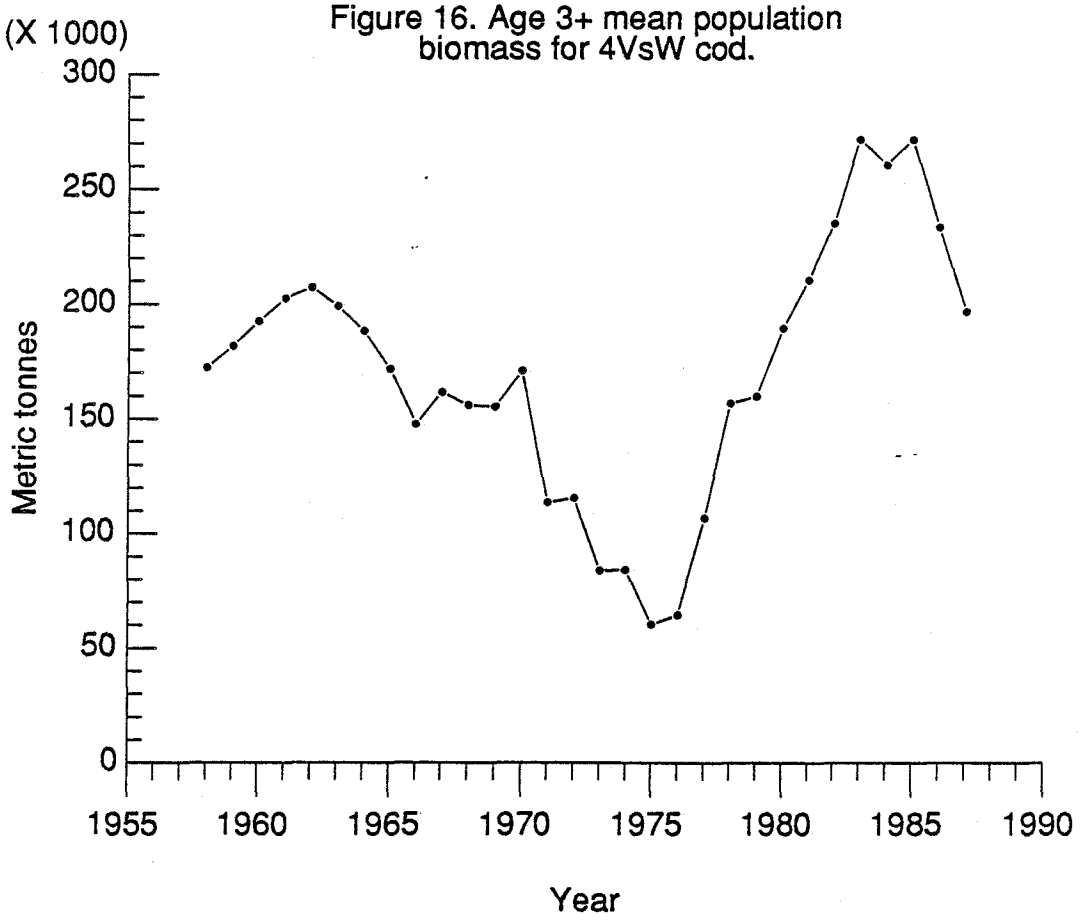


Figure 16. Age 3+ mean population biomass for 4VsW cod.



```
      ∇INPUT[□]∇
[0]   INPUT;ANS
[1]    'CATCH MATRIX ? '
[2]    c←□
[3]    'FIRST YEAR AND YOUNGEST AGE IN CATCH MATRIX ? '
[4]    ANS←□
[5]    YR←((1↑ANS)-1)+ι¯1↑⍴c
[6]    AG←((¯1↑ANS)-1)+ι1↑⍴c
[7]    'ENTER PARTIAL RECRUITMENT VECTOR FOR ALL AGES'
[8]    PR←□
[9]    'ASSUMED AGES OF FULL RECRUITMENT (START WITH FIRST FULLY RECRUITED AGE) ? '
[10]   AGE←AG↓□
[11]   'PRESENCE OR ABSENCE OF PLUS GROUP (P/A) ? '
[12]   NUM←'P'=□
[13]   'NATURAL MORTALITY ? '
[14]   m←□
[15]   'ENTER STARTING ESTIMATES OF AGE-SPECIFIC FS (TO BE ESTIMATED) FOR LAST YEAR '
[16]   ' EXCLUDE VALUE FOR PLUS ( IF ANY) GROUP '
[17]   FLY←□
[18]   'ENTER FIRST AND LAST AGES TO ESTIMATE'
[19]   FAG←□
[20]   FRST←FAG[1]
[21]   LAST←FAG[2]
[22]   'STARTING ESTIMATES OF YEAR-SPECIFIC FS FOR OLDEST'
[23]   ' NON-PLUS GROUP AGE (ENTER 0 IF NOT DESIRED)'
[24]   FAG←□
[25]   FVECT←FLY,1↓⌽FAG
[26]   CVECT←,c[(¯1+FRST+ι⍴FLY);¯1↑⍴c]
[27]   →(FAG=0)/S1
[28]   CVECT←CVECT,1↓⌽,c[(⍴FLY);]
[29]  S1:NVECT←(CVECT×(FVECT+m))÷(FVECT×(1-*-FVECT+m))
[30]   lbnd←(⍴NVECT)⍴0
[31]   ubnd←(⍴NVECT)⍴1000000
[32]   'INDEX OF ABUNDANCE (SAME NUMBER OF YEARS AS CATCH AT AGE MATRIX ) ? '
[33]   i←□
[34]   'AGES IN CALIBRATION INDEX ? '
[35]   ROWS←AG↓AGES←□
[36]   'INDEX FOR WHAT MONTH ( NO. FROM 1 TO 12 ) ? '
[37]   MNTH←□÷12
[38]   'STARTING AGE - SPECIFIC K COEFFICIENTS '
[39]   ' '
[40]   ' MATRIX OF AGE BY COEFFICIENT '
[41]   ' MODEL IS LN I =  LN ( BO+B1×POP) '
[42]   ' '
[43]   K←□
[44]   lbnd←lbnd,(⍴,K)⍴¯9000
[45]   ubnd←ubnd,(⍴,K)⍴9000
[46]   'ESTIMATES OF STANDARD ERROR IN INDEX  (ENTER 1 IF LOG MODEL)? '
[47]   ise←□
[48]   initial←NVECT,,K
[49]   alpha←1E¯3×NVECT
[50]   limit←100
[51]   'ALL THAT YOU CAN DO NOW IS WAIT'
[52]
```

```
     ∇minipop[□]∇
[0]  minipop;BOOL;J;DIAG;Q;LAMBDA;HESS;N;P;PAR;RSS;de;CAUSE;I;V;NPHI;PHI;pnlty;dpnlty;SHESS;NORM
[1]  ⍝ NON-LINEAR LEAST SQUARES USING MARQUARDT ALGORITHM
[2]   INPUT
[3]   P←⍴par←PAR←,initial
[4]   RSS←e+.×e←OBJ∆FN PAR ⍝ RESIDUAL SUM OF SQUARES
[5]   N←⍴,e
[6]   pnlty←alpha PNLTY∆FN PAR ⍝ PENALTY FOR CONSTRAINTS
[7]   NPHI←PHI←RSS+pnlty
[8]   LAMBDA←0.01
[9]   BOOL←(P×P)⍴1,P⍴0 ⍝ USED TO CREATE DIAG MATRIX
[10]  con←10
[11]  PRNT
[12]  J←1
[13] L3:→(limit<J←J+1)/L6 ⍝MAIN LOOP
[14]  PAR←par
[15]  PHI←NPHI
[16]  de←DIFF∆OBJ
[17]  Q←2×e+.×de ⍝ GRADIENT
[18]  HESS←2×(⍉de)+.×de ⍝ HESSIAN
[19]  dpnlty←DIFF∆PNLTY ⍝ DIFFERENCE FOR PENALTY
[20]  Q←Q+dpnlty[1;]
[21]  DIAG← 1 1 ⍉HESS←HESS+(2⍴P)⍴BOOL\dpnlty[2;]
[22]  LAMBDA←9.9999999999999E⁻7⌈LAMBDA×0.01
[23]  I←1
[24]  SHESS←HESS+(2⍴P)⍴BOOL\DIAG×LAMBDA←LAMBDA×10 ⍝ MARQUARDT METHOD
[25]  NORM←(+⌿SHESS*2)*0.5 ⍝ COLUMN NORMS
[26]  SHESS←SHESS÷(⍴SHESS)⍴NORM ⍝ SCALE HESSIAN
[27]  par←PAR+V←(Q⌹SHESS)÷NORM ⍝ STEP DIRECTION; STEP SIZE=1
[28]  →(~FRGN∆FN par)/L4
[29]  RSS←e+.×e←OBJ∆FN par
[30]  pnlty←alpha PNLTY∆FN par
[31]  →(PHI≥NPHI←RSS+pnlty)/L6
[32] L4:LAMBDA←LAMBDA×100
[33] L5:par←PAR+V←V×0.1*I ⍝INNER LOOP  REDUCE STEP SIZE
[34]  →(10<I←I+1)/L6
[35]  →(~FRGN∆FN par)/L5
[36]  RSS←e+.×e←OBJ∆FN par
[37]  pnlty←alpha PNLTY∆FN par
[38]  →(PHI≥NPHI←RSS+pnlty)/L6
[39]  →L5
[40] L6:PRNT
[41]  msr←RSS÷N-P
[42]  →(1=∧/CAUSE←(10≥I),(limit≥J),(1E⁻3(con←(((N-P)×Q+.×V)÷P×RSS)*0.5),(1E⁻4(|(NPHI-PHI)÷PHI),(9.9999999
[43]  (~CAUSE)/[1]exit
[44]  ' '
[45]  OUTPUT
```

```
      ∇ITERCOHORT[□]∇
[0]   ITERCOHORT;CATCH;J;MORT;FI;FC;ITER;I;Y;X;FCNEW;DIFF1
[1]    CATCH←⍵
[2]    J←¯1↑⍴CATCH
[3]    MORT←(⍴CATCH)⍴m
[4]    F←(⍴CATCH)⍴0
[5]    FI←FLY
[6]    →(NUM=0)/S3
[7]    FI←FI,¯1↑FI
[8]   S3:→(FAG=0)/S2
[9]    FC←FAG
[10]   →S1
[11]  S2:FC←(¯1↑⍴CATCH)⍴(¯1↑FI)
[12]  S1:ITER←0
[13]  OK9:I←⍴FI
[14]   F[(⍳I);J]←I⍴FI
[15]   F[I;]←J⍴FC
[16]   ITER←ITER+1
[17]   →(ITER≥20)/0
[18]   POP←(⍴CATCH)⍴0
[19]   POP[(⍳I);J]←((,CATCH[(⍳I);J])×FI+(,MORT[(⍳I);J]))÷FI×1-*-FI+(,MORT[(⍳I);J])
[20]   POP[I;]←((,CATCH[I;])×FC+(,MORT[I;]))÷FC×1-*-FC+(,MORT[I;])
[21]   →(NUM=0)/SK1
[22]   I←I-1
[23]   POP[I;]←((,CATCH[I;])×FC+(,MORT[I;]))÷FC×1-*-FC+(,MORT[I;])
[24]   F[I;]←J⍴FC
[25]  SK1:Y←J-1
[26]  AA:X←MORT[⍳I-1;Y]
[27]   POP[⍳I-1;Y]←(CATCH[⍳I-1;Y]×*X÷2)+(POP[1↓⍳I;Y+1]×*X)
[28]   →(1≤Y←Y-1)/AA
[29]   F[⍳I-1;⍳J-1]←(⍟(¯1 ¯1 ↓POP[⍳((1↑⍴POP)-NUM);])÷ 1 1 ↓POP[⍳((1↑⍴POP)-NUM);])- ¯1 ¯1 ↓MORT[⍳((1↑⍴POP)-
[30]   →(FAG≠0)/0
[31]   FCNEW←(+/[1]POP[AGE;]×F[AGE;])÷+/[1]POP[AGE;]
[32]   DIFF1←|(FCNEW-FC)÷FCNEW
[33]   FC←(¯1↓FCNEW),¯1↑FC
[34]   →((⌈/¯1↓DIFF1)>0.01)/OK9
```

```
      ∇OBJ∆FN[□]∇
[0]   R←OBJ∆FN A
[1]    s←(⍴NVECT)⍴A ⍝ survivors at designated age
[2]    FVECT←(⍟s÷(s-CVECT×*m÷2)×*-m)-m
[3]    FRF←(+/((1↑AGE)-FRST)↓FVECT×s)÷+/((1↑AGE)-FRST)↓s
[4]    FLY←PR×FRF
[5]    FLY[¯1+FRST+⍳1+LAST-FRST]←FVECT[⍳1+LAST-FRST]
[6]    →(FAG=0)/S1
[7]    FAG←(⌽(⍴FAG)↑⌽FVECT)
[8]   S1:k←((⍴ROWS),(¯1↑⍴K))⍴(-(⍴ROWS)×¯1↑⍴K)↑A ⍝ calibration coefficients
[9]    ITERCOHORT
[10]   popind←INTERFACE POP
[11]   R←,popind RESI k ⍝ calculate index residuals
```

```
     ∇DIFF∆PNLTY[□]∇
[0]  R←DIFF∆PNLTY;I;R1;DELTA;TPAR;fpnlty;bpnlty
[1]  ⍝ CALCULATES FIRST AND SECOND DIFFERENCES OF PENALTY FUNCTION
[2]   I←1
[3]   R← 2 0 ⍴0
[4]   DELTA←(0.01×PAR)+0.01×PAR=0
[5]  L1:TPAR←((I-1)↑PAR),(PAR[I]+DELTA[I]),I↓PAR
[6]   R1←(pnlty-fpnlty←alpha PNLTY∆FN TPAR)÷DELTA[I]
[7]   TPAR←((I-1)↑PAR),(PAR[I]-DELTA[I]),I↓PAR
[8]   bpnlty←alpha PNLTY∆FN TPAR
[9]   R←R,,R1,(fpnlty+bpnlty-2×pnlty)÷DELTA[I]
[10]  →L1×⍳2≥I←I+1
```

```
     ∇FRGN∆FN[□]∇
[0]  R←FRGN∆FN A
[1]   R←∧/(A)≥lbnd),A≤ubnd
[2]  ⍝ THIS FUNCTION SHOULD RETURN A 1 IF THE PARAMETERS
[3]  ⍝ ARE IN THE FEASIBLE REGION AND 0 OTHERWISE
[4]  ⍝ R←1 DEFAULT RETURNS 1
```

```
     ∇INTERFACE[□]∇
[0]  R←INTERFACE POPN
[1]   R←POPN×*-(F+m)×MNTH
[2]   R←R[ROWS;]
```

```
     ∇PNLTY∆FN[□]∇
[0]  R←alpha PNLTY∆FN A
[1]   R←+/alpha÷(⍴NVECT)↑A
[2]   R←0 ⍝ NO CONSTRAINTS
[3]
```

```
     ∇RESI[□]∇
[0]  R←POPIND RESI K
[1]  ⍝ K← 3 2 1 ⌹(⊖2,⍴POPIND)⍴,K
[2]  ⍝ ihat←(K[1;;]+K[2;;]×POPIND) ⍝ WITH INTERCEPT
[3]   K←⌹(⊖⍴POPIND)⍴,K
[4]   ihat←K×POPIND ⍝ WITHOUT INTERCEPT
[5]   R←((⍟i)-⍟ihat)
[6]
```