# Assessment of 4VsW Cod in 1993

R. Mohn and W. J. MacEachern
Marine Fish Division
Department of Fisheries and Oceans
P. O. Box 1006
Dartmouth N.S.
B2Y 4A2

## Abstract

The 1993 fishery for 4VsW cod landed 3474 t, compared to about 30000 t in 1992. This is the smallest catch in the history of the fishery. The low catch was due to a combination of resource depletion and management measures. The proportion of the catch taken in Subdiv. 4Vs steadily declined from 88% in 1988 to 67% in 1993 perhaps indicating a return to the more equal division of catches seen prior to the mid-1980's and the relative unimportance of the edge fishery in the winter. Foreign landings are reported to be very low, approximately 40 t. The 4VsW cod fishery was closed September 1, 1993.

As in recent years, the sequential population analysis (SPA) was calibrated using both July and March RV indices in ADAPT. The 1993 data points for both surveys were quite depressed which in turn produced low estimates from the SPA. The 1992 March survey point was the smallest ever seen and may indeed be unreliable as it was less than one tenth the 1991 or one fifth the 1993 values. The 1994 March survey was also quite low compared to the 1991 or 1993 levels.

The principal biological indices of the resource, research survey and commercial, suggest that the stock is seriously depleted. The surveys show a depressed stock similar in magnitude to what was seen in the 70's However the pattern is different from the 70's in that now there are relatively fewer of the larger fish. Only the 1990 yearclass in recent years is approaching the long term mean recruitment. Results of the SPA indicate that fishing mortality has been above $F_{Max}$ from 1988 to 1992 and that the spawning stock biomass is the lowest since 1970. The fishery should remain closed until there is an indication of sufficient recruitment to rebuild the spawning and fishable biomass pools.

The effects of grey seal predation were modeled and presented in conjunction with this assessment. The consumption of 4VsW cod by seals in 1993 is estimated at 17 thousand tons. Mohn and Bowen (in prep.) has the details of this model.

## Résumé

En 1993, les débarquements de morue de 4VsW ont été de 3 474 t, alors qu'ils atteignaient environ 30 000 t en 1992. Il s'agit des plus basses prises de l'histoire de la pêche, imputables à la fois à l'épuisement de la ressource et aux mesures de gestion. La proportion des captures provenant de la subdivision 4Vs est en régression constante, étant passée de 88 p. 100 en 1988 à 67 p. 100 en 1993, ce qui pourrait être le signe d'un retour à la division plus équitable des prises qui existait avant le milieu des années 80 et de l'insignifiance relative de la pêche en bordure de la zone durant l'hiver. Selon les indications, les débarquements des navires étrangers sont très faibles, se chiffrant à environ 40 t. La pêche de la morue dans 4VsW a été fermée le 1$^{er}$ septembre 1993.

Comme ces dernières années, on a étalonné l'analyse séquentielle de population (ASP) d'après les données des relevés de recherche de juillet et mars, au moyen du modèle ADAPT. Les points de données des deux relevés de 1993 étaient assez bas, ce qui explique que les estimations étaient elles aussi basses par rapport à l'ASP. Le point de données du relevé de mars 1992, le plus bas enregistré à ce jour, représentait seulement un dixième et un cinquième respectivement des valeurs de 1991 et de 1993, ce qui le rend sujet à caution. Les résultats du relevé de mars 1994 étaient également assez bas par rapport à ceux de mars 1991 et 1993.

Les principaux indices biologiques de l'état de la ressource, les relevés de recherche et les résultats de la pêche commerciale révèlent que le stock est extrêmement appauvri. Selon les relevés de recherche, son état de précarité est de l'ampleur de celui des années 70, quoiqu'il se manifeste différemment, le stock comportant maintenant relativement moins de gros poissons. Pour ce qui est des dernières années, seule la classe d'âge de 1990 approche du recrutement moyen à long terme. Les résultats de l'ASP indiquent que la mortalité par pêche a été supérieure à $F_{Max}$ de 1988 à 1992 et que la biomasse du stock reproducteur est à son plus bas depuis 1970. Il convient de maintenir la pêche fermée jusqu'à l'apparition d'indices d'un recrutement suffisant pour reconstituer la biomasse de reproducteurs et la biomasse exploitable.

On a modélisé et présenté les effets de la prédation par le phoque gris conjointement à la présente évaluation. La consommation de morue de 4VsW par les phoques en 1993 est estimée à 17 000 tonnes. Des renseignements détaillés sur le modèle sont fournis par Mohn et Bowe (en prép.)

## Description of the fishery

Landings of 4VsW cod ranged from 40,000 t to 80,000 t in the years 1958 to 1974 and then declined rapidly to a low of 10,000 t in 1977 (Table 1, Figure 1). Subsequent to extension of jurisdiction the landings quickly climbed again and were at or above 50,000 t from 1980 to 1986. Under quota restrictions, the TAC's have been reduced and consequently the catches have declined in recent years to 29800 t in 1992, and then radically to 3474 in 1993, the lowest catch on record. The low catch was due to a combination of resource depletion and stricter management measures, especially regarding small fish. Since 1977 the foreign catch has only exceeded 1000 t once and in 1993 was approximately 40 t, primarily bycatch in the silver hake fishery. The "edge" fishery located mainly in 4Vsb for 4TVn fish migrating in front of the ice was closed unitl May and was very low in 1993, taking about 80 t compared to thousands of tons in recent years. Prior to 1980, the total catch was dominated by the Div. 4W component. However, since 1980 the percentage of the catch coming from Subdiv. 4Vs climbed from 60% to a high of 87% in 1988 (Table 2). The percentage has declined for the last four years and was 67% in 1993, the lowest since 1983. The fishery was closed to by-catch only on September 1.

The proportion of the catch taken by each gear type was essentially unchanged from 1989 to 1992, with over 70% of the catch taken by otter trawls, 25% taken by longline and handline and the remainder taken primarily by seines and gillnets (Table 2).But in 1993 the longline catch was about 50% greater than the trawler catch. None of the gear sectors were close to their quota, Table 3, but large mobile gear > 100' had the largest shortfall, 810 out of a quota of 6429. This shortfall was in part due to the closures for small fish. (See Annand & Hanson in prep.) In 1993 some gear sectors were complaining about the difficulty in getting legal size catch. Conversations in 1993 and early 1994 with fishermen , their representatives and DFO field staff were surprisingly consistent in the view that there were neither many legal fish nor many under legal size ( < 43 cm).
The CAFSAC advice, TAC and nominal catches (kt) are:

| Year | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|
| F0.1 Reference | 38 | 32 | 33.2 | 34 | 20.7 | - | 11 | 3 |
| Advised Catch | 44 | 38 | 35.2[b] | 35.2[b] | 35.2[c] | 35.2[c] | 20.[b] | 2.5[b] |
| TAC | 44 | 38 | 35.2 | 35.2 | 35.2 | 35.2 | 11. | 0[e] |
| Catch | 45.5 | 38.4 | 36.7 | 34.3[a] | 32.9[a] | 29.8[a] | 3.5 | |
| Catch[d] | 43.5 | 35.9 | 34.2 | 29.7[a] | 24.1 | 25.4[a] | 3.5 | |

[a] Preliminary
[b] 50% rule
[c] Advised that constant catch would not be detrimental
[d] with nominal 4T component removed
[e] by-catch only

## Data

*Catch and weight at age*

Because of fewer samples than in earlier years, the 1993 catch at age was constructed by using three separate keys (compared to 7 in 1992). See Table 4 for details. The parameters of the length/weight relationships were estimated from the July RV survey. The keyed catch accounted for more than 98% of the total catch and was pro-rated to the total. Table 5 contains the catch at age for landings from 4VsW.

The mean size at age in southern Gulf (4TVn) cod is substantially smaller than in 4VsW cod and they are known to migrate into 4Vn in the winter to the degree that catches from the 4Vn (Jan.- Apr.) fishery are considered part of the 4TVn spawning group for management purposes. There have also been industry reports in the past that indicate parts of the 4TVn migration may extend southward into 4Vb and perhaps even 4Vc, however, as this usually involves small quantities of catch, the impact has been assumed negligible. However in recent years, the catch has been considerable Corrections for the proportion of the catch that are slower growing, and presumably to a large degree from 4T, were estimated for 1986-1992 (Table 6.). The "4T" corrected catch is used in all analyses. Because of the small 4Vsb catch in the first quarter of 1993, approximately 80 t, the 4T component was not estimated.

The commercial mean weights at age (Table 7) trended to smaller weights at age until 1992. The mean weights at age peaked in the early eighties. The 1993 weights are higher for older fish, but htis may be due to changes in the 1993 fishery, especially the 4Vb Jan-Apr closure.

*Commercial catch rates*

Catch and effort data from trawlers (TC 2+) for the years 1970-1988 were extracted from the NAFO data base and 1989-1993 were extracted from the Interzonal (ZIFF) database and aggregated into the same tonnage/gear/area/month categories defined by Sinclair and Smith (1987). See Table 8 for the details of the statistical analysis. Selection criteria removed catch or landings of less than 10 units. Throughout the 1980's the C/E remained higher than the 1970's and relatively stable, with the exception of 1985-86 which were the highest observed (Figure 2). The 1993 value is approximately one half of the 1992 value.

The Canadian OTB (TC 4-5) catch rates from the IOP were calculated for the years 1982-1993. See Table 9 for the details of the statistical analysis. The observed catch has varied between 7% and 17% of the total OTB catch during 1982-89, however, in the 1990s the IOP observed over a third of the OTB catch and about 50% in 1993. When standardized to the same basis, the C/E based on the IOP was significantly higher than that based on the commercial statistics in 1984-89 but nearly equal in 1982, 83 and 90 on, (Figure 2). A possible explanation for this pattern is discussed in Fanning & MacEachern (1991) and is attributed to changes induced by the introduction of the IQ program. Until the poor agreement in the two CPUE series is resolved they will not be included in tuning SPA's.

*Research vessel surveys*

The July stratified random trawl survey of 4VsW has been conducted annually since 1970. Table 10 contains the mean catch at age in numbers . The research vessel conducting the survey was changed in 1982 and 1983 due to the retirement of the A.T. Cameron, the temporary use of the Lady Hammond (in 1982) and the advent of the Alfred Needler in 1983. The cod catches from the A.T. Cameron and the Lady Hammond were adjusted by a cod conversion factor of 0.8, which is applied to the latter vessel, to account for the change in the survey vessel.

A second survey has been conducted in March from 1979 to 1992 with the exception of 1985. Table 11 contains the mean catch at age in numbers per standard tow. The same conversion factor was applied to the March surveys for the years 1979-83 when the Lady Hammond was the survey vessel. From time to time the estimation of abundance from the March survey has been complicated by missing strata due to the presence of ice in the survey area. The CAFSAC Groundfish subcommittee had previously recommended that methods of adjusting for the effect of missing strata be investigated, however this has not

been completed and the March survey index assumes that missing strata would have been equal to the overall mean of the sampled strata. In 1991 and 1992 there were no missing strata although a number of strata contained only 1 set. In 1993 one strata had only 1 set and 4 new strata were added in deeper water in the Laurentian Channel. The new strata are not included in the results in Table 14 nor in subsequent analysis. The CV's associated with the March survey estimates are generally larger than in the July survey, probably reflecting the more aggregated distribution of fish in the winter.

The July survey mean catch per tow in recent years, 1987-90, was higher than all years prior to 1982 except for 1973, but well below the peak of 1982-84. See Figure 3 or Table 10. The 1993 point was beneath the long term average but about 10 % higher than the 1991 1+ value but about 70% greater for 3+. The general trend in the March surveys (Table 11) was similar although 1986 and 1990 seemed to be extremely high and low, respectively, relative to the July estimates. The March survey estimate for ages 4+ was very low in 1990, 1992 and 1994. However, in 1991 the estimate, which includes the strong 1987 yearclass, is comparable to the early 1980's. The recovery from March 1992 to the 1993 survey is still beneath the long term mean, but is of similar magnitude to the 1991 March survey and the 1992 July survey.

Both surveys series have indicated that the 1986 and 1987 yearclasses are above average. The 1987 yearclass has constituted 44% to 49% of the mean catch per tow (in numbers) in 4 of the 5 surveys available for 1989 to 1991, and it was 30% of the total numbers in the fifth survey (July 1989). Both surveys have shown the presence of the 1990 yearclass, which, though stronger than its neighbors, is only about average in strength and not yet available to the fishery.

## Analysis

*Estimation of parameters*

The traditional aged population analysis was performed for this stock using software similar to ADAPT to fit the model which is described as:

Parameters:

| | | |
|---|---|---|
| Terminal F estimates -- | $F_{i,1992}$, i=3 to 8 |
| Calibration coefficients -- | $K_{1,i}$, i=3 to 8 for July RV survey |
| -- | $K_{2,i}$, i=3 to 9 for March RV survey |

Structure Imposed:

Error in catch assumed negligible
Partial recruitment fixed for ages 1, 2, and 9+ in year 94.
F on oldest age (15) set to 95% of the average F ages 7-9
No intercept was fitted
M=0.2 for all ages

Input:

$C_{i,t}$, i=1 to 15; t=1970 to 1993 - Full year catch at age
$J_{i,t}$, i=3 to 8; t=1970 to 1993 - July RV index
$M_{i,t}$, i=3 to 9; t=1979 to 1993 - March RV index (excluding 1985)

Objective function: Minimize:

$$\Sigma\,\Sigma\,\{\ln J_{i,t} - K_{1,i}\,N_{i,t}\}^2 - \Sigma\,\Sigma\,\{\ln M_{i,t} - K_{2,i}\,N_{i,t}\}^2$$

Summary:

Number of observations: 144 from July RV
98 from March RV

Number of parameters: 19, F's estimated by NLLS, K's algebraically

## Results

*SPA*

The SPA results (Tables 12-15, Figures 4-9) indicate that the average F(ages 7-9) has increased in recent years and is well above $F_{0.1}$ or $F_{Max}$ and is indeed the highest seen in 1992 and then fell dramatically in 1993. Moreover, the results show that the 6+ biomass is extremely low, at levels comparable to the late 70's. This year's SPA results indicate much lower recent recruitments than last years with levels well beneath the long term GM average of 59 million animals. The 1987 yearclass is the strongest in recent years but still well below the GM level, 50 versus 61 million (Figure 5). The 1990 yearclass, although only poorly estimated by the SPA, may be as strong as the 1987 yearclass. The July survey suggests this also while the March survey indicates that the 1990 yearclass is not nearly as strong.

The diagnostic statistics from ADAPT are given in Table 15. The coefficient of variation on the terminal F range from 34 to 51% with the youngest age having the poorest CV. As seen in previous years the CVs are higher for the March survey than the summer survey. The bias estimates for $F_{1993}$ are negative and range from 7 to 16% . The q's have small (<3%) negative biases. Because the biases are small, and the stock status is clear, the estimates of stock status were not corrected for bias.

A retrospective analysis was performed on these data and results are shown both in terms of average F and biomass. Figure 7a shows the estimates for average F for ages 7-9 using increasing data sets for the last 8 years. The average F was consistently underestimated in the late 80s. In terms of biomass (Figure 7b), the late 80s also show a large retrospective pattern which has been less marked in the last couple of years.

Figure 8 is the stock-recruit relationship estimated from the population analysis. The spawning biomass is approximated by the 6+ fish and the recruits are the numbers at age 1 in the following year. The points since 1987 are all lower on this graph than the earlier points which shows that even though the biomass was strong recruitment was weak. The 1990 point shows some recovery. The distribution of points in the stock recruit relationship were strongly affected when seal predation was included (See Figure 13 Mohn & Bowen in prep.).

Figure 9 shows the VPA numbers summed from age 3 to 8. The VPA numbers are compared to the estimates from the surveys after correction for the efficiency of the survey gear (the q's estimated in Table 15). This is done to allow a direct comparison of the results to the numbers age 3-8 from the surveys. The SPA numbers show a steady decline since the early 80's. On this scale the summer surveys show a slow, steady decline (excepting 1990). In the last 5 years the estimates from the spring survey are seen to be quite erratic.

*Multispecies model*

Additional SPAs were also run in which the removals by seals were incorporated in the analysis. See Mohn & Bowen (in prep.). This essentially treated grey seals as a fleet competing with other gear sectors for this resource. Seals predominantly eat cod before

they recruit to the fishery so the analogy would be to a small mesh fishery. The results are dependent upon the natural mortality rates assumed and new values of M were assumed which are thought to be more realistic and have higher rates on small cod (M = 1.0 0.8 0.6 0.4 for ages 1 to 4 and 0.2 for older) than the traditional M = 0.2. (See for example Sparholt 1990 or Anon 1993) The higher age dependent rates are denoted $M_R$.

Over the past 5 years, a number of studies have been conducted to improve our understanding of the interactions between grey seals and commercial fisheries in eastern Canada. Several models have recently been developed to examine trends in the consumption of the 4VsW cod stock by grey seals over the period 1970 to 1992. An age-structured model of the population dynamics of grey seals in eastern Canada and the seasonal distribution of grey seals are used to determine the number of grey seals feeding in the 4VsW study area. Estimates of the mass-specific energy requirements of seals, the fraction of three size-classes of cod in the grey seal diet, and the average energy content of the diet are then used to determine consumption of 4VsW cod by grey seals.

Both the Gulf of St. Lawrence and the Sable Island populations of grey seals have increased over the past decade. The 1993 Gulf population is estimated at 61,900 animals, with a doubling time of about 8 years. The 1993 Sable Island population is estimated to be 81,600 seals, which is consistent with preliminary data from the 1993 aerial survey. Sable Island pup production continues to increase at about 13% per year, which corresponds to a doubling time of slightly less than 6 years. Approximately 13% of the mean food intake was cod. Cod comprised from 1.6% to 44.1% by weight of the diet in individual samples collected between late 1988 and early 1993. Although the estimates varied considerably, there was no evidence of a trend in the percentage of cod in the diet over time. It is estimated that cod <30 cm, from 31-45 cm, and >45 cm fork length accounted for 44%, 36%, and 20% by weight of the cod in the diet, respectively. These length classes are roughly equivalent to 0-2 year-old cod, 3 to about 50% of 4 year-old cod, and 4+ year-old cod, respectively. Mean total annual food intake by grey seals in the 4VsW area increased from an estimated 12,000 t in 1970 (rounded to the nearest 1000 t) to about 138,000 t in 1993 The estimated biomass of cod consumed by grey seals increased from about 1,500 t to 17,300 t over the period 1970-1993. Predation by grey seals prior to the mid 1980's was unlikely to have been a significant source of mortality on 4VsW cod compared to other sources of natural mortality. By 1993, grey seal predation on cod may have been about 17,300 t compared to the 3,500 t landed by the commercial fishery. Most of this grey seal predation was on cod ages 1-4 (i.e., pre-recruits to the fishery).

Error analysis for the seal model consisted of sensitivity analysis on the parameters describing cod consumption and bootstrapping of the principal consumption data. The sensitivity linked the cod predation to each parameter This analysis showed that the cod consumption was more than 5 times more sensitive to the Sable herd's size than the Gulf herd's. The amount of energy available to the seal from its diet, the metabolizable energy, was also very important but fortunately it is fairly well known. The percentage of cod in the diet is also quite important but as mentioned above is quite variable in the available data. The percentage of cod in the diet may decline as the available biomass of cod declines. The bootstrapping exercise was carried out to show the effect of this variability in the cod consumption (Figure 10) using two models of seal predation, one with a constant percentage of seals in the diet and the second with a percentage that is proportional to the cod biomass.

The results from the alternate models including seals showed that seal predation could have a significant effect on the recruitment to the fishery. When seals were included more cod were estimated to have been born, but fewer survive to legal size. The inclusion of seals

also has potential effects on yield per recruit analysis and showed that the yield could be reduced to about a third when included in the calculations.

| Nat. Mortality | No Seals 0.2 | Seals 0.2 | No Seals MR | Seals MR |
|---|---|---|---|---|
| Recruits (1990 YC Millions) | 55 | 105 | 390 | 520 |
| 1+ Biomass (1993 kt) | 47 | 83 | 58 | 155 |
| 6+ Biomass (1993 kt) | 15.6 | 15.8 | 15.8 | 16.6 |
| F (2-8 1993) | 0.12 | 0.12 | 0.12 | 0.12 |
| F + Seals (2-8 1993) | | 0.37 | | 0.33 |
| F0.1 | 0.17 | 0.27 | .17 | 0.29 |
| Yield per recruit at F0.1 (g) | 400 | 156 | 54 | 29 |
| Potential yield from 1990 YC (kt) | 22 | 16 | 21 | 15 |

The potential yield from the 1990 yearclass is the product of the yield per recruit and the yearclass size. Implicit in this calculation is that fishing, predation and natural mortality patterns remain constant over the duration of this yearclass in the fishery, or up to about the year 2000. Because these models assume no compensation among the predators of cod, the above table may be thought of as a worst case scenario for the impact of seals for either natural mortality assumption. However, some compensation is thought to be likely, therefore the effect of seals on yield will less than these worst case scenarios suggest. Because it predicts lower cod consumption from 1990 on, the sensitivity run using a constant proportion of cod in the diet would have impacts that fall within the bounds of the Seals and No Seals columns above. See Mohn & Bowen (in prep.) for more details on the seal predation model and its results.

## Prognosis

*Projections*

The 1993 numbers are projected ahead from the VPA with a GM recruitment of 33 million (GM average 1984-1990) for ages 1-3 for starting population in 1994. The recent time period was chosen as an appropriate range because of the lower recruitment seen in recent years (Figure 5). The weights are the average commercial weights for the years 1990 - 1993 and represent mid-year values (age 1 assumed) , and the selectivity is the smoothed average from last year's assessment. The resultant values used in stock projections are:

| Age | $N_{1994}$ | Weight | Selectivity |
|---|---|---|---|
| 1 | 33000 | 0.10 | .000 |
| 2 | 27018 | 0.29 | .000 |
| 3 | 22121 | 0.66 | .014 |
| 4 | 10352 | 0.84 | .156 |
| 5 | 8181 | 1.07 | .480 |
| 6 | 6390 | 1.39 | .740 |
| 7 | 1148 | 1.71 | .951 |
| 8 | 405 | 2.00 | 1.000 |
| 9 | 148 | 2.79 | 1.000 |
| 10 | 27 | 2.91 | 1.000 |
| 11 | 24 | 4.38 | 1.000 |
| 12 | 13 | 3.64 | 1.000 |
| 13 | 7 | 6.94 | 1.000 |
| 14 | 3 | 13.32 | 1.000 |
| 15 | 0 | 12.09 | 1.000 |

Two sets of projections with these data were performed; assuming a catch at the 3474 t TAC for 1994 (The 1993 catch) and $F_{0.1}$ (0.22) for 1995- 96, and with no fishing in 1994 and $F_{0.1}$ afterwards.

| Year | F | Yield | Biomass | 6+ Biomass |
|---|---|---|---|---|
| 94 | 0.265 | 3476 | 42570 | 10915 |
| 95 | 0.220 | 4159 | 53565 | 16233 |
| 96 | 0.220 | 5671 | 64055 | 20890 |

| Year | F | Yield | Biomass | 6+ Biomass |
|---|---|---|---|---|
| 94 | 0.000 | 0 | 42570 | 10915 |
| 95 | 0.220 | 4762 | 57067 | 19359 |
| 96 | 0.220 | 6232 | 67005 | 23788 |

The severe depletion of the fishable biomass as estimated by the above VPA is reflected by very low $F_{0.1}$ yields for 1995 - 96 for either scenario. Projections were also done for 1995 assuming the 1993 F was repeated in t 1994 (Figure 11). The total , fishable and spawning biomasses are shown as well as yield. One observes that the 6+ or fishable biomass is of the same magnitude as the yield in the region of $F_{Max}$ which suggests that this is a "recruitment" fishery based on only a few yearclasses.

These preliminary estimates of grey seal predation on 4VsW cod are sensitive to uncertainties in the underlying data, to parameter estimates derived from these data or assumed on the basis of theory, and to uncertainties in the structural form of components of the model. Among these uncertainties, the issue of compensation among the components of natural mortality must be clarified before we can have confidence in the magnitude of the impact of grey seal predation on the dynamics of 4VsW cod. Other issues such as how grey seal predation on cod varies with changes in cod biomass and the age structure of the cod population and with changes in the relative availability of other major prey also need to be understood.

The issue of compensation in the components of M is uncertain at present. However, we do not expect either extreme to occur; that is, we do not expect that seal predation mortality will be simply added to the existing sources of M on cod or that seal mortality simply replaces other sources of M, with no net increase in M. The effect of seal predation will fall into the middle ground of some compensation.

Although we cannot be certain of the impact of grey seal predation on the stock, it seems clear whatever the effects of grey seals might be, these effects are likely to increase over the next several years. We arrive that this conclusion for two reasons. First, there is no indication that the increasing trend in the population size of grey seals will slow in the near future. Thus, we can expect more seals feeding in the 4VsW area. Second, it is not likely that grey seals will cease to feed on cod at low cod biomass, although a decrease in the fraction of cod in the diet of grey seals may occur if there is a further decrease in cod biomass.

The spawning stock biomass and fishable biomass are at the lowest levels seen since 1970. However, fish under legal size, mainly the 1990 yearclass, are still seen in the most recent surveys. If fishing remains closed, the chances for recovery are improved. The absence of any indication of even average recruitment since the 1990 yearclass is a source

of concern. The fishery should remain closed until there is an indication of sufficient recruitment to rebuild the spawning and fishable biomass.

## References

Anon, 1993, The WG Rpt on the assessment of demersal stocks in the North Sea and Skagerrak. Ices C.M. 1993/Assess 5

Annand, C and J. Hanson (in prep.) Management review 1993.

Fanning, L.P. and W.J. MacEachern. 1991. Assessment of 4VsW cod in 1990. CAFSAC Res Doc. 91/44. 42p.

Mohn, R and W.D. Bowen. (in prep.) A model of grey seal predation on 4VsW cod and its effects on the dynamics and potential yield of cod.

Sinclair, A. and S.J. Smith. 1987. Assessment of 4VsW cod. CAFSAC Res. Doc. 87/92. 62p.

Sparholt, H. 1990. Improved estimates of the natural mortality rates of nine commercially important fish species included in the North Sea Multispecies VPA model. J. Cons. int. Explor. Mer, 46: 211-223.

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 | 3042 | 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 | 29 | 52546 | 42578 | 9968 | 55000 |
| 1985 | 56553 | - | 870 | - | 21 | 11 | 57455 | 48189 | 9266 | 55000 |
| 1986 | 51467 [1] | - | - | - | 28 | 34 | 51529 | 44028 | 7501 | 48000 |
| 1987 | 45430 | - | - | - | 25 | 48 | 45503 | 39755 | 5748 | 44000 |
| 1988 | 38215 | - | - | - | 106 | 35 | 38356 | 33729 | 4627 | 38000 |
| 1989 | 36619 | - | - | - | 84 | 40 | 36743 | 29378 | 7365 | 35200 |
| 1990 | 34136 [1] | - | - | - | 127 [2] | 71 [2] | 34334 | 26340 | 7994 | 35200 |
| 1991 | 32698 [1] | - | - | - | 159 [2] | 58 [2] | 32915 | 24451 | 8464 | 35200 |
| 1992 | 29724 [1] | 3 [2] | - | - | 36 [2] | 42 [2] | 29805 | 21317 | 8488 | 35200 |
| 1993 | 3434 [1] | - | - | - | 15 [2] | 25 [2] | 3474 | 2316 | 1158 | 11000 |
| 1994 | | | | | | | | | | 46 [3] |

[1] Preliminary Catch Statistics (ZIFF)

[2] IOP

[3] Bycatch quota only

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

| | 4Vs | | | | | 4W | | | | | 4VsW | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | TRAWLS | LL | SDN | MIS | TOTAL | TRAWLS | LL | SDN | MIS | TOTAL | TRAWLS | 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 | 1416 | 159 | 3767 | 15632 | 17656 | 1500 | 181 | 3767 | 23104 |
| 1966 | 6374 | 143 | 14 | - | 6531 | 6614 | 1472 | 38 | 3035 | 11159 | 12988 | 1615 | 52 | 3035 | 17690 |
| 1967 | 6735 | 99 | 27 | - | 6861 | 6460 | 2405 | 71 | 2667 | 11603 | 13195 | 2504 | 98 | 2667 | 18464 |
| 1968 | 9501 | 48 | 18 | - | 9567 | 8360 | 2970 | 89 | 3902 | 15321 | 17861 | 3018 | 107 | 3902 | 24888 |
| 1969 | 3540 | 43 | 7 | - | 3590 | 4695 | 3567 | 13 | 2323 | 10598 | 8235 | 3610 | 20 | 2323 | 14188 |
| 1970 | 3054 | 21 | 1 | - | 3076 | 3602 | 3817 | 62 | 1261 | 8742 | 6656 | 3838 | 63 | 1261 | 11818 |
| 1971 | 5827 | 40 | - | - | 5867 | 4768 | 4819 | 26 | 1584 | 11197 | 10595 | 4859 | 26 | 1584 | 17064 |
| 1972 | 9856 | 115 | 4 | - | 9975 | 4732 | 3793 | 7 | 1480 | 10012 | 14588 | 3908 | 11 | 1480 | 19987 |
| 1973 | 6392 | 82 | 3 | - | 6477 | 4723 | 3748 | 20 | 961 | 9452 | 11115 | 3830 | 23 | 961 | 15929 |
| 1974 | 4644 | 56 | - | - | 4700 | 1335 | 2969 | 5 | 1691 | 6000 | 5979 | 3025 | 5 | 1691 | 10700 |
| 1975 | 1824 | 63 | - | - | 1887 | 3566 | 3185 | 11 | 1290 | 8052 | 5390 | 3248 | 11 | 1290 | 9939 |
| 1976 | 3755 | 42 | - | - | 3797 | 937 | 2913 | 14 | 1906 | 5770 | 4692 | 2955 | 14 | 1906 | 9567 |
| 1977 | 2751 | 50 | 4 | - | 2805 | 1873 | 3487 | 68 | 1657 | 7085 | 4624 | 3537 | 72 | 1657 | 9890 |
| 1978 | 9561 | 294 | 19 | - | 9874 | 7997 | 4552 | 839 | 1380 | 14768 | 17558 | 4846 | 858 | 1380 | 24642 |
| 1979 | 14853 | 438 | 86 | - | 15377 | 13742 | 5825 | 3245 | 988 | 23842 | 28637 | 6263 | 3331 | 988 | 39219 |
| 1980 | 28941 | 2116 | 321 | - | 31378 | 6298 | 6588 | 3440 | 1117 | 17443 | 35239 | 8704 | 3761 | 1117 | 48821 |
| 1981 | 27662 | 4274 | 171 | - | 32107 | 9148 | 8229 | 2433 | 1136 | 20946 | 36810 | 12503 | 2604 | 1136 | 53053 |
| 1982 | 32247 | 7069 | 794 | - | 40110 | 6352 | 6655 | 1943 | 615 | 15565 | 38599 | 13724 | 2737 | 615 | 55675 |
| 1983 | 26817 | 4475 | 671 | - | 31963 | 11280 | 5052 | 1936 | 667 | 18935 | 38097 | 9527 | 2607 | 667 | 50898 |
| 1984 | 37290 | 4123 | 879 | - | 42292 | 3683 | 3512 | 2144 | 473 | 9812 | 40973 | 7635 | 3023 | 473 | 52104 |
| 1985 | 39098 | 7449 | 718 | 44 | 47309 | 3746 | 3386 | 1229 | 883 | 9244 | 42844 | 10835 | 1947 | 927 | 56553 |
| 1986 | 35482 | 8277 | 237 | - | 43996 | 2728 | 3075 | 600 | 1068 | 7471 | 38210 | 11352 | 837 | 1068 | 51467 |
| 1987 | 33139 | 6276 | 311 | 11 | 39737 | 1748 | 2666 | 538 | 741 | 5693 | 34887 | 8942 | 849 | 752 | 45430 |
| 1988 | 26959 | 6077 | 612 | 56 | 33704 | 1124 | 2163 | 382 | 842 | 4453 | 28083 | 8240 | 994 | 898 | 38215 |
| 1989 | 22608 | 6324 | 400 | 40 | 29372 | 3332 | 2983 | 323 | 609 | 7247 | 25940 | 9307 | 723 | 649 | 36619 |
| 1990[1] | 22272 | 3840 | 224 | 4 | 26340 | 2799 | 4027 | 532 | 438 | 7796 | 25071 | 7867 | 756 | 442 | 34136 |
| 1991[1] | 20371 | 3827 | 253 | - | 24451 | 3739 | 3511 | 429 | 568 | 8247 | 24110 | 7338 | 682 | 568 | 32698 |
| 1992[1] | 17941 | 3203 | 170 | - | 21314 | 3596 | 4098 | 506 | 210 | 8410 | 21537 | 7301 | 676 | 210 | 29724 |
| 1993[1] | 1189 | 1071 | 56 | - | 2316 | 174 | 798 | 87 | 59 | 1118 | 1363 | 1869 | 143 | 59 | 3434 |

[1] Preliminary Interzonal data.

Table 3. Domestic quotas and catches from monthly Quota Reports.

| | FG <45 | | FG 45-64 | | MG 45-64 4T, 3Pn | | MG <65 ITQ | | FG 65-100 | | MG 65-100 | | Vessels >100 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Quota | Catch | Quota | Catch | Quota | Catch | Quota | Catch | Quota | Catch | Quota | Catch | Quota | Catch | Quota | Catch |
| Jan. 1 | 1519 | 0 | 620 | 0 | 0 | 0 | 1266 | 0 | 163 | 0 | 195 | 0 | 7237 | 0 | 11000 | 0 |
| Jan. 27 | 1519 | 0 | 620 | 0 | 0 | 0 | 1266 | 0 | 163 | 0 | 195 | 0 | 7237 | 18 | 11000 | 18 |
| Feb. 24 | 1519 | 0 | 620 | 0 | 0 | 0 | 1251 | 15 | 503 | 44 | 145 | 0 | 7047 | 86 | 11000 | 145 |
| Mar. 31 | 1519 | 1 | 620 | 25 | 0 | 0 | 1266 | 16 | 503 | 115 | 145 | 0 | 7047 | 226 | 11000 | 383 |
| May 5 | 1519 | 51 | 620 | 72 | 0 | 0 | 1266 | 48 | 503 | 232 | 340 | 75 | 6852 | 536 | 11000 | 1014 |
| June 2 | 1519 | 91 | 620 | 112 | 0 | 0 | 1266 | 99 | 533 | 410 | 340 | 132 | 6722 | 689 | 11000 | 1533 |
| July 7[1] | 1519 | 169 | 620 | 175 | 13 | 0 | 1250 | 156 | 583 | 392 | 340 | 132 | 6672 | 654 | 10997 | 1678 |
| Aug. 4 | 1519 | 421 | 620 | 216 | 13 | 0 | 1250 | 209 | 783 | 443 | 340 | 134 | 6472 | 731 | 10997 | 2154 |
| Sept. 1[2] | 1519 | 756 | 620 | 271 | 13 | 0 | 1250 | 349 | 836 | 492 | 330 | 209 | 6429 | 808 | 10997 | 2885 |
| Oct. 6 | 1519 | 933 | 620 | 327 | 13 | 0 | 1250 | 455 | 836 | 466 | 330 | 211 | 6429 | 807 | 10997 | 3199 |
| Nov. 4 | 1519 | 969 | 620 | 327 | 13 | 0 | 1250 | 457 | 836 | 466 | 330 | 212 | 6429 | 806 | 10997 | 3237 |
| Dec. 8 | 1519 | 997 | 620 | 280 | 13 | 0 | 1250 | 450 | 836 | 453 | 330 | 212 | 6429 | 797 | 10997 | 3189 |
| Dec. 31 | 1519 | 1033 | 620 | 280 | 13 | 0 | 1250 | 450 | 836 | 453 | 330 | 212 | 6429 | 810 | 10997 | 3238 |

[1] July 7 - FG <45' quota split into 6 portions: Jan. 1 to May 14 - 167mt; May 15 to June 30 - 300mt; July 1 to Aug. 15 - 300mt; Aug. 16 to Sept. 30 - 300mt; Oct. 1 to Dec. 31 - 300mt; Reserve - 152mt.

[2] As of Sept. 2 the fishery was closed for all gear sectors. Bycatch limits of 5-10% were permitted while directing for other species.

Table 4(a). Data used to calculate 1993 4VsW cod commercial catch at age.

| Key | Gear | Period[1] | Length/weight coefficients a | b | Source | Lengths | Aged | Catch |
|---|---|---|---|---|---|---|---|---|
| 1 | Mobile TC4+ | FY | .0063 | 3.0863 | March 4Vs | 1523 | 306 | 948 |
| 2 | Mobile TC1-3 | FY | .0087 | 3.0063 | July 4VsW | 4402 | 313 | 597 |
| 3 | LL, LHP | FY | .0087 | 3.0063 | July 4VsW | 4902 | 461 | 1870 |

[1] All age/length keys are full year (FY) periods. Available sampling did not allow for keys to be generated for more specific periods.

Table 4(b). Recalculated 4VsW cod catch at age ('000) by key for 1990.

| Age | Mobile TC4+ | Mobile TC1-3 | LL,LHP | Total |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 |
| 3 | 2 | 2 | 27 | 31 |
| 4 | 40 | 135 | 244 | 419 |
| 5 | 69 | 135 | 389 | 593 |
| 6 | 196 | 98 | 449 | 743 |
| 7 | 167 | 74 | 262 | 503 |
| 8 | 44 | 18 | 64 | 126 |
| 9 | 21 | 2 | 20 | 43 |
| 10 | 6 | 0 | 2 | 8 |
| 11 | 4 | 0 | 3 | 7 |
| 12 | 2 | 0 | 2 | 4 |
| 13 | 1 | 0 | 1 | 2 |
| 14 | 0 | 0 | 1 | 1 |
| 15 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 |
| Total | 552 | 464 | 1464 | 2480 |

Table 5. Commercial 4VsW cod catch at age (000's). (4TVn component included.)

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1293 | 1994 | 2046 | 1218 | 1273 | 1538 | 513 | 1 | 34 | 12 | 31 | 3 | 3 |
| 2 | 8631 | 12824 | 15865 | 10221 | 7321 | 8571 | 2866 | 23 | 94 | 93 | 92 | 258 | 138 |
| 3 | 8886 | 9643 | 11801 | 8001 | 13324 | 7402 | 2860 | 532 | 1168 | 1762 | 1765 | 3200 | 2473 |
| 4 | 14802 | 5125 | 11989 | 5803 | 11695 | 3163 | 4707 | 1229 | 4078 | 6559 | 4873 | 9136 | 7667 |
| 5 | 13673 | 6612 | 7384 | 9634 | 6854 | 4788 | 3900 | 1591 | 4817 | 9525 | 6937 | 7281 | 10123 |
| 6 | 4539 | 5128 | 6527 | 3324 | 2247 | 3297 | 2085 | 845 | 2582 | 5056 | 6177 | 4651 | 3681 |
| 7 | 1942 | 3419 | 3308 | 3370 | 669 | 2943 | 1287 | 490 | 767 | 1210 | 3050 | 2957 | 2568 |
| 8 | 759 | 1963 | 1880 | 4732 | 1008 | 623 | 447 | 199 | 247 | 377 | 1121 | 1421 | 1315 |
| 9 | 236 | 704 | 347 | 1684 | 196 | 497 | 136 | 118 | 107 | 76 | 313 | 397 | 679 |
| 10 | 72 | 367 | 466 | 389 | 153 | 686 | 53 | 33 | 75 | 23 | 92 | 135 | 318 |
| 11 | 137 | 159 | 68 | 551 | 13 | 172 | 12 | 42 | 31 | 10 | 50 | 69 | 153 |
| 12 | 56 | 173 | 3 | 8 | 2 | 123 | 47 | 44 | 27 | 4 | 26 | 32 | 65 |
| 13 | 9 | 156 | 36 | 21 | 0 | 41 | 0 | 11 | 28 | 3 | 4 | 22 | 54 |
| 14 | 12 | 80 | 0 | 21 | 0 | 6 | 4 | 3 | 10 | 0 | 0 | 2 | 55 |
| 15 | 4 | 40 | 3 | 18 | 0 | 6 | 0 | 2 | 1 | 0 | 1 | 5 | 19 |
| 16 | 4 | 52 | 7 | 47 | 0 | 19 | 2 | 6 | 2 | 0 | 7 | 2 | 19 |
| 1+ | 55055 | 48429 | 61735 | 49042 | 44755 | 33875 | 18919 | 5169 | 14068 | 24710 | 24539 | 29571 | 29330 |
| 2+ | 53762 | 46445 | 59689 | 47824 | 43482 | 32337 | 18406 | 5168 | 14034 | 24698 | 24508 | 29568 | 29327 |
| 3+ | 45131 | 33621 | 43824 | 37603 | 36161 | 23766 | 15540 | 5145 | 13940 | 24605 | 24416 | 29310 | 29189 |
| 4+ | 36245 | 23978 | 32023 | 29602 | 22837 | 16364 | 12680 | 4613 | 12772 | 22843 | 22651 | 26110 | 26716 |
| 5+ | 21443 | 18853 | 20034 | 23799 | 11142 | 13201 | 7973 | 3384 | 8694 | 16284 | 17778 | 16974 | 19049 |
| 6+ | 7770 | 12241 | 12650 | 14165 | 4288 | 8413 | 4073 | 1793 | 3877 | 6759 | 10841 | 9693 | 8926 |

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 6 | 1 | 4 | 3 | 0 | 8 | 7 | 0 | 1 | 2 | 0 |
| 3 | 3507 | 430 | 156 | 124 | 38 | 185 | 671 | 291 | 277 | 571 | 32 |
| 4 | 8679 | 5778 | 2253 | 4210 | 877 | 1512 | 2544 | 2329 | 3365 | 2541 | 427 |
| 5 | 7484 | 9101 | 8151 | 7640 | 5694 | 2399 | 4111 | 3983 | 6790 | 9251 | 605 |
| 6 | 6278 | 5678 | 7523 | 9221 | 5885 | 4531 | 3334 | 3659 | 4486 | 6080 | 758 |
| 7 | 1905 | 3829 | 4284 | 3589 | 6049 | 4075 | 3669 | 2208 | 3348 | 2125 | 513 |
| 8 | 1012 | 1250 | 2430 | 1571 | 2733 | 3295 | 1796 | 3212 | 1332 | 1401 | 129 |
| 9 | 625 | 544 | 1063 | 1123 | 1105 | 1731 | 2018 | 1600 | 1356 | 521 | 44 |
| 10 | 224 | 290 | 452 | 447 | 604 | 626 | 590 | 1879 | 861 | 471 | 8 |
| 11 | 149 | 153 | 284 | 285 | 233 | 260 | 251 | 328 | 457 | 231 | 7 |
| 12 | 52 | 63 | 173 | 105 | 131 | 153 | 156 | 135 | 154 | 178 | 4 |
| 13 | 24 | 34 | 68 | 66 | 61 | 64 | 29 | 55 | 65 | 33 | 2 |
| 14 | 15 | 17 | 20 | 11 | 11 | 9 | 15 | 15 | 10 | 7 | 1 |
| 15 | 6 | 8 | 17 | 19 | 14 | 10 | 58 | 14 | 6 | 6 | 0 |
| 16 | 11 | 5 | 15 | 18 | 12 | 11 | 35 | 13 | 5 | 7 | 0 |
| 1+ | 29977 | 27181 | 26893 | 28432 | 23447 | 18869 | 19284 | 19721 | 22513 | 23425 | 2530 |
| 2+ | 29977 | 27181 | 26893 | 28432 | 23447 | 18869 | 19284 | 19721 | 22513 | 23425 | 2530 |
| 3+ | 29971 | 27180 | 26889 | 28429 | 23447 | 18861 | 19277 | 19721 | 22512 | 23423 | 2530 |
| 4+ | 26464 | 26750 | 26733 | 28305 | 23409 | 18676 | 18606 | 19430 | 22235 | 22852 | 2498 |
| 5+ | 17785 | 20972 | 24480 | 24095 | 22532 | 17164 | 16062 | 17101 | 18870 | 20311 | 2071 |
| 6+ | 10301 | 11871 | 16329 | 16455 | 16838 | 14765 | 11951 | 13118 | 12080 | 11060 | 1466 |

Table 6. Estimated contribution of 4TVn fish in the catch at age (000's).

| | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 8 | 0 | 0 | 0 | 3 | 3 | 0 |
| 4 | 121 | 62 | 5 | 0 | 65 | 128 | 137 | 0 |
| 5 | 542 | 294 | 391 | 45 | 94 | 495 | 1019 | 0 |
| 6 | 1637 | 518 | 611 | 201 | 1082 | 897 | 163 | 0 |
| 7 | 221 | 584 | 579 | 353 | 602 | 2740 | 435 | 0 |
| 8 | 213 | 97 | 513 | 552 | 276 | 703 | 749 | 0 |
| 9 | 201 | 177 | 277 | 664 | 709 | 1029 | 336 | 0 |
| 10 | 108 | 112 | 155 | 106 | 828 | 800 | 186 | 0 |
| 11 | 96 | 13 | 0 | 49 | 5 | 25 | 147 | 0 |
| 12 | 24 | 9 | 1 | 118 | 0 | 85 | 70 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3+ | 3163 | 1874 | 2532 | 2088 | 3661 | 6905 | 3265 | 0 |
| 4+ | 3163 | 1866 | 2532 | 2088 | 3661 | 6902 | 3262 | 0 |
| 5+ | 3042 | 1804 | 2527 | 2088 | 3596 | 6774 | 3125 | 0 |
| 6+ | 2500 | 1510 | 2136 | 2043 | 3502 | 6279 | 2106 | 0 |
| Total Weight in mt. | 3469 | 2029 | 2496 | 2574 | 4606 | 8761 | 4358 | 0 |

Table 7. 4VsW cod weights at age from commercial landings.

| | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| 2 | .53 | .79 | .49 | .43 | .00 | .00 | .00 | .61 | .57 | .59 | .60 | .55 | .47 |
| 3 | .76 | 1.01 | .96 | .79 | .71 | .79 | .80 | .96 | .69 | .81 | .81 | .77 | .78 |
| 4 | 1.08 | 1.15 | .94 | 1.19 | .85 | 1.05 | 1.11 | 1.21 | .96 | 1.16 | 1.12 | 1.04 | 1.04 |
| 5 | 1.45 | 1.39 | 1.17 | 1.74 | 1.36 | 1.50 | 1.72 | 1.63 | 1.57 | 1.60 | 1.68 | 1.53 | 1.53 |
| 6 | 1.80 | 1.84 | 1.64 | 2.17 | 1.88 | 2.26 | 2.40 | 2.33 | 2.30 | 2.22 | 2.12 | 2.33 | 2.13 |
| 7 | 2.28 | 2.29 | 2.29 | 2.59 | 2.34 | 3.33 | 3.15 | 3.39 | 3.08 | 3.10 | 2.96 | 2.73 | 3.09 |
| 8 | 3.50 | 2.88 | 2.28 | 2.47 | 2.94 | 4.37 | 4.47 | 4.76 | 3.72 | 4.26 | 3.90 | 3.99 | 3.55 |
| 9 | 4.87 | 4.92 | 2.64 | 3.24 | 3.69 | 4.85 | 4.04 | 5.34 | 4.90 | 5.38 | 5.69 | 5.34 | 4.38 |
| 10 | 5.70 | 4.56 | 4.27 | 3.62 | 3.72 | 5.57 | 5.29 | 6.19 | 6.39 | 6.96 | 7.02 | 6.84 | 5.79 |
| 11 | 5.70 | 7.57 | 3.85 | 4.87 | 4.79 | 7.39 | 4.73 | 7.91 | 7.25 | 7.42 | 7.68 | 8.53 | 6.84 |
| 12 | 8.74 | 11.56 | 9.48 | 9.58 | 5.46 | 3.38 | 4.92 | 8.57 | 10.11 | 10.01 | 9.45 | 8.88 | 9.16 |
| 13 | 6.77 | 6.31 | 7.05 | .00 | 8.24 | 14.23 | 6.57 | 9.61 | 13.95 | 8.75 | 12.05 | 10.90 | 10.64 |
| 14 | 5.92 | .00 | 9.06 | .00 | 12.10 | 11.54 | 8.85 | 10.30 | 10.26 | 10.53 | 8.48 | 10.43 | 11.73 |
| 15 | 9.27 | 14.49 | 10.98 | .00 | 12.78 | 22.97 | 10.52 | 8.37 | 11.97 | 13.97 | 9.80 | 13.34 | 14.07 |
| 16 | 6.03 | 8.73 | 9.61 | .00 | 8.13 | 15.50 | 12.27 | 12.04 | 12.89 | 17.80 | 17.77 | 14.92 | 13.55 |

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| 2 | .54 | .68 | .27 | .00 | .35 | .29 | .00 | .46 | .19 | .00 |
| 3 | .74 | .71 | .68 | .48 | .63 | .77 | .75 | .77 | .63 | .57 |
| 4 | 1.06 | 1.03 | .95 | .93 | .97 | 1.01 | 1.00 | .88 | .79 | .86 |
| 5 | 1.50 | 1.45 | 1.26 | 1.28 | 1.26 | 1.28 | 1.23 | 1.14 | 1.01 | 1.05 |
| 6 | 2.06 | 1.97 | 1.65 | 1.54 | 1.73 | 1.56 | 1.40 | 1.46 | 1.31 | 1.39 |
| 7 | 2.69 | 2.38 | 2.38 | 1.87 | 1.92 | 2.19 | 1.68 | 1.57 | 1.76 | 1.79 |
| 8 | 3.64 | 3.10 | 2.74 | 2.61 | 2.37 | 2.21 | 2.27 | 1.96 | 1.84 | 2.21 |
| 9 | 4.03 | 3.84 | 3.67 | 3.58 | 2.79 | 2.50 | 2.18 | 2.37 | 1.96 | 4.05 |
| 10 | 5.19 | 5.03 | 4.99 | 4.31 | 3.67 | 3.93 | 2.17 | 2.29 | 2.72 | 3.71 |
| 11 | 7.09 | 6.32 | 5.30 | 6.49 | 4.92 | 5.10 | 4.38 | 2.89 | 2.49 | 7.75 |
| 12 | 8.44 | 6.13 | 6.87 | 6.32 | 7.06 | 5.16 | 6.19 | 3.53 | 2.60 | 4.78 |
| 13 | 9.28 | 9.38 | 10.18 | 7.23 | 7.65 | 8.55 | 8.49 | 4.14 | 5.67 | 11.02 |
| 14 | 10.58 | 11.12 | 9.57 | 11.68 | 11.17 | 12.28 | 12.33 | 12.98 | 13.53 | 13.44 |
| 15 | 12.63 | 11.12 | 11.89 | 12.69 | 12.16 | 7.87 | 10.38 | 9.18 | 12.83 | 14.27 |
| 16 | 13.21 | 14.49 | 14.52 | 13.19 | 14.76 | 15.38 | 11.41 | 10.75 | 12.97 | 16.01 |

Table 8. Standardized catch and effort for 4VsW cod from NAFO and ZIFF Data.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... .604
MULTIPLE R SQUARED.... .365

ANALYSIS OF VARIANCE

| SOURCE OF VARIATION | DF | SUMS OF SQUARES | MEAN SQUARES | F-VALUE |
|---|---|---|---|---|
| INTERCEPT | 1 | 1.620E0002 | 1.620E0002 | |
| REGRESSION | 44 | 3.385E0002 | 7.694E0000 | 21.219 |
| TYPE 1 | 9 | 1.576E0002 | 1.752E0001 | 48.304 |
| TYPE 2 | 1 | 3.187E0000 | 3.187E0000 | 8.790 |
| TYPE 3 | 11 | 9.430E0001 | 7.663E0000 | 21.134 |
| TYPE 4 | 23 | 1.856E0002 | 3.069E0000 | 22.254 |
| RESIDUALS | 1622 | 5.882E0002 | 3.626E-001 | |
| TOTAL | 1667 | 1.089E0003 | | |

PREDICTED CATCH RATE

STANDARDS USED VARIABLE NUMBERS: 5 1 1

| YEAR | TOTAL CATCH | PROP. | CATCH RATE MEAN | S. E. | EFFORT |
|---|---|---|---|---|---|
| 70 | 57434 | 0.744 | 0.962 | 0.096 | 59720 |
| 71 | 52563 | 0.685 | 0.721 | 0.070 | 72888 |
| 72 | 64645 | 0.597 | 0.781 | 0.072 | 78888 |
| 73 | 54093 | 0.688 | 0.758 | 0.070 | 71378 |
| 74 | 43741 | 0.706 | 0.662 | 0.062 | 66123 |
| 75 | 32517 | 0.571 | 0.475 | 0.048 | 68430 |
| 76 | 24407 | 0.578 | 0.653 | 0.063 | 37387 |
| 77 | 10390 | 0.286 | 0.713 | 0.083 | 14564 |
| 78 | 25405 | 0.529 | 1.435 | 0.143 | 17701 |
| 79 | 40030 | 0.631 | 1.873 | 0.183 | 21367 |
| 80 | 49252 | 0.598 | 1.343 | 0.124 | 36684 |
| 81 | 53718 | 0.587 | 1.360 | 0.120 | 39511 |
| 82 | 55754 | 0.643 | 1.628 | 0.140 | 34247 |
| 83 | 52380 | 0.652 | 1.621 | 0.144 | 32312 |
| 84 | 52546 | 0.719 | 1.787 | 0.161 | 29401 |
| 85 | 57455 | 0.606 | 2.259 | 0.204 | 25432 |
| 86 | 51529 | 0.571 | 2.282 | 0.206 | 22583 |
| 87 | 45503 | 0.594 | 1.653 | 0.155 | 27534 |
| 88 | 38356 | 0.588 | 1.464 | 0.135 | 26206 |
| 89 | 36743 | 0.555 | 1.505 | 0.140 | 24419 |
| 90 | 34334 | 0.540 | 1.880 | 0.176 | 18265 |
| 91 | 32915 | 0.618 | 1.407 | 0.134 | 23390 |
| 92 | 29805 | 0.636 | 1.577 | 0.154 | 18899 |
| 93 | 3474 | 0.239 | 0.764 | 0.118 | 4549 |

AVERAGE C.V. FOR THE MEAN: .097

Table 9. Standardized catch and effort for 4VsW cod from IOP data.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... .683
MULTIPLE R SQUARED.... .467

ANALYSIS OF VARIANCE

| SOURCE OF VARIATION | DF | SUMS OF SQUARES | MEAN SQUARES | F-VALUE |
|---|---|---|---|---|
| INTERCEPT | 1 | 3.094E-001 | 3.094E-001 | |
| REGRESSION | 24 | 9.315E0001 | 3.881E0000 | 7.251 |
| TYPE 1 | 11 | 2.888E0001 | 2.626E0000 | 4.905 |
| TYPE 2 | 11 | 5.561E0001 | 5.056E0000 | 9.445 |
| TYPE 3 | 2 | 3.884E0000 | 1.942E0000 | 3.628 |
| RESIDUALS | 199 | 1.065E0002 | 5.353E-001 | |
| TOTAL | 224 | 2.000E0002 | | |

PREDICTED CATCH RATE

STANDARDS USED VARIABLE NUMBERS: 1 5

| YEAR | TOTAL CATCH | PROP. | CATCH RATE MEAN | S. E. | EFFORT |
|---|---|---|---|---|---|
| 82 | 55754 | 0.075 | 1.751 | 0.403 | 31835 |
| 83 | 52380 | 0.080 | 1.577 | 0.347 | 33557 |
| 84 | 52546 | 0.125 | 2.957 | 0.658 | 17772 |
| 85 | 57455 | 0.102 | 3.342 | 0.744 | 17193 |
| 86 | 51529 | 0.053 | 2.874 | 0.673 | 17932 |
| 87 | 45503 | 0.073 | 2.669 | 0.619 | 17047 |
| 88 | 38356 | 0.133 | 2.185 | 0.484 | 17551 |
| 89 | 36743 | 0.114 | 2.917 | 0.680 | 12595 |
| 90 | 34334 | 0.241 | 1.897 | 0.426 | 18097 |
| 91 | 32915 | 0.153 | 1.469 | 0.351 | 22414 |
| 92 | 29805 | 0.079 | 1.110 | 0.264 | 26844 |
| 93 | 3474 | 0.073 | 1.023 | 0.254 | 3396 |

AVERAGE C.V. FOR THE MEAN: .230

Table 10. 4VsW cod July survey mean catch at age per tow.

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .03 | .01 | .00 | .00 | .25 | .02 | .00 | .00 | .05 | .29 | .01 | .02 | .00 |
| 1 | .42 | .44 | 1.78 | 1.84 | 1.48 | .95 | .67 | .21 | .88 | .35 | .20 | 1.33 | .73 |
| 2 | 4.73 | 2.20 | 2.77 | 12.59 | 9.45 | 2.43 | 3.70 | 2.75 | 3.75 | 3.04 | 2.01 | 3.65 | 62.94 |
| 3 | 1.66 | 10.22 | 3.41 | 19.79 | 5.53 | 3.76 | 4.22 | 6.97 | 8.96 | 4.60 | 5.31 | 5.53 | 52.60 |
| 4 | 2.58 | 2.30 | 9.04 | 16.07 | 1.62 | 1.76 | 2.60 | 4.53 | 9.80 | 4.76 | 2.94 | 8.44 | 18.37 |
| 5 | 1.28 | 4.53 | 1.67 | 6.44 | .58 | .86 | 1.65 | 2.82 | 2.71 | 5.18 | 4.98 | 3.22 | 4.12 |
| 6 | .42 | 1.66 | 1.72 | .53 | .64 | .19 | .32 | 1.24 | 1.00 | 2.59 | 3.47 | 2.31 | 2.23 |
| 7 | .50 | .99 | .46 | .83 | .11 | .23 | .15 | .27 | .25 | .77 | 1.37 | 1.19 | 1.20 |
| 8 | .16 | .42 | .16 | .26 | .13 | .06 | .26 | .18 | .05 | .29 | .37 | .44 | .51 |
| 9 | .03 | .18 | .14 | .12 | .06 | .12 | .00 | .04 | .03 | .12 | .10 | .14 | .11 |
| 10 | .07 | .02 | .04 | .15 | .05 | .01 | .18 | .00 | .02 | .02 | .08 | .16 | .12 |
| 11 | .08 | .04 | .00 | .05 | .02 | .00 | .02 | .03 | .00 | .01 | .03 | .04 | .06 |
| 12 | .03 | .02 | .00 | .00 | .02 | .02 | .00 | .02 | .00 | .00 | .00 | .01 | .00 |
| 13 | .05 | .06 | .00 | .00 | .00 | .00 | .04 | .00 | .00 | .01 | .00 | .01 | .00 |
| 14 | .00 | .00 | .00 | .06 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| 15 | .00 | .00 | .00 | .01 | .02 | .00 | .00 | .00 | .00 | .00 | .00 | .01 | .00 |
| 16 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .02 | .00 | .00 | .00 | .00 |
| 0+ | 12.04 | 23.09 | 21.19 | 58.74 | 19.95 | 10.40 | 13.82 | 19.05 | 27.51 | 22.04 | 20.87 | 26.50 | 143.01 |
| 1+ | 12.01 | 23.08 | 21.19 | 58.74 | 19.70 | 10.38 | 13.82 | 19.05 | 27.46 | 21.74 | 20.85 | 26.47 | 143.00 |
| 2+ | 11.59 | 22.64 | 19.41 | 56.90 | 18.22 | 9.44 | 13.15 | 18.84 | 26.59 | 21.40 | 20.66 | 25.15 | 142.27 |
| 3+ | 6.86 | 20.44 | 16.63 | 44.31 | 8.77 | 7.01 | 9.45 | 16.09 | 22.84 | 18.35 | 18.64 | 21.49 | 79.33 |
| 4+ | 5.20 | 10.22 | 13.23 | 24.53 | 3.24 | 3.24 | 5.22 | 9.12 | 13.89 | 13.76 | 13.33 | 15.96 | 26.74 |

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .02 | .07 | .00 | .03 | .04 | .07 | .03 | .00 | .00 | .00 | .01 |
| 1 | 13.72 | .41 | 1.29 | .36 | .64 | .06 | .25 | .13 | .47 | 1.69 | .09 |
| 2 | 13.31 | 7.27 | 1.68 | 1.32 | 1.51 | 4.70 | 8.86 | 5.06 | 1.44 | 5.51 | 1.05 |
| 3 | 44.47 | 12.82 | 7.88 | 1.53 | 4.97 | 7.29 | 7.38 | 18.22 | 2.73 | 6.58 | 6.83 |
| 4 | 19.25 | 19.09 | 9.56 | 6.16 | 4.83 | 5.89 | 5.01 | 8.64 | 5.58 | 3.83 | 7.65 |
| 5 | 9.88 | 12.94 | 9.32 | 3.89 | 8.86 | 3.27 | 3.47 | 3.83 | 3.90 | 2.43 | 5.00 |
| 6 | 4.42 | 6.01 | 5.12 | 3.26 | 3.61 | 3.41 | 1.35 | 1.41 | 1.32 | .81 | 3.04 |
| 7 | .99 | 4.13 | 2.56 | 1.15 | 2.71 | 1.95 | 2.00 | .60 | .39 | .15 | .95 |
| 8 | .55 | .41 | 1.01 | .55 | 1.47 | .98 | .47 | .29 | .20 | .08 | .22 |
| 9 | .14 | .33 | .48 | .24 | .34 | .22 | .32 | .11 | .18 | .03 | .00 |
| 10 | .08 | .10 | .11 | .15 | .02 | .05 | .01 | .07 | .05 | .02 | .01 |
| 11 | .04 | .23 | .11 | .04 | .08 | .12 | .00 | .00 | .05 | .00 | .00 |
| 12 | .02 | .01 | .07 | .00 | .04 | .02 | .02 | .00 | .00 | .00 | .00 |
| 13 | .02 | .01 | .00 | .02 | .01 | .00 | .01 | .00 | .00 | .00 | .00 |
| 14 | .00 | .01 | .00 | .00 | .00 | .02 | .00 | .00 | .00 | .01 | .00 |
| 15 | .00 | .00 | .01 | .00 | .03 | .00 | .00 | .00 | .00 | .00 | .00 |
| 16 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| 0+ | 106.91 | 63.82 | 39.21 | 18.59 | 29.17 | 28.04 | 29.19 | 38.35 | 16.31 | 21.14 | 24.85 |
| 1+ | 106.89 | 63.75 | 39.21 | 18.67 | 29.13 | 27.97 | 29.17 | 38.35 | 16.31 | 21.14 | 24.84 |
| 2+ | 93.16 | 63.35 | 37.92 | 18.31 | 28.48 | 27.92 | 28.92 | 38.22 | 15.94 | 19.45 | 24.75 |
| 3+ | 79.86 | 56.08 | 36.24 | 16.99 | 26.98 | 23.21 | 20.06 | 33.16 | 14.40 | 13.94 | 23.70 |
| 4+ | 35.39 | 43.26 | 28.36 | 15.45 | 22.00 | 15.92 | 12.68 | 14.94 | 11.67 | 7.36 | 16.87 |

Table 11. 4VsW cod Spring survey mean catch at age per tow.

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| 1 | .26 | .86 | 8.25 | 2.65 | .85 | .22 | .00 | .19 | .35 | .60 | .58 | .12 | .02 |
| 2 | 2.12 | 2.71 | 3.80 | 22.22 | 3.17 | 1.49 | .00 | 10.88 | .92 | 7.96 | 17.96 | 1.60 | 3.50 |
| 3 | .89 | 2.04 | 5.29 | 17.91 | 42.14 | 1.85 | .00 | 19.44 | 2.87 | 9.49 | 10.40 | 5.08 | 12.15 |
| 4 | .60 | 1.67 | 7.79 | 11.84 | 25.52 | 9.37 | .00 | 23.58 | 4.50 | 4.26 | 4.23 | 2.56 | 21.92 |
| 5 | 1.37 | 2.52 | 4.87 | 7.24 | 4.96 | 6.21 | .00 | 11.67 | 10.14 | 4.32 | 4.80 | .86 | 5.09 |
| 6 | 1.02 | 2.90 | 5.76 | 1.99 | 5.85 | 2.92 | .00 | 13.13 | 4.82 | 4.88 | 1.68 | .31 | 1.49 |
| 7 | .47 | 1.43 | 3.20 | 1.36 | 1.32 | 2.53 | .00 | 6.27 | 3.32 | 1.43 | .70 | .19 | .35 |
| 8 | .29 | .30 | 1.53 | 1.08 | .62 | .77 | .00 | 1.34 | 1.20 | 1.87 | .22 | .36 | .02 |
| 9 | .07 | .06 | .18 | .28 | .29 | .50 | .00 | .73 | .24 | .46 | .25 | .13 | .10 |
| 10 | .10 | .03 | .14 | .14 | .10 | .20 | .00 | .28 | .10 | .19 | .05 | .12 | .00 |
| 11 | .06 | .01 | .03 | .06 | .04 | .02 | .00 | .04 | .04 | .18 | .03 | .04 | .01 |
| 12 | .02 | .00 | .02 | .03 | .04 | .09 | .00 | .05 | .03 | .04 | .02 | .03 | .00 |
| 13 | .03 | .01 | .00 | .01 | .01 | .00 | .00 | .01 | .03 | .02 | .00 | .01 | .02 |
| 14 | .01 | .00 | .00 | .00 | .04 | .01 | .00 | .01 | .01 | .00 | .01 | .00 | .01 |
| 15 | .01 | .00 | .00 | .01 | .00 | .00 | .00 | .00 | .00 | .03 | .02 | .00 | .00 |
| 16 | .00 | .00 | .00 | .01 | .00 | .02 | .00 | .01 | .00 | .00 | .00 | .00 | .00 |
| 0+ | 7.33 | 14.55 | 40.86 | 66.83 | 84.94 | 26.19 | .00 | 87.62 | 28.56 | 35.75 | 40.94 | 11.42 | 44.69 |
| 1+ | 7.33 | 14.55 | 40.86 | 66.83 | 84.94 | 26.19 | .00 | 87.62 | 28.56 | 35.75 | 40.94 | 11.42 | 44.69 |
| 2+ | 7.07 | 13.68 | 32.62 | 64.18 | 84.09 | 25.97 | .00 | 87.43 | 28.22 | 35.15 | 40.37 | 11.29 | 44.66 |
| 3+ | 4.95 | 10.98 | 28.81 | 41.96 | 80.92 | 24.48 | .00 | 76.55 | 27.30 | 27.18 | 22.41 | 9.69 | 41.16 |
| 4+ | 4.06 | 8.93 | 23.52 | 24.05 | 38.78 | 22.63 | .00 | 57.11 | 24.43 | 17.69 | 12.01 | 4.62 | 29.02 |

| | 1992 | 1993 | 1994 |
|---|---|---|---|
| 0 | .00 | .00 | .00 |
| 1 | .07 | .03 | .10 |
| 2 | .52 | 2.86 | .16 |
| 3 | .25 | 5.62 | .30 |
| 4 | .25 | 3.83 | .83 |
| 5 | .49 | 2.43 | .46 |
| 6 | .31 | 1.08 | .68 |
| 7 | .11 | .16 | .33 |
| 8 | .05 | .08 | .26 |
| 9 | .02 | .01 | .03 |
| 10 | .00 | .00 | .02 |
| 11 | .01 | .00 | .00 |
| 12 | .03 | .00 | .00 |
| 13 | .01 | .00 | .00 |
| 14 | .00 | .00 | .00 |
| 15 | .00 | .00 | .00 |
| 16 | .00 | .00 | .00 |
| 0+ | 2.14 | 16.10 | 3.17 |
| 1+ | 2.14 | 16.10 | 3.17 |
| 2+ | 2.07 | 16.07 | 3.07 |
| 3+ | 1.55 | 13.21 | 2.91 |
| 4+ | 1.30 | 7.59 | 2.61 |

Table 12. VPA estimates of population numbers. (January 1 in thousands)

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 84967 | 84750 | 67000 | 61756 | 74330 | 84686 | 70862 | 66558 | 101969 | 90245 |
| 2 | 80064 | 68395 | 67592 | 53004 | 49459 | 59704 | 67943 | 57553 | 54492 | 83454 |
| 3 | 40548 | 57741 | 44394 | 40984 | 34148 | 33870 | 41126 | 53034 | 47099 | 44529 |
| 4 | 47459 | 25158 | 38549 | 25668 | 26316 | 15902 | 21033 | 31084 | 42939 | 37505 |
| 5 | 39971 | 25463 | 15960 | 20713 | 15765 | 10963 | 10157 | 12961 | 24337 | 31466 |
| 6 | 17292 | 20353 | 14864 | 6386 | 8241 | 6705 | 4644 | 4787 | 9172 | 15567 |
| 7 | 6583 | 10050 | 12024 | 6264 | 2220 | 4714 | 2507 | 1915 | 3155 | 5173 |
| 8 | 3843 | 3632 | 5135 | 6851 | 2079 | 1213 | 1197 | 888 | 1125 | 1889 |
| 9 | 902 | 2460 | 1198 | 2503 | 1328 | 790 | 429 | 575 | 547 | 697 |
| 10 | 375 | 525 | 1377 | 667 | 526 | 910 | 197 | 228 | 364 | 351 |
| 11 | 487 | 242 | 98 | 706 | 194 | 292 | 124 | 114 | 157 | 230 |
| 12 | 321 | 274 | 54 | 19 | 79 | 147 | 83 | 91 | 55 | 101 |
| 13 | 126 | 212 | 68 | 37 | 8 | 63 | 9 | 26 | 34 | 21 |
| 14 | 114 | 95 | 32 | 23 | 11 | 7 | 14 | 7 | 11 | 3 |
| 15 | 9 | 83 | 5 | 26 | 0 | 9 | 0 | 8 | 3 | 0 |
| 1+ | 323061 | 299434 | 268351 | 225608 | 214704 | 219975 | 220325 | 229828 | 285460 | 311230 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 106087 | 112118 | 63401 | 62841 | 26178 | 27117 | 34558 | 45397 | 50740 | 29015 |
| 2 | 73875 | 86829 | 91792 | 51906 | 51450 | 21433 | 22201 | 28293 | 37168 | 41542 |
| 3 | 68242 | 60401 | 70856 | 75028 | 42491 | 42123 | 17544 | 18174 | 23165 | 30423 |
| 4 | 34863 | 54275 | 46556 | 55774 | 58254 | 34400 | 34346 | 14252 | 14853 | 18798 |
| 5 | 24771 | 24134 | 36170 | 31180 | 37811 | 42466 | 26126 | 24420 | 10931 | 10797 |
| 6 | 17143 | 14004 | 13171 | 20454 | 18756 | 22722 | 27393 | 14967 | 15107 | 7133 |
| 7 | 8170 | 8447 | 7257 | 7453 | 11066 | 10218 | 11796 | 15565 | 7398 | 8822 |
| 8 | 3140 | 3929 | 4240 | 3618 | 4378 | 5595 | 4490 | 6610 | 7799 | 2894 |
| 9 | 1205 | 1557 | 1931 | 2281 | 2047 | 2454 | 2382 | 2447 | 3027 | 3868 |
| 10 | 502 | 704 | 915 | 967 | 1302 | 1183 | 1047 | 1116 | 1164 | 1163 |
| 11 | 266 | 328 | 454 | 462 | 589 | 804 | 560 | 551 | 469 | 527 |
| 12 | 180 | 173 | 206 | 233 | 243 | 344 | 401 | 287 | 252 | 148 |
| 13 | 79 | 124 | 113 | 110 | 144 | 142 | 125 | 255 | 125 | 69 |
| 14 | 14 | 61 | 81 | 43 | 68 | 87 | 55 | 43 | 154 | 44 |
| 15 | 2 | 12 | 48 | 17 | 22 | 40 | 53 | 35 | 25 | 118 |
| 1+ | 338542 | 367094 | 337192 | 312367 | 254800 | 211129 | 183077 | 172414 | 172375 | 155360 |

| | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|
| 1 | 24834 | 54791 | 0 | 0 |
| 2 | 23756 | 20333 | 44859 | 0 |
| 3 | 34006 | 19450 | 16646 | 36726 |
| 4 | 24301 | 27578 | 15676 | 13115 |
| 5 | 13089 | 17848 | 19650 | 10659 |
| 6 | 5161 | 7197 | 8917 | 8640 |
| 7 | 3005 | 1893 | 2645 | 1964 |
| 8 | 4222 | 1007 | 1000 | 636 |
| 9 | 1243 | 800 | 255 | 229 |
| 10 | 1942 | 212 | 359 | 42 |
| 11 | 514 | 639 | 118 | 36 |
| 12 | 248 | 129 | 132 | 21 |
| 13 | 87 | 81 | 43 | 10 |
| 14 | 30 | 22 | 8 | 5 |
| 15 | 23 | 11 | 9 | 0 |
| 1+ | 136461 | 151990 | 110317 | 72083 |

Table 13. Fishing mortality at age from VPA

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.00 |
| 2 | 0.13 | 0.23 | 0.30 | 0.24 | 0.18 | 0.17 | 0.05 | 0.00 |
| 3 | 0.28 | 0.20 | 0.35 | 0.24 | 0.56 | 0.28 | 0.08 | 0.01 |
| 4 | 0.42 | 0.26 | 0.42 | 0.29 | 0.68 | 0.25 | 0.28 | 0.04 |
| 5 | 0.47 | 0.34 | 0.72 | 0.72 | 0.65 | 0.66 | 0.55 | 0.15 |
| 6 | 0.34 | 0.33 | 0.66 | 0.86 | 0.36 | 0.78 | 0.69 | 0.22 |
| 7 | 0.39 | 0.47 | 0.36 | 0.90 | 0.40 | 1.17 | 0.84 | 0.33 |
| 8 | 0.25 | 0.91 | 0.52 | 1.44 | 0.77 | 0.84 | 0.53 | 0.28 |
| 9 | 0.34 | 0.38 | 0.39 | 1.36 | 0.18 | 1.19 | 0.43 | 0.26 |
| 10 | 0.24 | 1.48 | 0.47 | 1.04 | 0.39 | 1.79 | 0.35 | 0.17 |
| 11 | 0.37 | 1.30 | 1.45 | 1.99 | 0.08 | 1.05 | 0.11 | 0.53 |
| 12 | 0.21 | 1.19 | 0.18 | 0.64 | 0.03 | 2.60 | 0.98 | 0.77 |
| 13 | 0.08 | 1.68 | 0.88 | 0.98 | 0.00 | 1.27 | 0.00 | 0.64 |
| 14 | 0.12 | 2.66 | 0.00 | 5.25 | 0.00 | 3.99 | 0.36 | 0.60 |
| 15 | 0.65 | 0.75 | 0.91 | 1.33 | 1.03 | 1.19 | 0.89 | 0.31 |
| 7-9 | 0.33 | 0.59 | 0.42 | 1.23 | 0.45 | 1.07 | 0.60 | 0.29 |
| 3-13 | 0.31 | 0.78 | 0.58 | 0.95 | 0.37 | 1.08 | 0.44 | 0.31 |

| | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.03 | 0.04 | 0.03 | 0.06 | 0.04 | 0.05 | 0.01 | 0.00 |
| 4 | 0.11 | 0.21 | 0.17 | 0.21 | 0.20 | 0.19 | 0.12 | 0.08 |
| 5 | 0.25 | 0.41 | 0.37 | 0.41 | 0.37 | 0.31 | 0.31 | 0.24 |
| 6 | 0.37 | 0.44 | 0.51 | 0.46 | 0.37 | 0.41 | 0.41 | 0.46 |
| 7 | 0.31 | 0.30 | 0.53 | 0.49 | 0.50 | 0.33 | 0.48 | 0.62 |
| 8 | 0.28 | 0.25 | 0.50 | 0.51 | 0.42 | 0.37 | 0.38 | 0.65 |
| 9 | 0.24 | 0.13 | 0.34 | 0.33 | 0.49 | 0.36 | 0.35 | 0.65 |
| 10 | 0.26 | 0.08 | 0.23 | 0.24 | 0.48 | 0.30 | 0.28 | 0.55 |
| 11 | 0.25 | 0.05 | 0.23 | 0.26 | 0.47 | 0.44 | 0.34 | 0.49 |
| 12 | 0.78 | 0.04 | 0.17 | 0.23 | 0.43 | 0.28 | 0.34 | 0.81 |
| 13 | 2.29 | 0.18 | 0.06 | 0.22 | 0.76 | 0.28 | 0.30 | 0.75 |
| 14 | 4.51 | 0.00 | 0.00 | 0.04 | 1.38 | 0.48 | 0.32 | 0.29 |
| 15 | 0.40 | 0.50 | 0.63 | 0.64 | 0.57 | 0.50 | 0.51 | 0.61 |
| 7-9 | 0.28 | 0.23 | 0.46 | 0.44 | 0.47 | 0.35 | 0.40 | 0.64 |
| 3-13 | 0.47 | 0.19 | 0.29 | 0.31 | 0.41 | 0.30 | 0.30 | 0.48 |

| | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.01 | 0.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.04 | 0.00 |
| 4 | 0.14 | 0.07 | 0.12 | 0.16 | 0.11 | 0.14 | 0.19 | 0.04 |
| 5 | 0.36 | 0.28 | 0.23 | 0.54 | 0.40 | 0.49 | 0.62 | 0.06 |
| 6 | 0.37 | 0.50 | 0.34 | 0.66 | 0.80 | 0.80 | 1.31 | 0.10 |
| 7 | 0.38 | 0.49 | 0.74 | 0.54 | 0.89 | 0.44 | 1.22 | 0.34 |
| 8 | 0.41 | 0.58 | 0.50 | 0.64 | 1.46 | 1.17 | 1.27 | 0.25 |
| 9 | 0.56 | 0.54 | 0.76 | 0.49 | 1.57 | 0.60 | 1.61 | 0.24 |
| 10 | 0.44 | 0.67 | 0.59 | 0.62 | 0.91 | 0.38 | 2.09 | 0.24 |
| 11 | 0.47 | 0.58 | 0.95 | 0.55 | 1.19 | 1.38 | 1.54 | 0.24 |
| 12 | 0.25 | 0.63 | 1.10 | 0.33 | 0.92 | 0.90 | 2.34 | 0.24 |
| 13 | 0.88 | 0.31 | 0.84 | 0.63 | 1.20 | 2.15 | 1.91 | 0.24 |
| 14 | 0.25 | 0.34 | 0.07 | 0.47 | 0.81 | 0.72 | 4.15 | 0.24 |
| 15 | 0.50 | 0.58 | 0.58 | 0.77 | 1.10 | 0.92 | 1.39 | 0.24 |
| 7-9 | 0.45 | 0.54 | 0.67 | 0.56 | 1.31 | 0.74 | 1.37 | 0.28 |
| 3-13 | 0.39 | 0.42 | 0.56 | 0.47 | 0.86 | 0.77 | 1.29 | 0.18 |

Table 14. Biomass at age from VPA. (January 1 in kilotons)

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.7 | 3.7 | 2.4 | 2.8 | 3.6 | 5.7 | 4.8 | 4.5 | 4.1 | 3.8 |
| 2 | 35.4 | 15.7 | 19.0 | 11.7 | 10.3 | 8.9 | 10.1 | 8.5 | 13.5 | 19.9 |
| 3 | 25.9 | 36.6 | 32.5 | 35.7 | 21.2 | 18.7 | 17.1 | 22.2 | 21.6 | 28.9 |
| 4 | 44.2 | 22.8 | 36.0 | 25.0 | 28.1 | 13.0 | 18.2 | 29.1 | 42.2 | 36.0 |
| 5 | 52.0 | 31.9 | 19.6 | 24.0 | 20.2 | 13.9 | 11.5 | 17.4 | 32.7 | 43.4 |
| 6 | 27.7 | 32.9 | 24.3 | 9.6 | 13.1 | 12.1 | 8.1 | 9.1 | 18.4 | 30.1 |
| 7 | 12.1 | 20.4 | 24.4 | 12.9 | 4.6 | 10.6 | 6.3 | 5.1 | 9.0 | 13.9 |
| 8 | 11.4 | 10.3 | 13.2 | 15.7 | 4.9 | 3.3 | 3.8 | 3.4 | 4.4 | 6.7 |
| 9 | 4.1 | 10.2 | 4.9 | 6.9 | 3.6 | 2.4 | 1.6 | 2.4 | 2.7 | 3.4 |
| 10 | 2.1 | 2.8 | 6.5 | 3.0 | 1.6 | 3.2 | 0.9 | 1.2 | 1.8 | 2.0 |
| 11 | 2.2 | 1.4 | 0.6 | 3.0 | 0.9 | 1.2 | 0.7 | 0.6 | 1.0 | 1.5 |
| 12 | 3.2 | 1.9 | 0.4 | 0.2 | 0.5 | 0.8 | 0.3 | 0.5 | 0.4 | 0.9 |
| 13 | 0.9 | 1.6 | 0.5 | 0.3 | 0.0 | 0.6 | 0.1 | 0.1 | 0.2 | 0.2 |
| 14 | 0.5 | 0.6 | 0.0 | 0.2 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 |
| 15 | 0.1 | 0.6 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 1+ | 225.5 | 193.3 | 184.4 | 151.0 | 112.6 | 94.4 | 83.6 | 104.4 | 152.1 | 190.8 |
| 6+ | 64.3 | 82.6 | 74.9 | 51.7 | 29.3 | 34.2 | 22.0 | 22.6 | 37.9 | 58.8 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.4 | 4.6 | 2.7 | 2.9 | 1.1 | 1.0 | 2.1 | 3.1 | 2.7 | 1.7 |
| 2 | 17.9 | 21.3 | 21.5 | 11.3 | 12.0 | 5.6 | 3.6 | 4.2 | 7.0 | 7.1 |
| 3 | 46.4 | 41.8 | 48.2 | 49.1 | 25.1 | 26.1 | 11.9 | 6.5 | 8.6 | 15.8 |
| 4 | 31.2 | 51.7 | 42.7 | 49.9 | 53.0 | 30.0 | 28.2 | 11.3 | 10.1 | 15.0 |
| 5 | 30.7 | 33.7 | 47.3 | 39.3 | 47.2 | 52.6 | 29.8 | 26.9 | 11.8 | 12.0 |
| 6 | 32.0 | 25.8 | 26.1 | 36.9 | 33.3 | 39.1 | 42.4 | 20.8 | 22.5 | 10.0 |
| 7 | 21.8 | 21.7 | 17.5 | 20.0 | 26.5 | 22.6 | 25.5 | 27.3 | 12.7 | 17.2 |
| 8 | 11.4 | 13.7 | 14.6 | 11.3 | 14.7 | 16.2 | 11.5 | 16.5 | 16.4 | 6.0 |
| 9 | 5.4 | 7.7 | 8.8 | 9.5 | 7.7 | 9.2 | 8.0 | 7.7 | 8.2 | 9.4 |
| 10 | 2.9 | 4.3 | 5.7 | 5.4 | 6.2 | 5.3 | 4.6 | 4.4 | 4.2 | 3.9 |
| 11 | 1.8 | 2.4 | 3.5 | 3.2 | 3.8 | 4.6 | 2.9 | 3.1 | 2.2 | 2.3 |
| 12 | 1.5 | 1.4 | 1.7 | 2.1 | 1.8 | 2.3 | 2.6 | 1.7 | 1.7 | 0.7 |
| 13 | 0.7 | 1.4 | 1.1 | 1.1 | 1.3 | 1.3 | 1.0 | 1.8 | 0.9 | 0.5 |
| 14 | 0.2 | 0.5 | 0.9 | 0.5 | 0.7 | 0.9 | 0.5 | 0.5 | 1.4 | 0.4 |
| 15 | 0.0 | 0.1 | 0.5 | 0.2 | 0.3 | 0.4 | 0.6 | 0.4 | 0.3 | 1.1 |
| 1+ | 208.4 | 231.9 | 242.9 | 242.6 | 234.7 | 217.2 | 175.3 | 136.3 | 110.7 | 103.1 |
| 6+ | 77.8 | 78.9 | 80.4 | 90.1 | 96.4 | 101.8 | 99.7 | 84.2 | 70.4 | 51.5 |

| | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|
| 1 | 1.7 | 2.6 | 0.0 | 0.0 |
| 2 | 3.5 | 4.4 | 6.2 | 0.0 |
| 3 | 16.0 | 8.0 | 9.0 | 12.1 |
| 4 | 21.3 | 22.6 | 12.2 | 9.7 |
| 5 | 14.6 | 19.1 | 18.5 | 9.7 |
| 6 | 6.9 | 9.6 | 10.9 | 10.2 |
| 7 | 4.9 | 2.8 | 4.2 | 3.0 |
| 8 | 9.4 | 1.8 | 1.7 | 1.3 |
| 9 | 2.7 | 1.9 | 0.5 | 0.6 |
| 1 | 4.5 | 0.5 | 0.9 | 0.1 |
| 1 | 2.1 | 1.6 | 0.3 | 0.2 |
| 1 | 1.4 | 0.5 | 0.4 | 0.1 |
| 1 | 0.6 | 0.4 | 0.2 | 0.1 |
| 1 | 0.3 | 0.2 | 0.1 | 0.0 |
| 1 | 0.3 | 0.1 | 0.1 | 0.0 |
| 1+ | 90.2 | 76.0 | 65.2 | 47.0 |
| 6+ | 33.1 | 19.5 | 19.3 | 15.6 |

Table 15. Diagnostics from ADAPT.

Final iteration # 18
lambda = 0.001000
rss = 133.55,
sumresid = 0.00,

Relative change in phi parameter < 0.0001
Mean Square of the Residuals = 0.598874

| | Age | Est. Param | SE | CV | Bias (%) |
|---|---|---|---|---|---|
| F | | | | | |
| | 3 | 0.00096 | 0.00049 | 0.512 | -15.8 |
| | 4 | 0.03656 | 0.01399 | 0.383 | -8.2 |
| | 5 | 0.06460 | 0.02225 | 0.344 | -6.9 |
| | 6 | 0.10163 | 0.03879 | 0.382 | -9.4 |
| | 7 | 0.33760 | 0.14828 | 0.439 | -10.7 |
| | 8 | 0.25191 | 0.11311 | 0.449 | -11.8 |
| Summer Survey | | | | | |
| | 3 | 0.219 | 0.03444 | 0.157 | -1.1 |
| | 4 | 0.258 | 0.04070 | 0.158 | -1.1 |
| | 5 | 0.247 | 0.03885 | 0.158 | -1.2 |
| | 6 | 0.211 | 0.03321 | 0.158 | -1.2 |
| | 7 | 0.202 | 0.03199 | 0.158 | -1.3 |
| | 8 | 0.173 | 0.02745 | 0.158 | -1.5 |
| March Survey | | | | | |
| | 3 | 0.152 | 0.03108 | 0.204 | -1.9 |
| | 4 | 0.179 | 0.03676 | 0.205 | -1.9 |
| | 5 | 0.195 | 0.03998 | 0.205 | -2.0 |
| | 6 | 0.203 | 0.04177 | 0.205 | -2.0 |
| | 7 | 0.179 | 0.03700 | 0.206 | -2.1 |
| | 8 | 0.167 | 0.03442 | 0.207 | -2.4 |
| | 9 | 0.135 | 0.02778 | 0.206 | -2.9 |

Figure 1. Catch and TAC history for 4VsW cod.

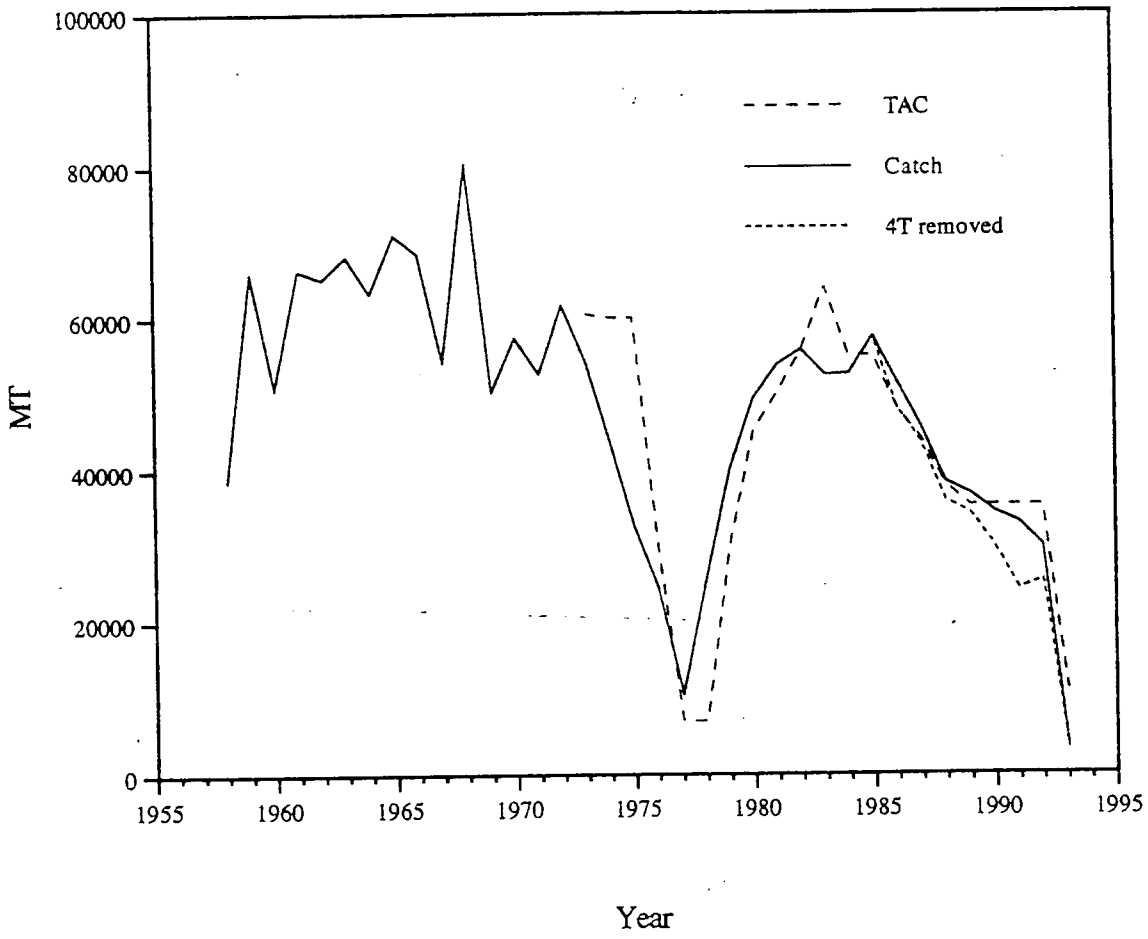


Figure 2. Catch rates from landings statistics (ZIFF) and IOP.

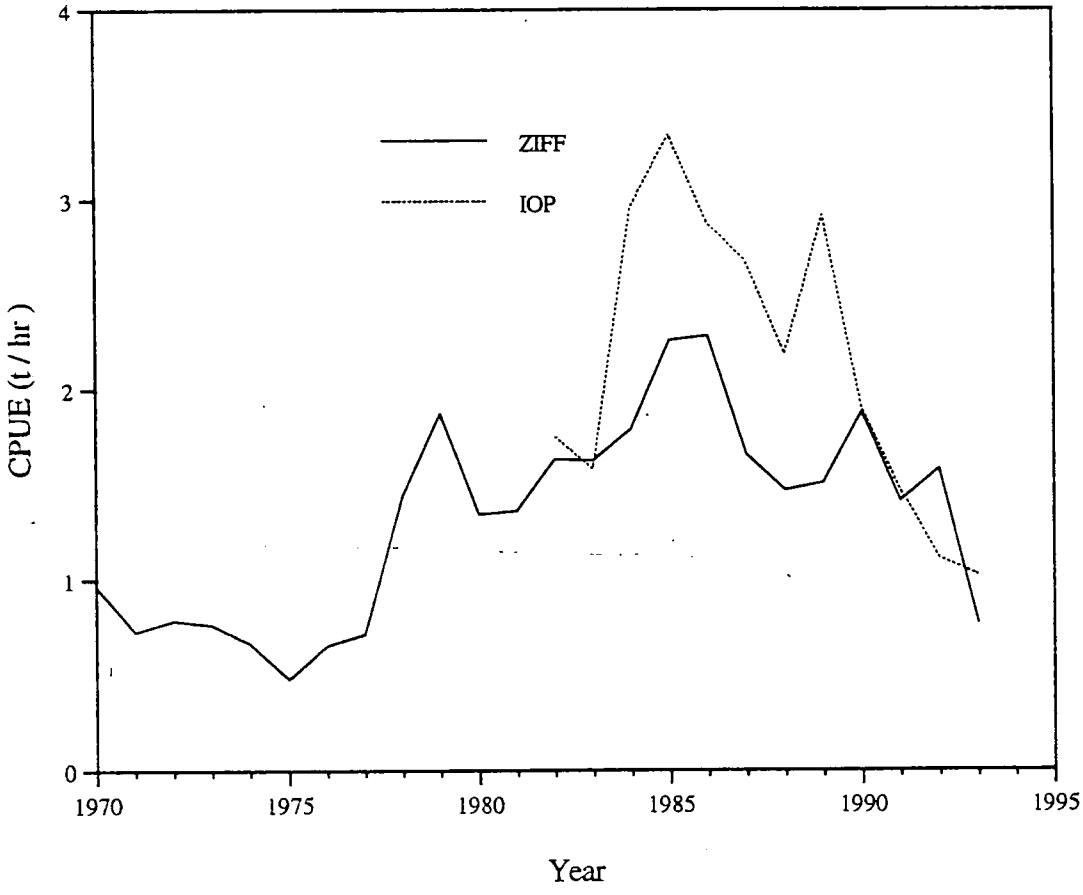


Figure 3. Survey numbers per standard tow (3+) for 4VsW cod.

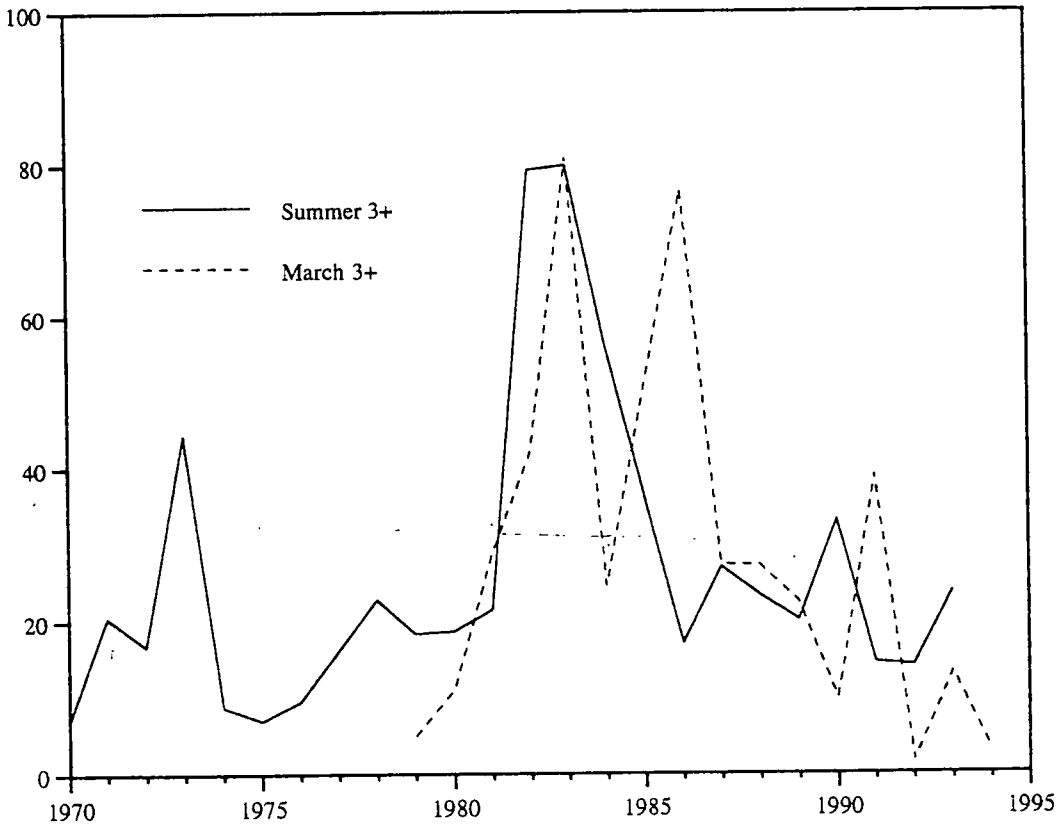


Figure 4. Biomass estimates from VPA.

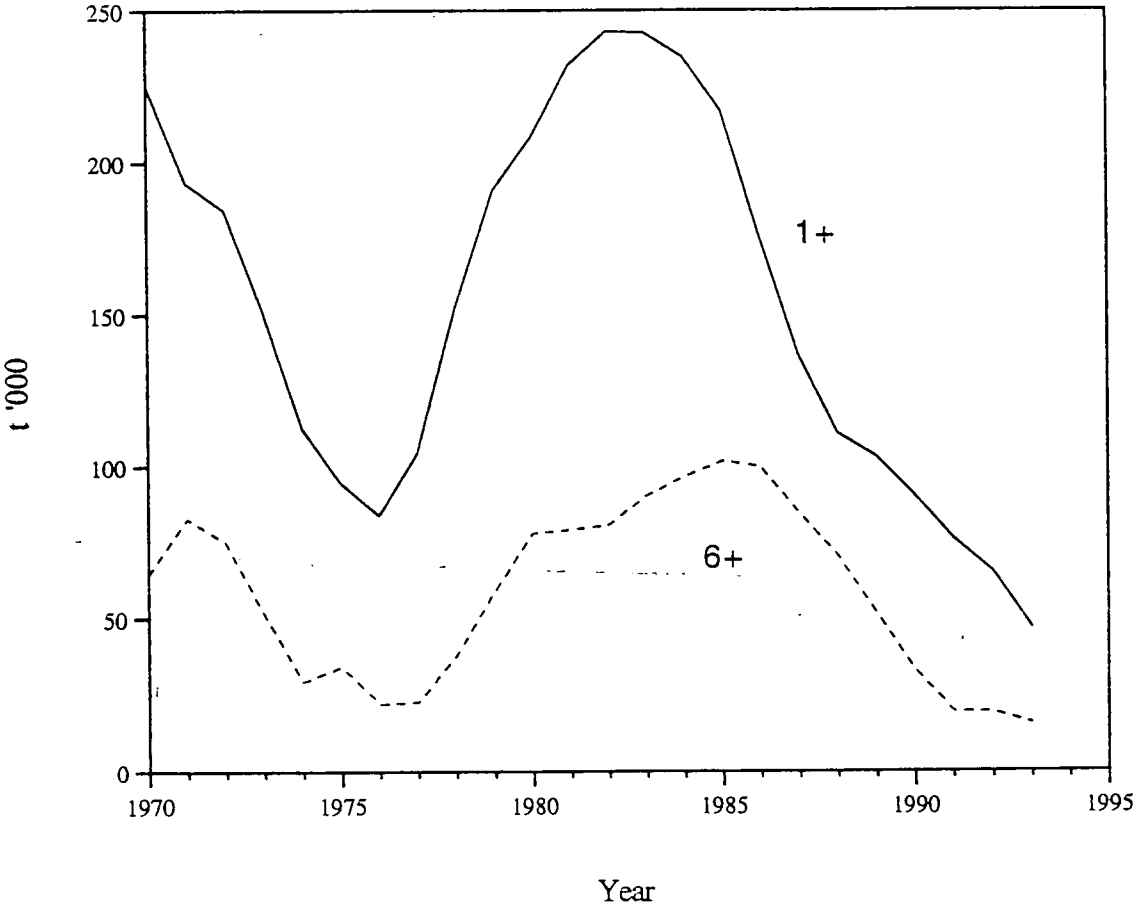


Figure 5. 4VsW cod recruitment series (Age 1) from VPA.

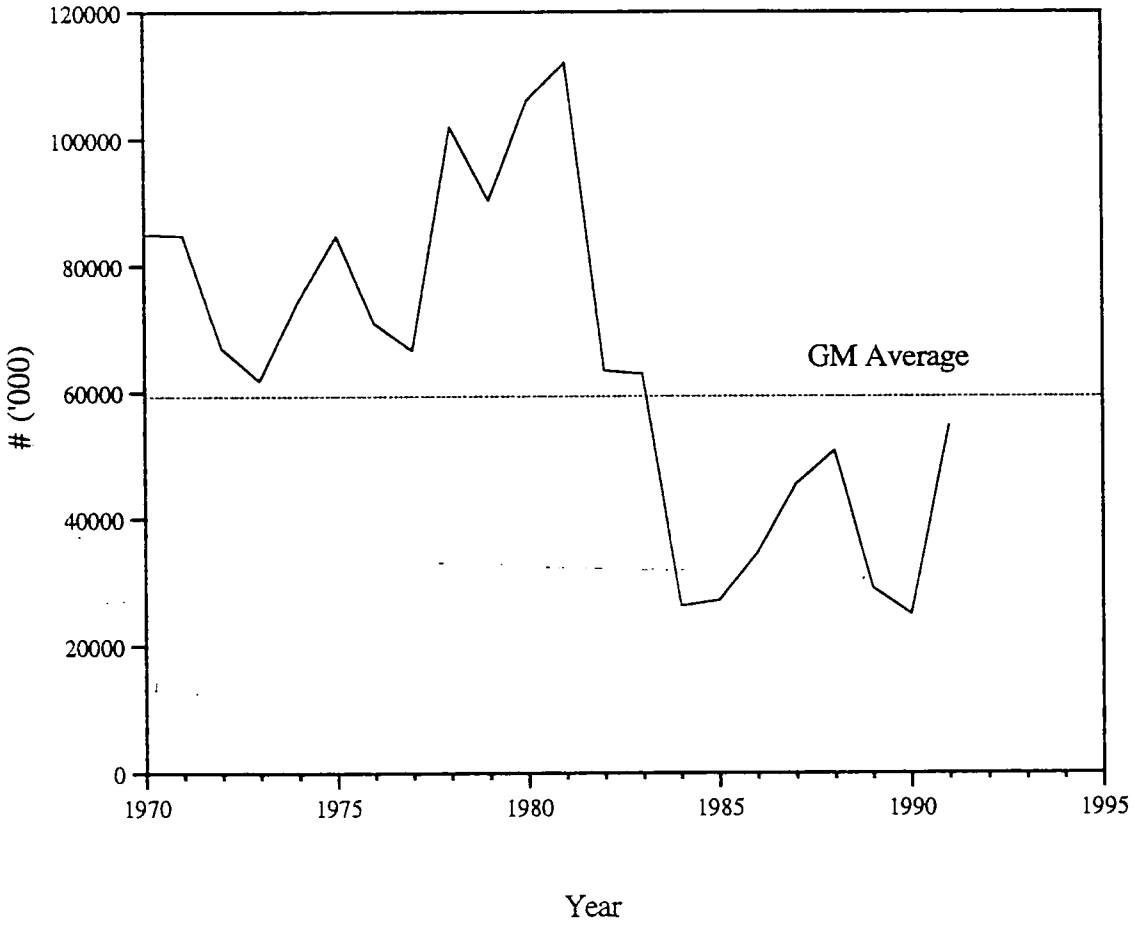


Figure 6. Estimates of 4VsW cod average fishing mortality.

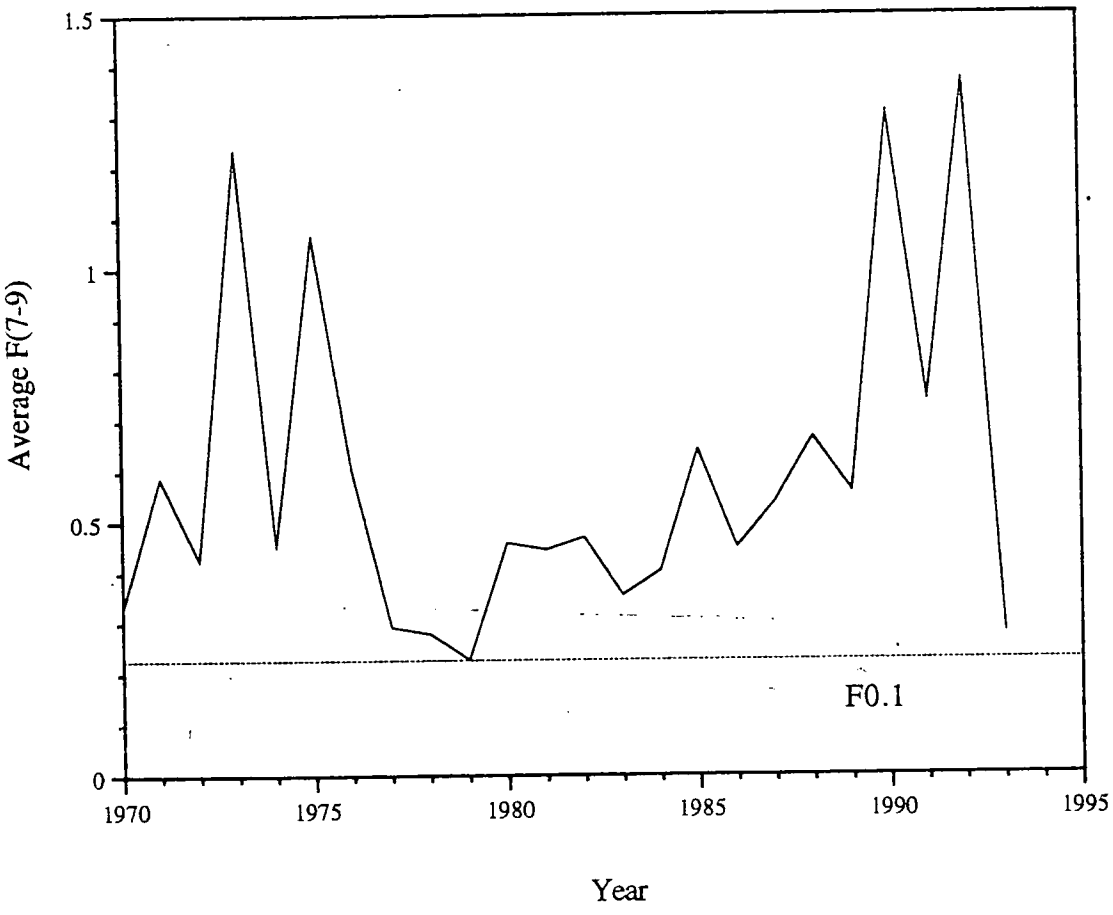
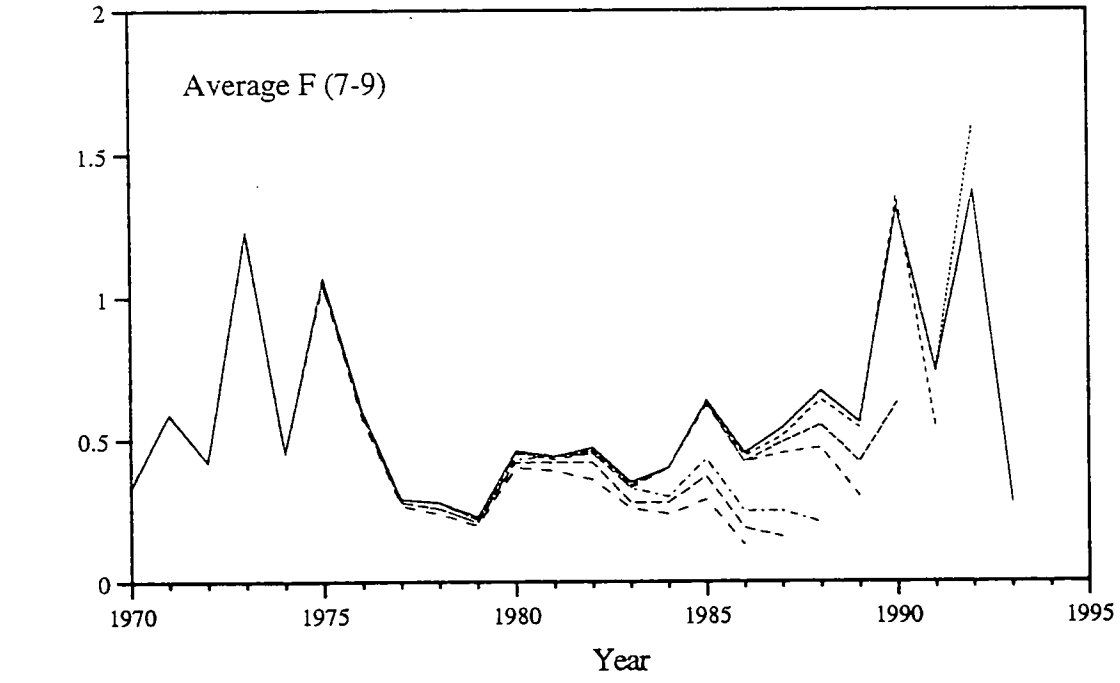


Figure 7. Retrospective analysis of 4VsW cod.



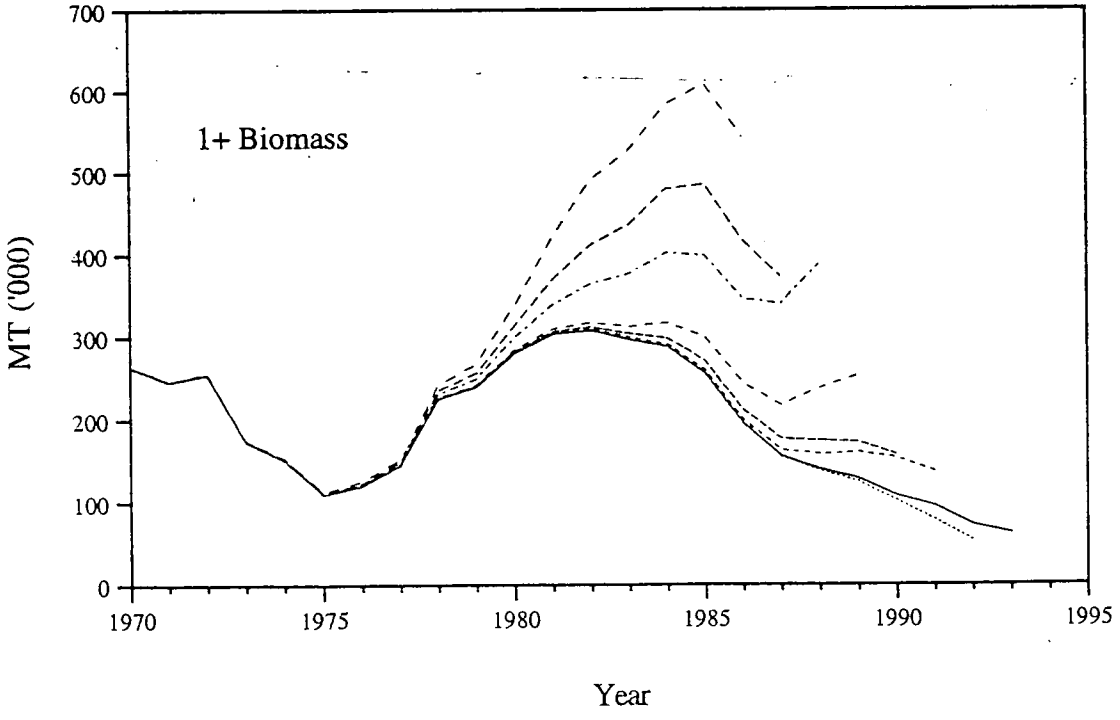



Figure 8. 4VsW cod stock-recruit relationship.

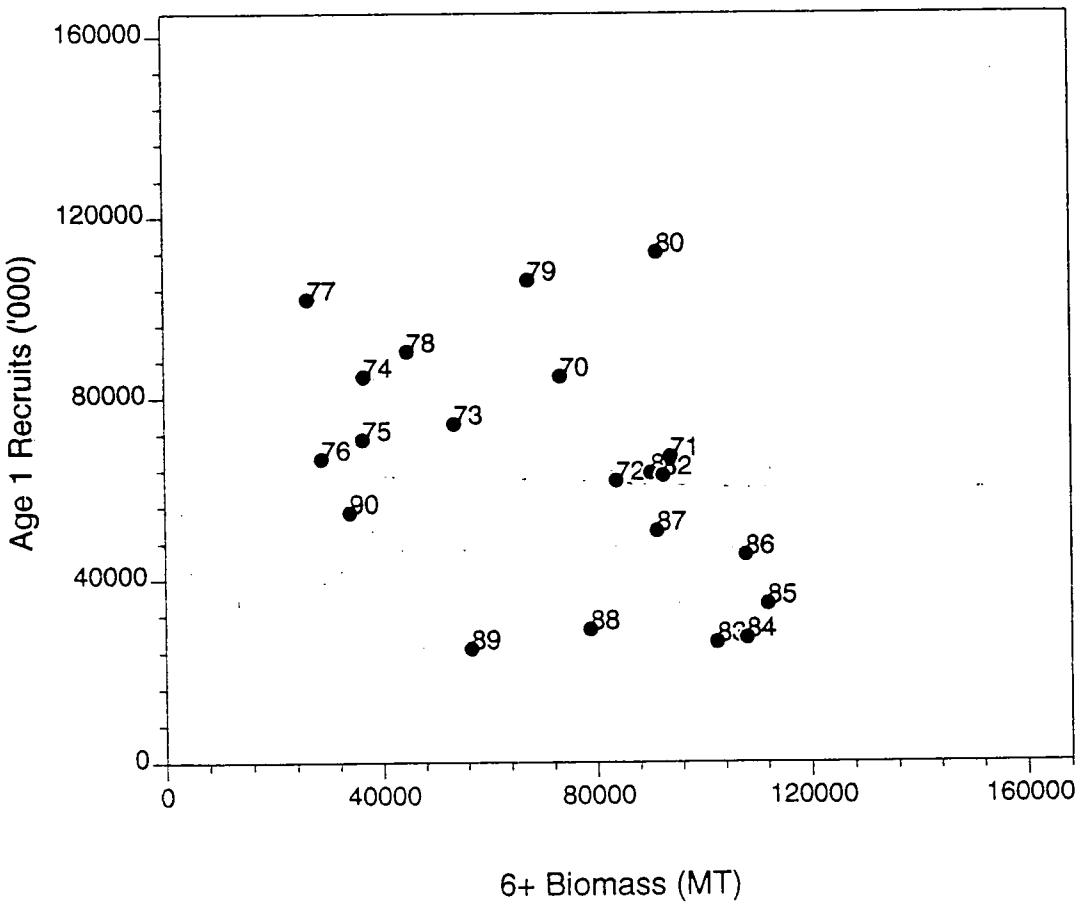


Figure 9. 4VsW cod numbers (3 - 8) from VPA and q corrected surveys.

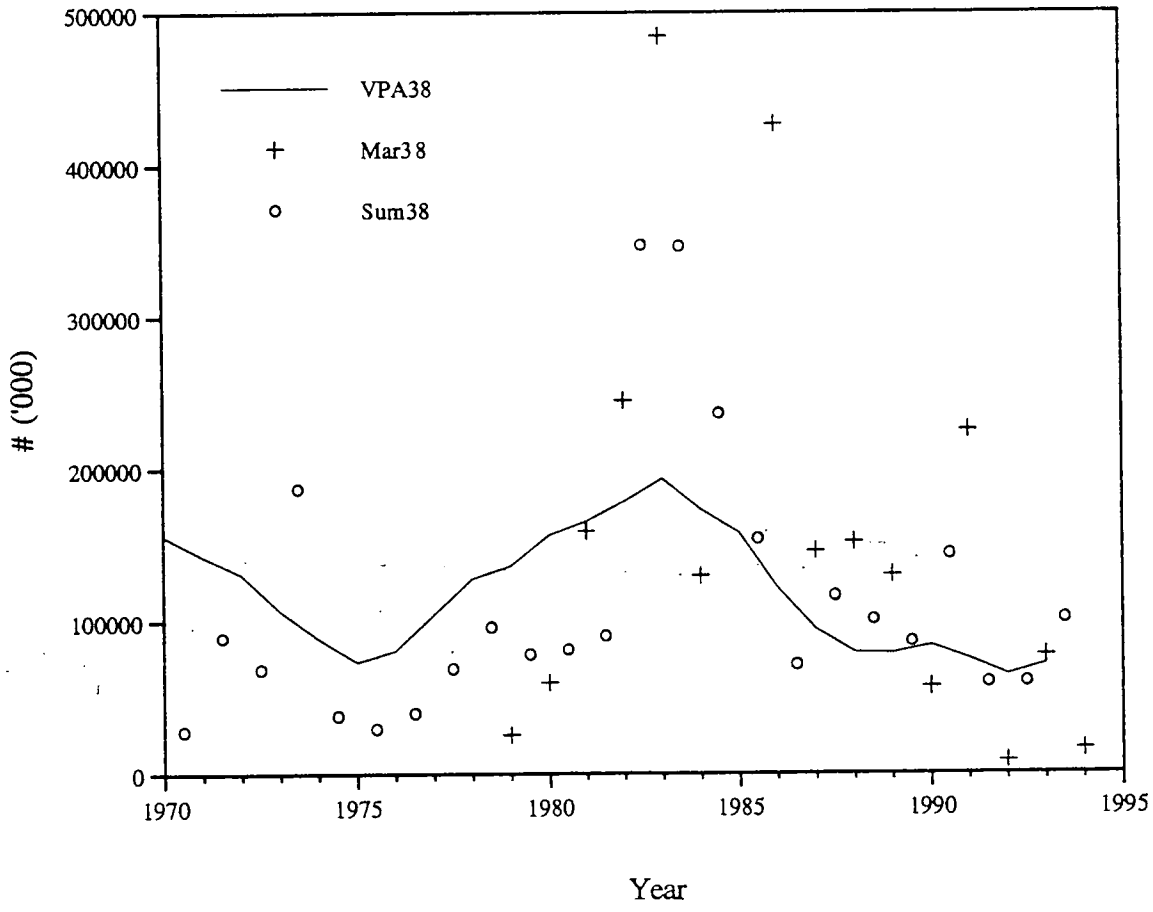


Figure 10. Two models for extrapolating 4VsW cod consumption by seals with 95% error bars. The commercial landings are shown for comparison.

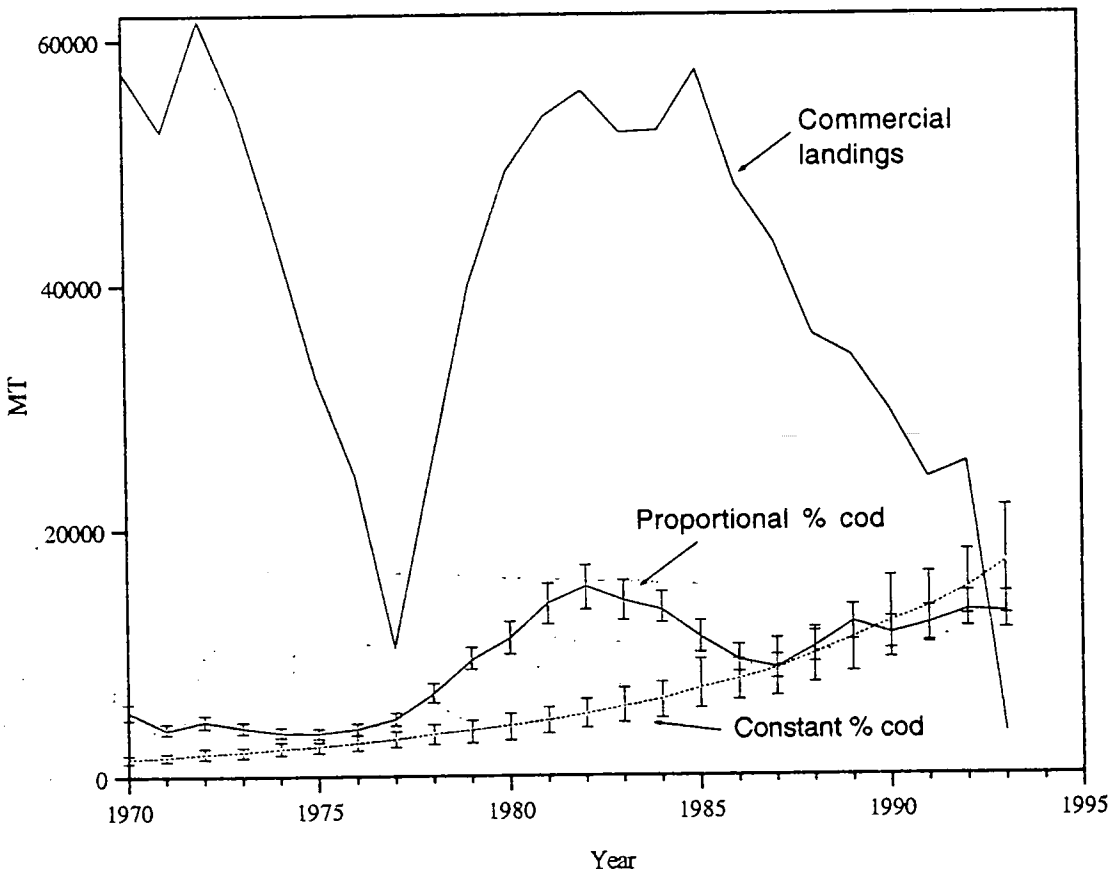


Figure 11. Biomasses (Dec. 1, 1995) and yield (1995) over a range of Fs. The 1993 F of 0.28 was assumed for 1994.