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Assessment of 4VsW cod in 1997 incorporating additional sources of mortality

by

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Abstract

The most recent stock assessment of 4VsW (Fanning et al. 1996) was completed in early 1996 and considered data up to the end of 1995. Thus this assessment will include new data for two complete calendar years, 1996 and 1997.

Comprising the south eastern portion of the Scotian Shelf, 4VsW has traditionally been fished for cod by large offshore trawlers with smaller vessels taking less than 25% of the total catch. Catches during the period 1958 to 1992 ranged from 10,000 to 80,000 metric tonnes annually, averageing 49,600. Due to the very low status of the stock the directed fishery for 4VsW cod was closed in September 1993 and has remained so since that time.

This assessment differs from previous assessments in that it contains explicit seal predation as well as an increase in natural mortality in 1985. However, an appendix has been added with the traditional natural mortaltiy assumptions to aid in linking with previous reports.

The short-term prospects for this fishery remain dismal. The productivity of the stock is very low, there are several factors causing increased mortality overall in addition to seal predation on the younger age groups. Although many scenarios were considered, producing a variety of results, there is little uncertainty about the status of the spawning stock biomass. The estimates of spawning stock biomass for recent years are very low in all cases.

Résumé

L'évaluation des stocks la plus récente de 4VsW (Fanning et coll.1996) a été terminée au début de 1996 et a tenu compte des données recueillies jusqu'à la fin de 1995. Ainsi, cette évaluation comprendra de nouvelles données pour deux années civiles complètes, 1996 et 1997.

Comprenant la portion sud-est de la plate-forme néo-écossaise, 4VsW a traditionnellement été exploitée pour la morue par les gros chalutiers hauturiers, les petits bateaux capturant moins de 25 % du total des prises. De 1958 à 1992, les prises ont été de 10 000 à 80 000 tonnes métriques par année, donnant une moyenne de 49 600. En raison du fort épuisement du stock, la pêche sélective de la morue 4VsW a été fermée en septembre 1993 et le demeure depuis.

Cette évaluation diffère des précédentes en ce sens qu'elle contient des données précises sur la prédation des phoques et sur une augmentation de la mortalité naturelle en 1985. Cependant, un appendice contenant les hypothèses traditionnelles concernant la mortalité naturelle a été ajouté pour faire le lien avec les rapports précédents.

Les perspectives à court terme de cette pêche demeurent sombres. La productivité du stock est très faible et plusieurs facteurs font accroître la mortalité en plus de la prédation des phoques sur les poissons plus jeunes. De nombreux scénarios ont été examinés, produisant toute une gamme de résultats, mais il y a peu d'incertitude au sujet de la situation de la biomasse reproductrice. Dans tous les cas, les estimations de la biomasse reproductrice des dernières années sont très faibles.

Introduction

The most recent stock assessment of 4VsW (Fanning et al. 1996) was completed in early 1996 and considered data up to the end of 1995. Thus this assessment will include new data for two complete calendar years.

Comprising the south eastern portion of the Scotian Shelf, 4VsW has traditionally been fished for cod by large offshore trawlers with smaller vessels taking less than 25% of the total catch. Catches during the period 1958 to 1992 ranged from 10,000 to 80,000 metric tonnes annually, averageing 49,600. Due to the very low status of the stock the directed fishery for 4VsW cod was closed in September 1993 and has remained so since that time.

The removals since the closure have been taken as strictly regulated bycatch in other fisheries operating in the area or, in 1996 and 1997, during the commercial index part of the 4VsW Sentinel Program. The reported landings (Table 1; Figure 1) for 1996 and 1997 were 310 and 231 metric tonnes respectively. Unlike the years when there was a directed fishery, half or more of the catch in each year since the closure has been taken by longliners (Table 2). This is primarily due to lack of quota for target species for mobile gear in 4VsW in recent years, i.e. haddock is closed and pollock scarce in 4VsW.

Due to corrections done after the Zonal Advisory Process meeting (Anon. 1998) some details of the analysis differ between this document and Stock Status Report A3-03. However, the overall outlook and stock status are not affected.

Data

Catch at age

Construction of a catch at age has been hampered by a lack of commercial or observer samples. Given that there is no directed fishery, cod landings are small, scattered and unpredictable. There were a total of four mobile and one longline samples with two additional length frequencies collected in 1996. In 1997, there were four mobile gear samples, no fixed gear and no additional length frequencies collected. Samples and combinations for 1996 and 1997 are given in Table 3a and 3b respectively. The complete catch at age, including 1970-1995 from Fanning et al. (1996) is given in Table 4a. The 4VsW catch at age was adjusted for the amount estimated to be from 4TVn cod in the years 1986-92 (Mohn and MacEachern, 1993 and 1994) however this has not been required for subsequent years (Table 4b). Commercial mean weights at age (Table 5, Figure 2) continue to be very low. Comparison of the reported landings to the catch biomass computed from the catch numbers at age multiplied by the commercial weights at age are included in Table 5 as the 'ratio with catch column'.

Seal Predation Removals

In this assessment seal predation removals are treated as an additional source of fishing mortality, by addition of the seal catch at age to the commercial catch at age. Seal predation removals of 4VsW cod were estimated following the approach of Mohn and Bowen (1994, 1996). Their results have been updated with more recent data on seal population numbers and diet data. The first of the two approaches in Mohn and Bowen (1996), treating cod as a constant proportion of the grey seal diet independent of cod abundance, with the new data led to a constant proportion of 12.6%. The resulting consumption biomass and implied catch at age are in Table 6a and Figure 3a. Their second approach was a proportional ration (Lotka-Volterra) model with the proportion of cod in the diet related to the abundance of cod. Because the seal consumption depends on the cod abundance, which depends on seal consumption, a number of iterations (less than 3) are required to obtain stable estimates of the consumption biomass and catch at age. The resulting proportion of cod in the seal diet (Figure 3b) ranges from <3% to nearly 30%. The catch at age and biomass values reported here (Table 6b, Figure 3a) differ from earlier analyses, reported in the Stock Status Report A3-03 (1998), because the adjustments to survey data and natural mortality (reported below) have been included in the iterations of the population model to estimate seal consumption of cod. These two models, referred to as the constant proportion and variable proportion models, were considered bounding scenarios. The Lotka-Volterra dynamics of the variable model predicts very high consumption of cod, greater than 25% of the seal diet, during the mid-1980's, when cod was abundant and seals were becoming abundant. Because this is well above any observed proportions, a third scenario, considered more likely than either above, was to constrain the upper limit of the variable proportion model. In this constrained proportion model, the seal diet is limited to a maximum of approximately 20% cod, more consistent with the available diet data. The resulting consumption biomass and implied catch at age are in Table 6c and Figure 3a and the seal diet proportion is in Figure 3b.

Indices of Abundance

There are now three useful indices of abundance for this stock (Figure 4). The July RV series runs from 1970 to 1997 without exception. The March RV series runs from 1979 to 1997 however 1985 and 1996 were missed. The newest survey series is the 4VsW Sentinel Survey which has been conducted in Sept.-Oct. for 1995-1997. All three surveys use stratified random survey designs although there are some differences in the stratification schemes employed.

For a number of years the assessments of this stock have applied a conversion factor to the July RV results for the AT Cameron survey series (1970-1981) and Lady Hammond (1982) to adjust them to the Alfred Needler equivalents. This factor was 0.8 (Fanning, 1985) determined from comparative fishing experiments conducted at the time of the change-over in research vessel. With the extended time series now available since the conversion it has been possible to estimate a conversion factor based on the idea of allowing a step to occur in the survey q's

estimated by ADAPT. Research on this approach (Mohn, 1998 in press) clearly identified a break in the series in 1982, consistent with the first vessel change (AT Cameron to Lady Hammond). This approach estimates the conversion factor to be 1.70, close to the swept volume ratio of the two gears used (1.90). The factor is quite different from that obtained in the comparative fishing experiment (Fanning, 1985). There did not appear to be any difference in the Lady Hammond to Alfred Needler, however, with only one year of Lady Hammond data this would be difficult to detect anyway. Given that the latter two vessels are both stern trawlers and used the same gear, there was little *a priori* reason to expect a difference. The July survey series reported in this assessment has been adjusted using the ADAPT estimated conversion factors and so, is quite different from previous assessments. The March RV series is reported in unadjusted values throughout, as the AT Cameron was never involved in that survey.

The July RV series (Table 7) has declined by an order of magnitude since the closure in 1993 and the latest surveys are the lowest ever. At the same time the age composition has collapsed and the oldest fish caught in the July 1997 survey was only 8 years old. The March survey series (Table 8) is more variable than the July series but there was good agreement between the two series up to 1995 indicating that the stocks were low and declining. The 1996 survey was incomplete due to mechanical problems with the survey vessel. In 1997 the March survey was very high (4th overall in the series) with large numbers of 3 and 4 year olds, however almost all of these fish were caught in two sets. While these two sets represent real aggregations of cod, removing these two sets from the data causes the overall stratified numbers to drop from 48 fish per tow to about seven, the fourth lowest in the series. The survey recruitment indices for March and July (Figure 5) are the weighted means of the estimates of each yearclass at ages 2 and 3. Age 2 and 3 given twofold weight due to lower RV catchability from VPA. The indices showed reasonably good correspondence up to the 1994 yearclass. The March survey estimates of the 1994 and 1995 yearclasses are highly dependent on the two large sets in the 1997 survey.

The 4VsW Sentinel Survey has been conducted by commercial longliners in Sept.-Oct. each year since 1995. The set locations are randomly generated, using the summer RV stratification scheme. Three additional strata are surveyed between the inshore edge of the RV strata (~50 fm contour) and approximately the 19 m (10 fm) contour. Each set consists of 1500 hooks (all #12 circle hooks, baited with frozen mackeral) fished inside a 3 nautical mile circle centered on the selected point. The distribution of catches has remained constant but the stratified mean catch per set declined in 1996 and remained at the lower level in 1997.

The seasonal survey distributions among the three surveys in 1996 (Figure 6) and 1997 (Figure 7) are similar to those of recent years.

The mean length at age in the July RV survey by Division (Table 9) suggests that there has been some increase in length at age in 4W but it is less apparent in 4Vs. The 1990 yearclass, in 4W, is at or near the smallest at age in the entire series.

Stock Assessment

Total Mortality

Two related approaches to estimating the total mortality from RV surveys have been used. The simpler approach was to compute Z based on the survivors from age i to i+1 and for appropriate groupings of ages and the smoothing over years. Using this approach, three age groupings were calculated, ages 1-3, 4-6 and 7-9 (Figure 8) using three-year centered running means. The Z's for ages 1-3 are mostly negative due to the increasing recruitment to the survey gear at those ages however, they are indicative of relative changes in mortality over time. High mortality in the 1970's, a period of increasing catches, appear to have been reduced by the increased mesh size and restrictive catch limits imposed in 1977. The rapid increase in age 1-3 mortality in the 1980's is consistent with the widely discussed period of intense discarding of undersize fish. These apparent discards are not represented in the catch at age. The steady increase in age 1-3 mortality from 1987 to the present is consistent with the increasing consumption of cod by grey seals. The ages 4-6 and 7-9 are fully recruited to the survey and hence the Z's are an absolute measure of total mortality. Both these age groups have had trends of increasing total mortality since the low in 1977-79. The closure of the fishery in 1993 did not produce any noticable reduction in Z. Most estimates of Z's from surveys since the closure of the fishery indicate that the total mortality has continued to be greater than 1.

The alternative approach (A. Sinclair, pers. comm.) estimates a linear model of the log survey catch using age (over ages 4-10) and yearclass as predictors. The parameter estimate (and standard error) for the age term is the total mortality estimate. The sucessive estimates from overlapping four year blocks (Figure 8) give a time series of total mortality. These results are entirely consistent with the previous approach and again suggest that Z's since the closure of the fishery have remained above 1.

Population Reconstruction

The age-based population analysis used as the basis of the last assessment of this stock was revised slightly and updated in Appendix 1. This was not used as the basis of the current assessment *per se* but is provided solely as a point of comparison with previous assessment models. Because of the number of factors which were revised in this assessment, the population reconstruction which was used as the basis of the Stock Status Report is presented as a " full run". The complete results for the full run are included and the sensitivity of those results to alternative assumptions regarding the various factors is examined.

All population reconstructions, i.e. runs, were estimated using an ACON (Black, 1998) implementation of ADAPT. Bootstrap (1000 resamples from residuals) bias corrections were applied to the estimated population numbers. The full run structure is as follows:

Parameters:

Log Survivors	$\ln(N_{i,1997})$, i=3 to 10
Calibration Coefficients	$q_{J,i}$, i=3 to 8 for July RV survey
(estimated algebraically)	$q_{M,i}$, i=3 to 9 for March RV survey

Structure Imposed:

Error in catch assumed negligible
Partial recruitment in 1997 fixed for ages 1,2, and 11+
F_{15} (oldest age) set to average F on ages 9 and 10
No intercepts were fitted

Natural mortality	M_t=0.2 for all ages, for t≤1985
	M_t=0.4 for all ages, for t>1985

Input:

Full year catch at age	$C_{i,t}$, i=1 to 15; t=1970 to 1997
Estimated seal removals	$S_{i,t}$, i=1 to 8; t=1970 to 1997
July RV index	$J_{i,t}$, i=3 to 8; t=1970 to 1997
March RV index	$M_{i,t}$, i=3 to 9; t=1979 to 1997 (excluding 1985, 96, 97)

Objective Function:

$$\text{Min } \{\sum_i \sum_t (\ln J_{i,t} - \ln q_{J,i} \cdot N_{i,t})^2\} + \{\sum_i \sum_t (\ln M_{i,t} - \ln q_{M,i} \cdot N_{i,t})^2\}$$

Summary:

Number of observations:	168 from July RV
	112 from March RV
Number of parameters:	21
	8 estimated in NLLS; 13 algebraically

Age 1 and 2 in terminal year estimated from GM average of recruitment over the range 2 to 6 years previously.

Assessment Results

Summary statistics from the NLLS fit of the full model are given in Table 10. Also included in Table 10 are the bootstrap bias correction results based on 1000 replicates. The bootstrap CV's are generally smaller than those implied by the model fit statistics (i.e. log standard errors). The residuals (Table 11 and Figure 9) show strong survey-specific year effects in 1986 and 1997 but they are generally more random appearing than in previous assessments (Fanning et al. 1996). The observed (q-adjusted survey) and estimated population numbers for ages three to eight (Figure 10) show close agreement in most years. While there is some retrospective variability visible in Figure 11, the tremendous bias which has been the reason to

reject the analytical assessment of this stock in the past, is present in only three or four years in the early 1980's. This suggests that, while the survey adjustments included in this assessment have been effective in addressing the retrospective to a large degree, there still remain additional retrospective-inducing factors impacting primarily on those particular years. Some retrospectivepattern is still apparent in recent years as well.

The basic results of the population analysis given are numbers at age (Table 12), recruitment and total and spawning stock biomass (Figure 12). The spawning stock is approximated by the age 5+ stock from the biomass at age (Table 13).

Total exploitation mortality is partitioned into the fishing mortality rate due to predation by seals (Table 14) and that due to the fleet (Table 15). Exploitation rates (Figure 13) are broken down by age groups. Seal exploitation rates on adults (ages 5-7 in Figure 13) were small relative to the fishery until the early 1990's. Since the closure of the fishery, in late 1993, exploitation was almost entirely due to seals. Seal predation on the younger age groups (ages 3-4 in Figure 13) was half or more of the total since 1985 and 100% since 1994.

The long-term stock recruitment plot (Figure 14) is based on the full model ADAPT run and the untuned catch at age from 1958 to 1969 attributed to Halliday (1975). Recent age 1 recruitment is well below the mean of 1970-1995.

The production plot (Figure 15) links gross and net stock production for a given year. The difference between gross and net production is the sum of fishery catch and seal predation. The two types of removals are separated on the graph by a small horizontal bar on the vertical line for the years since 1970. Gross production collapsed in 1985 and was negative for five of the eight years to 1992. It has increased slightly since the closure of the fishery in late 1993 and has been slightly positive since 1993. The production to biomass ratio, P/B, is plotted over time and currently, P/B is below average but above the very low levels from the early 1980's to the early 1990's.

Projection results to 1999, summarized in the Armstrong plot (Figure 16), indicate that $F_{0.1}$ yield would be about 1,900 t. and would result in about an 3,700 t. decrease in biomass. Due to the pattern of exploitation when seals are included in the model, about half of the population biomass and most of the exploitation is in the age groups less than five years old and so, not represented in Figure 16. Projection results must also be interpreted with the fact that the seal consumption is projected to be almost 3,600 t. in itself, before any fishery exploitation.

Alternative Assumptions

Our rationale throughout is that each of the model refinements included in the full run may not be perfect as implemented but in all cases they represent a better approach than ignoring the pertinent factor. The sensitivity analysis (Table 16) is based on the comparison of selected key measures from the full run (first line in Table 16) with each of the alternative assumptions. Only one assumption is varied in each run as listed below, no combined effects have been examined.

i. March 1997 RV survey point

The March 1997 survey estimate of stratified mean catch per tow was extremely high (Figure 4), particularly in light of the other indicators of stock status. The large estimate was driven by two sets, both south of Sable Island, which accounted for 77% of the entire survey catch by weight and 86% by numbers. Excluding these two sets, the 1997 survey drops from the fourth largest to the fourth smallest in the 17 years surveyed. The age composition included relatively large numbers of older fish, arising from cohorts not seen in previous surveys. For these reasons, this 1997 survey was considered anomalous and has been excluded from the full run. The alternative assumption examined was to include the March 1997 at face value.

ii. Seal predation

As described above, the seal predation on 4VsW cod was modeled under three scenarios. The full run, as the basis of the assessment, assumes the constrained proportional model. The alternatives of constant proportion and variable proportion (unconstrained Lotka-Volterra) are summarized in Table 6. In addition to the explicit seal consumption models, the option of no consumption of cod by seals was also included, particularly for camparison with previous assessments.

iii. Natural mortality

In this assessment all sources of mortality other than seal consumption and reported fishery landings are grouped as natural mortality. The traditional assumption, that M=0.2 for all ages and all years, has been challenged on three grounds, seal predation, discarding, and increased natural mortality due to unfavourable environmental conditions. The consumption by grey seals has been included explicitly in this assessment, however, the other two factors are included as a single increase in natural mortality from 0.2 to 0.4 in 1986 and constant afterward. Recent work (Dutil et al. 1998) has suggested that in 4VsW and other cod stocks there have been significant changes in natural mortality associated with poor condition and cold water temperatures. These conditions arose in 1986 and have remained since then. Anecdotal reports and analyses of discarding (unpublished data) have also suggested that discarding may have been considerable in the late 1980's and early 1990's. In the full model, the single step increase in M (.2 to .4 in 1986) was selected as a simple, yet reasonable, approximation to these factors, which was consistent with a number of other stocks. The alternative assumption was the traditional constant M=0.2.

iv. Research vessel adjustment

As described above, the full run uses a conversion factor between the AT Cameron and the subsequent vessels of 1.7 (i.e. convert up to 1981). The alternative was to use the previous conversion factor of 0.8, derived from comparative fishing experiments. The current stock status is relatively insensitive to the RV conversion factor however the retrospective effect using the

0.8 conversion factor is very large in the late 1980's. This is substantially reduced in the full model run.

The sensitivity measures (Table 16) are considered in two groups, the impact on key population parameters and the impact on model fit diagnostics. In the first group, the responses selected are the beginning of year spawning stock biomass (SSB) in 1998; the projected change in SSB with no fishing in 1998, expressed as tonnage and percentage; the yield projected to cause no change in SSB, if applicable; the estimated size of the 1994 year class at age 1, the last year class estimated; and geometric mean recruitment for the last five yearclasses. The model fit diagnostics are the mean square residual, the retrospective metric and the mean bootstrap relative bias estimate for the survivors (Table 10 for full model). The retrospective metric is defined as:

$$Z_{ret} = \Sigma_y (B_{full,y} - B_{term,y}) / B_{full,y}$$

where y is from 1997 back to 1987 where $B_{full,y}$ is the total biomass in year y estimated from the full time series and $B_{term,y}$ is the total biomass in year y estimated when y is the terminal year of ten one-year incremental truncations of the series.

Sensitivity Results

Only one of the alternative asssumptions can be clearly ruled out on the basis of the model fit diagnostics. The retrospective metric is 25 times larger for the model using the previous RV conversion factor (Run 'Old RV' in Table 16) than for the full model. The retrospective in this run has been examined in some detail and was the basis of the analysis leading to the new conversion factor used in all other runs (Mohn, in press). This run was not considered further in this assessment. The retrospective was also very strong for the model assuming no change in natural mortality, i.e. M=0.2 throughout, lending support to the models using a change in M.

The stock biomass under the different scenarios (Figure 17) is most affected by the assumption regarding M. The constant M=0.2 model has a much lower peak in the mid-1980's and has the highest biomass in the current year. It also has the most optimistic projected biomass with 22% growth in the absence of fishing and yields up to 8800 t. would not cause any decline in biomass (Table 16). For the other scenarios, although the individual biomass estimates are variable, they all agree that the current biomass is at or near the lowest in their respective 28 year series.

The total exploitation mortality of seal consumption and fleet catch combined (Figure 18) shows a large difference from the full model for the constant proportion model for seal consumption. The difference is most extreme in the most recent years where the exploitation mortality rates range from 0.01 to about 0.09 for all the scenarios except the constant proportion model which is greater than 0.9.

The recruitment estimates (Figure 19) are very sensitive to the model scenarios considered. The 1994 yearclass estimates of age 1 recruits range from more than 100 million to less than 5 million, values near the long term geometric mean and less than 10% of the long term geometric mean of their time series, respectively.

The sensitivity analyses suggest that our current estimates of stock status (biomass and exploitation) may be reasonably robust however, the degree of model sensitivity in the recruitment estimates makes projection results highly uncertain, above and beyond the degree of error captured in the risk analysis below.

Risk Analysis

The risk plots (Figure 20) shows the cumulative probability of declines in spawning stock biomass (with respect to the beginning of 1998) with constant removals in 1998, 1999 and 2000 in the upper panel. The comparable risk plot for the probability of F exceeding $F_{0.1}$ is given in the lower panel. Although the risk plots suggest that catches up to 2,000 t. have essentially no risk of exceeding the $F_{0.1}$ target, these same yields have a high risk (>50%) of producing a decline in the spawning stock biomass. This is due, in part, to inclusion of predation by seals on the younger age groups, which causes the $F_{0.1}$ value to be drastically higher than the traditional 0.2. In this analysis, $F_{0.1}$ is 0.92. The parameter uncertainty expressed in the risk plots must be interpreted very carefully as it ignores the uncertainty in the model specification. This is highlighted for four of the models considered in the sensitivity analysis (Figure 21). The frequency distributions of bootstrap estimates of the 1998 spawning stock biomass vary substantially in position and in shape. The position of the full model (lowest panel) distribution represents clearly the intermediate seal diet assumption i.e. between no seal predation and constant proportion predation. What is also shown is the importance of the exclusion compared to the inclusion of the March 1997 survey data in the full model.

Outlook

The short-term prospects for this fishery remain dismal. The productivity of the stock is very low, there are several factors causing increased mortality overall in addition to seal predation on the younger age groups. Although many scenarios were considered, producing a variety of results, there is little uncertainty about the status of the spawning stock biomass. The estimates of spawning stock biomass for recent years are very low in all cases.

In the full model, presented here as the most plausible assessment, the spawning stock biomass, while not declining, has not rebuilt since the closure of the fishery. Based on one year projections, the exploitation rate and change in biomass associated with a range of yields indicate that, even with no fishery, the spawning stock biomass is projected to decline by about 18%. Although this has been cast in terms of risk, the risk analysis contributes little as there is little point

as there is a very high probability that the biomass will decline in 1999 without any fishing. Thus even by-catch in other fisheries may pose a serious threat to the recovery of this stock.

A more optimistic prognosis for this stock is based on including the March 1997 survey data. Although considered unreliable, the March 1997 survey suggests that there are more cod in the stock area than detected by the July survey. If the March 1997 survey were included in the population analysis, then the apparent prospects for improvements in the spawning stock biomass would be much better. Projections based on this population model suggest that the spawning stock biomass could increase by 15% in the absence of any fishery and catches up to 4,000 t. would not cause any decline in biomass. It is cautioned that this assessment has the highest degree of uncertainty in the parameter estimates (Figure 21) as well as being the most optimistic.

Varying models of seal consumption of cod lead to different conclusions about the impact of seal predation on the rebuilding of the cod stock. If cod is a constant proportion of the seal diet it suggests that cod recruitment at age 1 has been good in recent years but that survival of those recruits to age 3 or 4 has been very poor. This leads to the conclusion that cod stock rebuilding will not likely occur while this degree of predation continues. Alternatively, the variable proportion model of cod in the seal diet suggests that recruitment, even at age 1, has been poor and that subsequent survivorship to age 3 or 4 has been much less of a factor in the failure to rebuild than it is in the constant proportion model. The full model in this assessment lies between these but, regardless of which model of seal consumption of cod is closer to reality, the recruitment and subsequent survivorship must both improve before it is likely that the stock will rebuild strongly.

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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	50644	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	-	-	-	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	34172	-	-	-	150	81	34403	26274	8129	35200
1991	32804	-	-	-	-	-	32804	24596	8208	35200
1992	29724 [1]	3 [2]	-	-	36 [2]	42 [2]	29805 [1]	21317 [1]	8488 [1]	35200
1993	3434 [1]	-	-	-	15 [2]	25 [2]	3474 [1]	2316 [1]	1158 [1]	11000
1994	366 [1]	-	-	-	-	2 [2]	368 [1]	180 [1]	188 [1]	
1995	280 [1]	-	-	-	-	1 [2]	281 [1]	184 [1]	96 [1]	
1996	308 [1]	-	-	-	-	2 [2]	310 [1]	159 [1]	149 [1]	
1997	231 [1]					0 [2]	231 [1]	104 [1]	127 [1]	

[1] Preliminary Catch Statistics (ZIFF)
[2] International Observer Program

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	23800	28595	6263	3331	988	39177
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	4511	28083	8240	994	898	38215
1989	22608	6324	400	40	29372	3332	2983	323	609	7247	25940	9307	723	649	36619
1990	22218	3825	224	4	26271	2839	4080	530	452	7901	25057	7905	754	456	34172
1991	20529	3838	229	.	24596	3579	3675	371	583	8208	24108	7513	600	583	32804
1992	17941	3203	170	.	21314	3596	4098	506	210	8410	21537	7301	676	210	29724
1993	1189	1071	56	.	2316	174	798	87	59	1118	1363	1869	143	59	3434
1994	144	32	4	.	180	32	142	.	12	186	176	174	4	12	366
1995	110	63	1	10	184	12	74	.	10	96	122	137	1	20	280
1996	89	68	1	2	159	14	127	0	7	148	103	195	1	9	307
1997	36	54	1	13	104	11	96	.	20	127	47	150	1	33	231

Table 3. Commercial sampling information usd in 1996 and 1997 catch at age for 4VsW cod.

a.) 1996 Catch at age data

Mobile

AGE	AVERAGE LENGTH	AVERAGE WEIGHT	CATCH (000's) MEAN	CATCH (000's) STD. ERR.	CATCH (000's) CV
1			0		
2			0		
3	41.54	0.66	4.00	0.84	0.20
4	46.77	1.00	12.00	1.37	0.12
5	54.89	1.62	12.00	1.53	0.13
6	60.70	2.23	12.00	1.59	0.14
7	66.20	2.94	9.00	1.36	0.15
8	67.08	3.08	3.00	0.89	0.32
9	76.08	4.55	1.00	0.44	0.60
10	77.98	4.78	1.00	0.32	0.58
11	87.13	7.39	0.10	0.31	0.65

Period: Full Year
Ages: 218
Lengths: 672
Catch: 104

Length-Weight parameters
a= 0.005482
b= 3.13618
Source: July RV Survey

Longline

AGE	AVERAGE LENGTH	AVERAGE WEIGHT	CATCH (000's) MEAN	CATCH (000's) STD. ERR.	CATCH (000's) CV
1			0		
2			0		
3	41.48	0.66	32.00	6.04	0.19
4	45.35	0.89	75.00	8.18	0.11
5	51.30	1.30	41.00	6.30	0.15
6	55.21	1.66	19.00	3.70	0.20
7	60.64	2.24	8.00	1.93	0.26
8	63.04	2.45	2.00	0.84	0.45
9	67.00	2.92	0.30	0.20	1.13
10	75.25	4.21	0.20	0.18	1.04

Period: Full Year
Ages: 218
Lengths: 339
Catch: 195

Length-Weight parameters
a= 0.005482
b= 3.13618
Source: July RV Survey

b.) 1997 Catch at age data

Combined

AGE	AVERAGE LENGTH	AVERAGE WEIGHT	CATCH (000's) MEAN	CATCH (000's) STD. ERR.	CATCH (000's) CV
1			0		
2			0		
3	38.90	0.55	2.00	1.75	0.79
4	43.03	0.80	14.00	3.48	0.25
5	46.85	1.04	28.00	4.82	0.17
6	56.37	1.93	16.00	3.88	0.25
7	57.46	2.00	17.00	3.62	0.22
8	67.69	3.26	17.00	3.25	0.19
9	71.15	3.93	7.00	2.13	0.31
10	77.13	5.40	3.00	1.40	0.44
11	80.42	5.46	3.00	1.23	0.42
12	81.22	5.53	1.00	0.64	0.74
13	84.50	6.07	0.40	0.46	1.04
14	82.50	5.63	1.00	0.57	1.02

Period: Full Year
Ages: 183
Lengths: 760
Catch: 231

Length-Weight parameters
a= 0.005799
b= 3.12405
Source: July RV Survey

Table 4a. Commercial catch at age for 4VsW cod (not adjusted for 4TVn component).

	Age																		
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1+	3+	6+
1970	1293	8631	8886	14802	13673	4539	1942	759	236	72	137	56	9	12	4	4	55055	45131	7770
1971	1984	12824	9643	5125	6612	5128	3419	1963	704	367	159	173	156	80	40	52	48429	33621	12241
1972	2046	15865	11801	11989	7384	6527	3308	1880	347	466	68	8	36	0	3	7	61735	43824	12650
1973	1218	10221	8001	5803	9634	3324	3370	4732	1684	389	551	8	21	21	18	47	49042	37603	14165
1974	1273	7321	13324	11695	6854	2247	669	1008	196	153	13	2	0	0	0	0	44755	36161	4288
1975	1538	8571	7402	3163	4788	3297	2943	623	497	686	172	123	41	6	6	19	33875	23766	8413
1976	513	2866	2860	4707	3900	2085	1287	447	136	53	12	47	0	4	0	2	18919	15540	4073
1977	1	23	532	1229	1591	845	490	199	118	33	42	44	11	3	2	6	5169	5145	1793
1978	34	94	1168	4078	4817	2582	767	247	107	75	31	27	28	10	1	2	14068	13940	3877
1979	12	93	1762	6559	9525	5056	1210	377	76	23	10	4	3	0	0	0	24710	24605	6759
1980	31	92	1765	4873	6937	6177	3050	1121	313	92	50	26	4	0	1	7	24539	24416	10841
1981	3	258	3200	9136	7281	4651	2957	1421	397	135	69	32	22	2	5	2	29571	29310	9693
1982	3	138	2473	7667	10123	3681	2568	1315	679	318	153	65	54	55	19	19	29330	29189	8926
1983	0	6	3507	8679	7484	6278	1905	1012	625	224	149	52	24	15	6	11	29977	29971	10301
1984	0	1	430	5778	9101	5678	3829	1250	544	290	153	63	34	17	8	5	27181	27180	11871
1985	0	4	156	2253	8151	7523	4284	2430	1063	452	284	173	68	20	17	15	26893	26889	16329
1986	0	3	124	4210	7640	9221	3589	1571	1123	447	285	105	66	11	19	18	28432	28429	16455
1987	0	0	38	877	5694	5885	6049	2733	1105	604	233	131	61	11	14	12	23447	23447	16838
1988	0	8	185	1512	2399	4531	4075	3295	1731	626	260	153	64	9	10	11	18869	18861	14765
1989	0	7	671	2544	4111	3334	3669	1796	2018	590	251	156	29	15	58	35	19284	19277	11951
1990	0	0	291	2329	3983	3659	2208	3212	1600	1879	328	135	55	15	14	13	19721	19721	13118
1991	0	1	277	3365	6790	4486	3348	1332	1356	861	457	154	65	10	6	5	22513	22512	12080
1992	0	2	571	2541	9251	6080	2125	1401	521	471	231	178	33	7	6	7	23425	23423	11060
1993	0	0	32	427	605	758	513	129	44	8	7	4	2	1	0	0	2530	2530	1466
1994	0	0	0	4	68	29	72	15	5	1	0	0	0	0	0	0	194	194	122
1995	0	0	6	14	45	51	21	18	8	2	0	0	0	0	0	0	165	165	100
1996	0	0	36	87	53	31	17	5	1.3	1.2	0.1	0	0	0	0	0	232	232	56
1997	0	0	2	14	28	16	17	17	7	3	3	1	0.4	1	0	0	109	109	65

Table 4b. Commercial catch at age for 4VsW cod adjusted for estimated 4TVn component in 1986-92.
(These data are used in the Sequential Population Analyses)

	Age																		
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1+	3+	6+
1970	1293	8631	8886	14802	13673	4539	1942	759	236	72	137	56	9	12	4	4	55055	45131	7770
1971	1984	12824	9643	5125	6612	5128	3419	1963	704	367	159	173	156	80	40	52	48429	33621	12241
1972	2046	15865	11801	11989	7384	6527	3308	1880	347	466	68	8	36	0	3	7	61735	43824	12650
1973	1218	10221	8001	5803	9634	3324	3370	4732	1684	389	551	8	21	21	18	47	49042	37603	14165
1974	1273	7321	13324	11695	6854	2247	669	1008	196	153	13	2	0	0	0	0	44755	36161	4288
1975	1538	8571	7402	3163	4788	3297	2943	623	497	686	172	123	41	6	6	19	33875	23766	8413
1976	513	2866	2860	4707	3900	2085	1287	447	136	53	12	47	0	4	0	2	18919	15540	4073
1977	1	23	532	1229	1591	845	490	199	118	33	42	44	11	3	2	6	5169	5145	1793
1978	34	94	1168	4078	4817	2582	767	247	107	75	31	27	28	10	1	2	14068	13940	3877
1979	12	93	1762	6559	9525	5056	1210	377	76	23	10	4	3	0	0	0	24710	24605	6759
1980	31	92	1765	4873	6937	6177	3050	1121	313	92	50	26	4	0	1	7	24539	24416	10841
1981	3	258	3200	9136	7281	4651	2957	1421	397	135	69	32	22	2	5	2	29571	29310	9693
1982	3	138	2473	7667	10123	3681	2568	1315	679	318	153	65	54	55	19	19	29330	29189	8926
1983	0	6	3507	8679	7484	6278	1905	1012	625	224	149	52	24	15	6	11	29977	29971	10301
1984	0	1	430	5778	9101	5678	3829	1250	544	290	153	63	34	17	8	5	27181	27180	11871
1985	0	4	156	2253	8151	7523	4284	2430	1063	452	284	173	68	20	17	15	26893	26889	16329
1986	0	3	124	4089	7098	7584	3368	1358	922	339	189	81	66	11	19	18	25269	25266	13955
1987	0	0	30	815	5400	5367	5465	2636	928	492	220	122	61	11	14	12	21573	21573	15328
1988	0	8	185	1507	2008	3920	3496	2782	1454	471	260	152	64	9	10	11	16337	16329	12629
1989	0	7	671	2544	4066	3133	3316	1244	1354	484	202	38	29	15	58	35	17196	17189	9908
1990	0	0	291	2264	3889	2577	1606	2936	891	1051	323	135	55	15	14	13	16060	16060	9616
1991	0	1	274	3237	6295	3589	608	629	327	61	432	69	65	10	6	5	15608	15607	5801
1992	0	2	568	2404	8232	5897	1690	652	185	285	84	108	33	7	6	7	20160	20158	8954
1993	0	0	32	427	605	758	513	129	44	8	7	4	2	1	0	0	2530	2530	1466
1994	0	0	0	4	68	29	72	15	5	1	0	0	0	0	0	0	194	194	122
1995	0	0	6	14	45	51	21	18	8	2	0	0	0	0	0	0	165	165	100
1996	0	0	36	87	53	31	17	5	1.3	1.2	0.1	0	0	0	0	0	232	232	56
1997	0	0	2	14	28	16	17	17	7	3	3	1	0.4	1	0	0	109	109	65

Table 5. 4VsW cod weights at age from commercial landings.

	Age																Ratio with catch
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1971	0.05	0.19	0.49	1.07	1.45	1.80	2.28	3.50	4.87	5.70	5.70	8.74	6.77	5.92	9.27	6.03	1.07
1972	0.07	0.40	0.80	1.11	1.40	1.84	2.29	2.88	4.82	4.56	7.57	11.56	6.31	.	14.49	8.73	1.12
1973	0.09	0.25	0.74	0.96	1.18	1.64	2.29	2.28	2.64	4.27	3.85	9.48	7.05	9.06	10.98	9.61	1.09
1974	0.13	0.31	0.68	1.18	1.74	2.17	2.59	2.47	3.24	3.62	4.87	9.58	.	.	.	.	1.09
1975	0.09	0.28	0.59	0.89	1.37	1.88	2.34	2.94	3.69	3.72	4.79	5.46	8.24	12.10	12.78	8.13	1.16
1976	0.08	0.26	0.55	1.04	1.50	2.26	3.33	4.37	4.85	5.57	7.39	3.38	14.23	11.54	22.97	15.50	1.04
1977	0.14	0.28	0.73	1.11	1.72	2.40	3.15	4.47	4.04	5.29	4.73	4.92	6.57	8.85	10.52	12.27	0.98
1978	0.07	0.47	0.93	1.21	1.63	2.33	3.39	4.76	5.34	6.19	7.91	8.57	9.61	10.30	8.37	12.04	1.01
1979	0.05	0.42	0.68	0.96	1.56	2.30	3.08	3.72	4.90	6.39	7.25	10.11	13.95	10.26	11.97	12.89	1.00
1980	0.07	0.51	0.80	1.16	1.59	2.22	3.10	4.26	5.38	6.96	7.42	10.01	8.75	10.53	13.97	17.80	1.00
1981	0.08	0.54	0.79	1.12	1.68	2.12	2.96	3.90	5.69	7.02	7.68	9.45	12.05	8.48	9.80	17.77	1.00
1982	0.10	0.55	0.77	1.04	1.53	2.33	2.73	3.99	5.34	6.84	8.53	8.88	10.90	10.43	13.34	14.92	1.00
1983	0.07	0.39	0.77	1.04	1.53	2.13	3.09	3.55	4.38	5.79	6.84	9.16	10.64	11.73	14.07	13.55	1.00
1984	.	0.54	0.74	1.06	1.50	2.06	2.69	3.64	4.03	5.19	7.09	8.44	9.28	10.58	12.63	13.21	1.00
1985	.	0.68	0.71	1.03	1.45	1.97	2.38	3.10	3.84	5.03	6.32	6.13	9.88	11.12	11.12	14.49	1.00
1986	.	0.27	0.68	0.95	1.26	1.65	2.38	2.74	3.67	4.99	5.30	6.87	10.18	9.57	11.89	14.52	1.00
1987	.	.	0.48	0.93	1.28	1.54	1.87	2.61	3.58	4.31	6.49	6.32	7.23	11.68	12.69	13.19	1.00
1988	.	0.35	0.63	0.97	1.26	1.73	1.92	2.37	2.79	3.67	4.92	7.06	7.65	11.17	12.16	14.76	1.00
1989	.	0.29	0.77	1.01	1.28	1.56	2.19	2.21	2.50	3.93	5.10	5.16	8.55	12.28	7.87	15.38	0.99
1990	.	.	0.76	1.00	1.23	1.40	1.68	2.27	2.18	2.17	4.38	6.19	8.49	12.33	10.38	11.41	1.00
1991	.	0.46	0.77	0.88	1.14	1.46	1.57	1.96	2.37	2.29	2.89	3.53	4.14	12.98	9.18	10.75	1.00
1992	.	0.19	0.63	0.79	1.01	1.31	1.76	1.84	1.96	2.72	2.49	2.60	5.67	13.53	12.83	12.97	1.00
1993	.	.	0.57	0.86	1.05	1.39	1.79	2.21	4.05	3.71	7.75	4.78	11.02	13.44	14.27	16.01	1.03
1994	.	.	0.69	1.28	1.53	1.83	1.80	2.12	2.70	2.85	.	.	.	.	.	.	0.92
1995	.	.	0.69	0.87	1.25	1.69	2.06	2.34	3.08	4.28	.	8.09	.	.	.	.	0.99
1996	.	.	0.66	0.93	1.41	1.86	2.48	2.67	3.49	4.41	7.39	.	.	.	.	.	0.98
1997	.	.	0.55	0.80	1.04	1.93	2.00	3.26	3.93	5.40	5.46	5.53	6.07	5.63	.	.	1.02

Table 6. Estimated seal consumption of 4VsW cod in numbers at age and total biomass under three models of seal predation on cod. The fractions refer to the fraction of the seals total diet biomass being taken as cod.

6a.) Constant proportion of cod in seal diet.

	Age								Biomass	Fraction in
Year	1	2	3	4	5	6	7	8	(tonnes)	seal diet
1970	2971	1302	378	184	84	51	31	19	1286	0.126
1971	3262	1430	415	202	92	56	34	21	1411	0.126
1972	3599	1578	458	223	102	62	37	23	1557	0.126
1973	3984	1746	507	247	113	68	41	25	1724	0.126
1974	4377	1919	558	271	124	75	46	28	1894	0.126
1975	4744	2079	604	294	134	81	49	30	2053	0.126
1976	5280	2315	673	327	149	91	55	33	2285	0.126
1977	5808	2546	740	360	164	100	60	37	2513	0.126
1978	6441	2823	821	399	182	110	67	41	2787	0.126
1979	7147	3133	910	443	202	123	74	45	3093	0.126
1980	7891	3459	1005	489	223	135	82	50	3415	0.126
1981	8702	3815	1109	539	246	149	90	55	3766	0.126
1982	9606	4211	1224	595	272	165	100	61	4157	0.126
1983	10580	4638	1348	655	299	181	110	67	4579	0.126
1984	11862	5200	1511	735	335	203	123	75	5133	0.126
1985	13274	5819	1691	822	375	228	138	84	5744	0.126
1986	14858	6513	1893	920	420	255	155	94	6430	0.126
1987	16622	7286	2117	1029	470	285	173	105	7193	0.126
1988	18587	8148	2368	1151	525	319	193	117	8043	0.126
1989	20794	9115	2649	1288	588	357	216	131	8999	0.126
1990	23269	10200	2964	1441	658	399	242	147	10069	0.126
1991	26041	11415	3317	1613	736	446	271	164	11269	0.126
1992	29144	12775	3713	1805	824	500	303	184	12612	0.126
1993	32616	14297	4155	2020	922	559	339	206	14114	0.126
1994	36504	16001	4650	2261	1032	626	380	230	15797	0.126
1995	40858	17910	5205	2530	1155	700	425	258	17681	0.126
1996	45737	20048	5826	2833	1293	784	476	288	19792	0.126
1997	51202	22444	6522	3171	1447	878	532	323	22157	0.126

6b.) Variable (Lotka-Volterra) proportion of cod in seal diet.

	Age								Biomass	Percent in
Year	1	2	3	4	5	6	7	8	(tonnes)	seal diet
1970	2094	1012	381	209	113	68	42	25	1302	0.128
1971	1796	859	316	179	101	61	37	23	1127	0.101
1972	2140	1061	422	219	110	67	41	25	1336	0.108
1973	2382	1186	476	229	103	63	38	23	1393	0.102
1974	3580	1554	438	209	93	56	34	21	1487	0.099
1975	6956	2662	417	204	95	57	35	21	2001	0.123
1976	5251	2180	521	236	95	58	35	21	1843	0.102
1977	4712	2215	782	343	129	78	47	29	2202	0.111
1978	11092	4637	1140	536	231	140	85	51	4090	0.185
1979	7777	3616	1242	615	290	176	107	65	3984	0.163
1980	7305	3822	1682	791	341	207	125	76	4626	0.171
1981	13232	6321	2317	1069	444	269	163	99	6735	0.226
1982	17396	8230	2949	1346	548	332	202	122	8568	0.26
1983	17148	8829	3776	1691	663	402	244	148	9970	0.275
1984	15233	7791	3292	1621	756	458	278	169	9661	0.237
1985	16714	8561	3627	1838	895	543	329	200	10960	0.241
1986	22410	10108	3200	1744	938	569	345	209	11636	0.228
1987	31404	11991	1847	1189	762	462	281	170	10744	0.188
1988	34495	13415	2326	1261	675	409	248	151	11255	0.177
1989	23324	10774	3639	1652	665	404	245	148	10805	0.151
1990	12150	6787	3320	1507	607	368	223	135	8437	0.106
1991	13030	5776	1738	928	487	295	179	109	6334	0.071
1992	12182	4874	987	592	355	215	130	79	4750	0.048
1993	10639	4220	818	407	193	117	71	43	3494	0.031
1994	13420	5121	785	414	213	129	78	48	4001	0.032
1995	15063	5485	563	358	227	138	84	51	4104	0.029
1996	17114	6184	582	337	195	118	72	43	4272	0.027
1997	18205	6525	554	335	203	123	75	45	4457	0.025

6c.) Constrained proportion of cod in seal diet.

	Age								Biomass	Percent in
Year	1	2	3	4	5	6	7	8	(tonnes)	seal diet
1970	2620	1186	379	194	96	58	35	21	1292	0.127
1971	1796	859	316	179	101	61	37	23	1127	0.101
1972	2140	1061	422	219	110	67	41	25	1336	0.108
1973	2382	1186	476	229	103	63	38	23	1393	0.102
1974	3580	1554	438	209	93	56	34	21	1487	0.099
1975	6956	2662	417	204	95	57	35	21	2001	0.123
1976	5251	2180	521	236	95	58	35	21	1843	0.102
1977	4712	2215	782	343	129	78	47	29	2202	0.111
1978	8301	3549	948	454	201	122	74	45	3308	0.15
1979	7399	3326	1043	512	237	144	87	53	3450	0.141
1980	7657	3604	1276	610	270	164	99	60	3899	0.144
1981	10514	4817	1592	751	325	197	120	73	4954	0.166
1982	12722	5818	1914	895	382	232	141	85	5921	0.18
1983	13207	6314	2319	1070	445	270	164	99	6735	0.186
1984	13211	6236	2223	1089	503	305	185	112	6944	0.171
1985	14650	6916	2465	1228	583	354	215	130	7630	0.172
1986	17879	7951	2416	1250	627	380	231	140	8512	0.167
1987	22535	9168	2009	1093	587	356	216	131	8613	0.151
1988	24950	10255	2351	1195	585	355	215	131	9328	0.146
1989	21806	9779	3045	1433	619	375	228	138	9721	0.136
1990	12150	6787	3320	1507	607	368	223	135	8437	0.106
1991	13030	5776	1738	928	487	295	179	109	6334	0.071
1992	12182	4874	987	592	355	215	130	79	4750	0.048
1993	10639	4220	818	407	193	117	71	43	3494	0.031
1994	13420	5121	785	414	213	129	78	48	4001	0.032
1995	15063	5485	563	358	227	138	84	51	4104	0.029
1996	17114	6184	582	337	195	118	72	43	4272	0.027
1997	18205	6525	554	335	203	123	75	45	4457	0.025

Table 7. 4VsW Cod July RV mean catch per tow. Years 1970-81 are adjusted by a factor of 1.70 based on NLLS-estimated change in catchability.

	Age																	Totals		
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Unk	Age 0+	Age 3+	Age 6+
1970	0.06	0.89	10.06	3.53	5.49	2.72	0.89	1.06	0.34	0.06	0.15	0.17	0.06	0.11	.	.	.	25.62	14.59	2.85
1971	0.02	0.94	4.68	21.74	4.89	9.64	3.53	2.11	0.89	0.38	0.04	0.09	0.04	0.13	.	.	.	49.12	43.49	7.21
1972	.	3.79	5.89	7.25	19.23	3.55	3.66	0.98	0.34	0.30	0.09	.	.	.	.	.	.	45.08	35.40	5.36
1973	.	3.91	26.79	42.10	34.19	13.70	1.13	1.77	0.55	0.26	0.32	0.11	.	.	0.13	0.02	.	124.97	94.27	4.28
1974	0.53	3.15	20.10	11.77	3.45	1.23	1.36	0.23	0.28	0.13	0.11	0.04	0.04	.	.	0.04	.	42.46	18.68	2.23
1975	0.04	2.02	5.17	8.00	3.74	1.83	0.40	0.49	0.13	0.26	0.02	.	0.04	.	.	.	.	22.15	14.91	1.34
1976	.	1.43	7.87	8.98	5.53	3.51	0.68	0.32	0.55	.	0.38	0.04	.	0.09	.	.	.	29.38	20.08	2.06
1977	.	0.45	5.85	14.83	9.64	6.00	2.64	0.57	0.38	0.09	.	0.06	0.04	.	.	.	.	40.55	34.25	3.79
1978	0.11	1.87	7.98	19.06	20.85	5.77	2.13	0.53	0.11	0.06	0.04	.	.	.	.	.	0.04	58.55	48.59	2.91
1979	0.62	0.74	6.47	9.79	10.13	11.02	5.51	1.64	0.62	0.26	0.04	0.02	.	0.02	.	.	.	46.87	39.04	8.11
1980	0.02	0.43	4.28	11.30	6.25	10.59	7.38	2.91	0.79	0.21	0.17	0.06	.	.	.	.	.	44.40	39.68	11.53
1981	0.04	2.83	7.77	11.77	17.96	6.85	4.91	2.53	0.94	0.30	0.34	0.09	0.02	0.02	.	0.02	.	56.38	45.74	9.17
1982	.	0.91	78.68	65.75	22.96	5.15	2.79	1.50	0.64	0.14	0.15	0.08	.	.	.	.	.	178.74	99.15	5.29
1983	0.02	13.72	13.31	44.47	19.25	9.88	4.42	0.99	0.55	0.14	0.08	0.04	0.02	0.02	.	.	.	106.91	79.86	6.26
1984	0.07	0.41	7.27	12.82	19.09	12.94	6.01	4.13	0.41	0.33	0.10	0.23	0.01	0.01	0.01	.	.	63.84	56.09	11.24
1985	.	1.29	1.68	7.88	9.56	9.32	5.12	2.56	1.01	0.48	0.11	0.11	0.07	.	.	0.01	.	39.20	36.23	9.47
1986	0.03	0.36	1.32	1.53	6.16	3.89	3.26	1.15	0.55	0.24	0.15	0.04	.	0.02	.	.	.	18.70	16.99	5.41
1987	0.04	0.64	1.51	4.97	4.83	8.86	3.61	2.71	1.47	0.34	0.02	0.08	0.04	0.01	.	0.03	.	29.16	26.97	8.31
1988	0.07	0.06	4.70	7.29	5.89	3.27	3.41	1.95	0.98	0.22	0.05	0.12	0.02	.	0.02	.	.	28.05	23.22	6.77
1989	0.03	0.25	8.86	7.38	5.01	3.47	1.35	2.00	0.47	0.32	0.01	.	0.02	0.01	.	.	.	29.18	20.04	4.18
1990	.	0.13	5.06	18.22	8.64	3.83	1.41	0.60	0.29	0.11	0.07	.	.	.	.	.	.	38.35	33.16	2.47
1991	.	0.47	1.82	3.38	6.97	4.91	1.63	0.43	0.19	0.24	0.07	0.05	0.02	.	.	.	.	20.17	17.88	2.63
1992	.	1.69	5.02	6.60	4.08	2.59	0.88	0.15	0.07	0.04	0.02	.	.	.	0.01	.	.	21.14	14.44	1.16
1993	0.01	0.09	1.00	6.36	7.18	5.66	3.16	1.10	0.27	0.00	0.02	.	.	.	.	.	.	24.85	23.75	4.55
1994	0.06	0.11	1.30	2.81	2.39	1.11	0.49	0.51	0.06	0.04	0.04	0.02	.	.	.	.	.	8.93	7.46	1.16
1995	0.21	0.18	0.66	2.39	2.41	1.91	0.77	0.42	0.49	0.07	.	.	.	.	.	.	.	9.52	8.46	1.75
1996	0.01	0.42	2.14	1.62	0.92	0.65	0.35	0.10	0.05	0.01	0.01	.	.	.	.	.	.	6.28	3.71	0.52
1997	.	0.05	0.59	0.85	0.61	0.23	0.02	0.08	0.04	.	.	.	.	.	.	.	0.12	2.61	1.97	0.27
																				3
																		2.12	2.13	3.53

Table 8. 4VsW Cod March RV mean catch per tow

	Age																	Totals		
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	0+	3+	6+
1979	.	0.26	2.12	0.89	0.6	1.37	1.02	0.47	0.29	0.07	0.1	0.08	0.02	0.03	0.01	0.01	.	7.34	4.96	2.10
1980	.	0.86	2.71	2.04	1.67	2.52	2.90	1.43	0.3	0.06	0.03	0.01	.	0.01	.	.	.	14.54	10.97	4.74
1981	.	8.25	3.80	5.29	7.79	4.87	5.76	3.20	1.53	0.18	0.14	0.03	0.02	.	.	.	.	40.86	28.81	10.86
1982	.	2.65	22.22	17.91	11.84	7.24	1.99	1.36	1.08	0.28	0.14	0.06	0.03	0.01	.	0.01	0.01	66.83	41.96	4.97
1983	.	0.85	3.17	42.14	25.52	4.96	5.85	1.32	0.62	0.29	0.1	0.04	0.04	0.01	0.04	.	.	84.95	80.93	8.31
1984	.	0.22	1.49	1.85	9.37	6.21	2.92	2.53	0.77	0.5	0.2	0.02	0.09	.	0.01	.	0.02	26.20	24.49	7.06
1985	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1986	.	0.19	10.88	19.44	23.58	11.67	13.13	6.27	1.34	0.73	0.28	0.04	0.05	0.01	0.01	.	0.01	87.63	76.56	21.87
1987	.	0.35	0.92	2.87	4.50	10.14	4.82	3.32	1.2	0.24	0.1	0.04	0.03	0.03	0.01	.	.	28.57	27.30	9.79
1988	.	0.60	7.96	9.49	4.26	4.32	4.88	1.43	1.87	0.46	0.19	0.18	0.04	0.02	.	0.03	.	35.73	27.17	9.10
1989	.	0.58	17.96	10.40	4.23	4.80	1.68	0.70	0.22	0.25	0.05	0.03	0.02	.	0.01	0.02	.	40.95	22.41	2.98
1990	.	0.12	1.60	5.08	2.56	0.86	0.31	0.19	0.36	0.13	0.12	0.04	0.03	0.01	.	.	.	11.41	9.69	1.19
1991	.	0.02	3.50	12.15	21.92	5.09	1.49	0.35	0.02	0.1	.	0.01	0	0.02	0.01	.	.	44.68	41.16	2.00
1992	.	0.07	0.52	0.25	0.25	0.49	0.31	0.11	0.05	0.02	.	0.01	0.03	0.01	.	.	.	2.12	1.53	0.54
1993	.	0.03	2.86	5.62	3.83	2.43	1.08	0.16	0.08	0.01	.	.	.	.	.	.	.	16.10	13.21	1.33
1994	.	0.10	0.16	0.30	0.83	0.46	0.68	0.33	0.26	0.03	0.02	.	.	.	.	.	.	3.17	2.91	1.32
1995	.	0.23	0.39	0.63	1.19	2.05	0.48	0.25	0.12	0.002	0.01	.	.	.	.	.	.	5.35	4.73	0.86
1996	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1997	.	0.16	6.88	17.08	13.56	4.70	3.88	1.03	0.68	0.36	0.32	.	.	.	.	.	.	48.64	41.60	6.27

Table 9. Mean length at age in 4Vs and 4W cod from July RV surveys.

SubDivision 4Vs

Year	Age 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
70	7.00	16.78	26.63	42.89	48.68	53.87	59.25	64.05	65.09	97.00	82.00	70.06		73.51		
71	.	.	29.20	35.70	45.02	52.38	56.31	56.69	63.40	70.00	70.00			67.00		
72	.	22.99	32.21	42.65	44.51	52.52	56.69	57.33	64.24	89.79	60.15					
73	.	21.56	31.66	40.04	46.93	53.01	65.46	67.12	62.55	82.00	.	79.43		.	.	82.00
74	.	21.11	30.94	38.72	47.84	54.20	58.83	62.67	68.71	68.37	82.92	97.00		.	.	115.00
75	.	20.84	32.87	40.89	47.31	54.52	60.69	67.09	70.45	75.76	88.00					
76	.	19.56	29.62	35.95	45.43	56.34	64.57	71.60	70.11	.	81.27			100.00		
77	.	25.01	28.88	40.21	48.18	56.80	65.70	72.13	81.80	82.12		83.68				
78	.	20.58	36.42	43.13	49.59	58.05	68.39	75.71	79.00	85.00	88.00			.	.	.
79	.	16.72	31.14	37.44	47.08	53.96	63.27	75.38	84.39	88.77	97.00	93.53	112.00	94.00		
80	.	16.00	26.04	41.68	48.09	55.72	63.96	71.75	78.33	98.89	96.88	105.20				
81	.	19.62	34.78	40.89	51.07	58.02	63.36	71.31	84.58	91.98	100.83	100.00	112.00	109.00	.	115.00
82	.	14.06	30.36	37.17	44.78	55.69	62.69	66.07	71.95	81.69	86.92	96.49		.	103.00	
83	.	16.41	25.64	39.59	48.34	54.76	62.68	71.41	73.06	84.81	79.00	100.29	109.00	109.00		
84	.	19.63	31.10	39.60	47.71	55.95	59.43	62.92	76.27	67.76	72.00	100.46	115.00	91.00	109.00	
85	.	18.21	26.72	35.98	43.44	50.35	56.78	61.71	68.42	72.49	77.39	92.92	71.27	.	.	133.00
86	10.00	13.00	26.65	35.78	45.08	51.60	56.44	61.68	64.56	74.97	83.17	92.55		106.00		
87	.	14.53	27.83	36.57	43.78	51.46	55.23	58.90	62.82	68.13	78.00	87.97	95.14	112.00	.	113.60
88	7.00	.	28.12	36.09	42.27	52.56	56.16	57.85	64.45	69.23	84.00	86.84	91.00	.	106.14	
89	.	25.00	28.69	36.24	44.33	50.20	54.25	62.03	65.56	63.59	91.60	106.00	107.20	100.00		
90	10.00	14.74	29.02	33.66	41.63	51.64	55.32	65.34	71.08	69.85	70.85					
91	.	19.00	27.36	37.16	42.77	49.43	56.67	61.59	72.16	76.41	73.03	88.18	103.00			
92	.	.	29.41	36.09	43.18	49.87	56.54	55.12	65.15	67.37	94.00				94.00	
93	.	12.52	26.93	34.31	42.38	49.79	52.32	56.49	78.55							
94	.	17.78	27.78	34.10	41.06	47.82	52.89	60.05	67.88	64.56	82.00	97.00				
95	8.08	17.50	28.89	35.01	43.58	47.09	51.24	54.60	57.99	52.06						
96	10.00	26.11	31.35	35.73	41.72	51.22	53.27	56.29	59.72	79.00	58.00					
97	.	25.00	29.87	36.91	42.49	47.98	49.00	60.02	67.00							

Division 4W

Year	Age 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
70	10.00	20.32	35.79	46.32	53.34	61.95	72.50	77.98	79.67	79.00	83.46	.	112.00			
71	7.00	17.05	25.69	37.76	51.80	56.00	59.65	67.77	69.36	73.14	.	67.00	100.00			
72	.	19.72	31.45	43.15	55.27	60.47	67.77	82.00	79.00	98.00						
73	.	21.64	29.66	40.61	48.28	52.06	60.65	57.98	69.40	61.00	95.74	.	.	.	97.00	
74	9.05	24.87	32.21	38.94	48.65	55.85	64.83	75.70	74.59	63.46	73.00	.	88.00			
75	10.00	21.74	29.30	37.98	46.67	56.13	66.96	80.05	.	88.07	.	.	100.00			
76	.	21.07	30.66	38.14	46.84	52.25	60.09	69.34	.	.	.	88.00				
77	.	23.96	32.48	41.43	48.16	59.06	64.24	71.45	85.03	.	.	.	76.00			
78	9.55	20.15	34.72	42.18	50.73	57.98	66.52	67.39	79.36	100.00	118.00	.	.	.	.	.
79	9.05	17.15	29.70	37.00	46.41	52.20	60.04	68.00	75.00	69.41						
80	8.29	19.62	32.40	38.98	46.15	52.06	58.35	61.84	81.35	71.50						
81	7.89	20.67	29.31	40.57	47.06	54.88	57.39	61.10	64.72	80.55	79.00	94.00				
82	7.00	18.68	31.55	37.19	42.30	49.57	55.39	60.66	65.71	64.77						
83	7.00	19.80	29.39	37.91	47.04	51.64	58.22	61.72	61.46	64.00						
84	11.01	21.24	28.69	37.93	44.22	52.90	56.77	59.56	65.49	72.98	70.00	68.52				
85	.	18.24	23.70	34.98	42.26	49.65	54.71	60.04	66.74	77.81	.	88.00	100.00			
86	10.00	20.41	29.99	37.03	42.90	53.74	59.87	63.47	71.87	74.90	72.51					
87	7.00	17.31	25.71	36.01	41.63	48.02	53.40	58.35	58.44	97.00						
88	9.23	19.60	30.04	34.84	42.19	50.64	56.22	58.69	61.57	59.74						
89	7.00	17.77	31.86	38.18	43.68	50.98	52.39	75.78	74.30	85.00						
90	.	20.50	29.51	36.58	42.57	47.81	54.78	55.18	64.00							
91	.	11.17	29.55	35.31	41.06	46.06	48.08	51.25	55.81	.	.	55.00				
92	.	18.55	22.87	32.89	36.80	43.23	45.28	52.92	50.41	94.00						
93	7.00	14.36	27.62	32.78	40.26	44.50	45.57	49.80	51.62	94.00	70.00					
94	10.02	22.40	29.29	33.15	37.05	40.80	46.41	48.49	52.00	.	73.00					
95	8.53	19.33	27.90	34.00	37.78	40.30	42.29	45.65	45.66	49.00						
96	.	18.98	27.53	34.07	39.25	44.27	45.61	50.83	54.62							
97	8.26	23.16	26.63	34.40	39.65	47.66	.	.	49.00							

Table 10. Statistics from ADAPT model fit for 4VsW cod full model run.

Log survivor estimates			Survey q's	
Age	Estimate	SE	July	March
3	7.56807	0.905969	0.34	0.12
4	7.34633	0.680716	0.41	0.16
5	6.78729	0.559422	0.39	0.19
6	6.00189	0.54197	0.3	0.2
7	7.11949	0.353705	0.28	0.16
8	6.12164	0.374761	0.25	0.14
9	3.38885	0.349067		0.09
10	6.19668	0.361103		

Bootstrap estimates of bias and bias adjustments						
Ages	Survivors	Bootstrap mean	Bias	Relative bias	Adjusted survivors	Bootstrap CV
1	0	0	0	1	0	1
2	22476	22411	-66	0	22542	0.09
3	4948	5052	104	0.02	4844	0.2
4	1935	2699	763	0.39	1172	0.78
5	1551	1822	271	0.18	1279	0.62
6	887	1008	121	0.14	765	0.57
7	404	466	62	0.15	342	0.54
8	1236	1321	85	0.07	1151	0.36
9	456	497	41	0.09	414	0.38
10	30	31	2	0.05	28	0.34
11	491	516	25	0.05	466	0.33
12	187	195	8	0.04	179	0.3
13	31	32	1	0.04	30	0.3
14	11	11	0	0.04	10	0.3
15	14	15	1	0.04	13	0.31

Table 11. Residuals from 4VsW cod ADAPT full model run.

	July RV						March RV							
	Age						Age							
Year	3	4	5	6	7	8	3	4	5	6	7	8	9	Ages 3-9
1970	-0.89	-0.68	-1.14	-1.21	0	-0.56	.	.	.	.	.	.	.	-0.75
1971	0.54	-0.27	0.49	-0.02	0.31	0.87	.	.	.	.	.	.	.	0.32
1972	-0.22	0.78	0.17	0.52	-0.69	-0.69	.	.	.	.	.	.	.	-0.02
1973	1.55	1.67	1.27	0.29	0.84	0.05	.	.	.	.	.	.	.	0.95
1974	0.63	-0.43	-0.92	-0.06	-0.49	0.15	.	.	.	.	.	.	.	-0.19
1975	0.08	-0.11	-0.18	-0.87	-0.02	-0.07	.	.	.	.	.	.	.	-0.20
1976	-0.11	0.02	0.47	-0.04	-0.04	1.21	.	.	.	.	.	.	.	0.25
1977	0.06	0.06	0.54	1	0.5	0.93	.	.	.	.	.	.	.	0.52
1978	0.45	0.5	-0.05	0.26	-0.05	-0.46	.	.	.	.	.	.	.	0.11
1979	-0.19	-0.01	0.37	0.74	0.58	0.69	-1.84	-2.29	-1.39	-0.97	-0.51	0.1	0.05	-0.36
1980	-0.46	-0.48	0.57	0.86	0.84	0.61	-1.43	-1.24	-0.54	-0.1	0.21	-0.26	-0.48	-0.15
1981	-0.36	0.16	0.14	0.67	0.47	0.55	-0.42	-0.11	0.12	0.81	0.83	1.14	0.3	0.33
1982	0.9	0.26	-0.78	-0.16	-0.04	-0.42	0.57	0.38	0.11	-0.26	0.2	0.47	0.58	0.14
1983	0.3	-0.18	-0.11	-0.1	-0.63	-0.31	1.21	0.9	-0.22	0.4	0.05	0.17	0.12	0.12
1984	-0.5	-0.44	-0.12	0.17	0.48	-0.86	-1.47	-0.34	-0.27	-0.32	0.34	0.16	0.95	-0.17
1985	-1.19	-0.71	-0.79	-0.28	-0.03	-0.11	.	.	.	.	.	.	.	-0.52
1986	-2.14	-1.22	-1.08	-1.04	-1.12	-0.76	1.29	0.87	0.54	0.55	0.91	0.45	1.07	-0.13
1987	-0.86	-0.69	-0.27	-0.16	-0.47	0.04	-0.51	-0.01	0.41	0.29	0.03	0.11	-0.11	-0.17
1988	-0.63	-0.37	-0.51	-0.32	0.18	-0.6	0.52	0.05	0.32	0.24	0.09	0.34	0.48	-0.02
1989	-0.84	-0.66	-0.16	-0.36	-0.04	-0.13	0.4	-0.1	0.63	-0.02	-0.81	-0.65	-0.42	-0.24
1990	0.3	-0.35	-0.23	0.16	-0.11	-0.49	-0.09	-0.83	-1.23	-1.3	-1.06	-0.28	0.41	-0.39
1991	0.14	-0.3	-0.19	0.16	-0.03	0.07	2.21	1.52	0.27	-0.1	-0.2	-1.64	0.58	0.19
1992	0.91	1.11	-0.28	-0.38	-0.66	-0.1	-1.51	-1.16	-1.62	-1.54	-1	-0.62	-0.32	-0.55
1993	0.66	1.41	2.6	1.08	0.99	1.45	1.42	1.5	2.14	0.21	-0.64	0.45	0	1.02
1994	0.88	-0.02	0.12	1.29	-0.16	-1.17	-0.51	-0.32	-0.19	1.79	-0.19	0.68	0.78	0.23
1995	0.64	1.15	0.26	0.54	2	0.4	0.17	1.17	0.92	0.31	1.74	-0.61	-3.98	0.36
1996	0.31	0.09	0.5	-0.7	-0.95	0.94	.	.	.	.	.	.	.	0.03
1997	0.02	-0.27	-0.67	-2.07	-1.66	-1.23	.	.	.	.	.	.	.	-0.98

Table 12. Population numbers at age (thousands) in 4VsW cod full model run.

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Ages 1-15
1970	91183	82854	41764	48156	40290	17447	6663	3883	902	373	487	323	132	101	17	334575
1971	90345	71114	58952	25810	25858	20528	10125	3666	2473	525	240	274	214	100	72	310296
1972	73461	70548	45842	39255	16332	15096	12112	5162	1205	1388	98	53	68	34	10	280664
1973	69304	56357	42444	26473	21093	6591	6394	6886	2503	673	715	19	36	23	28	239539
1974	85513	53483	35819	27080	16216	8459	2332	2151	1336	526	199	87	8	10	0	233219
1975	103744	65621	35758	16874	11400	6991	4842	1273	830	916	292	151	69	7	9	248777
1976	86320	77252	43561	22201	10768	4916	2688	1270	459	230	129	83	12	19	0	249908
1977	85326	65458	58683	32606	13704	5202	2086	1005	616	253	140	95	26	10	12	265222
1978	127266	65594	51567	46857	25272	9664	3424	1222	617	397	177	77	38	11	5	332188
1979	121169	96655	50408	40304	34262	16150	5465	2042	736	408	257	117	39	6	0	368018
1980	150569	92499	76040	38733	26600	19219	8518	3301	1283	534	313	202	92	29	5	417937
1981	187558	116320	72387	59505	26751	15257	9997	4124	1634	767	354	211	142	72	24	495103
1982	129089	144043	90642	54930	39772	15019	8105	5401	2025	978	506	227	144	96	57	491034
1983	152939	94175	112543	70242	37225	23058	8756	4185	3155	1044	513	276	127	69	29	508336
1984	98475	113266	71385	86871	48688	23303	12953	5297	2421	2018	652	285	179	82	43	465918
1985	109897	68671	87090	56044	64910	31172	13665	6973	3104	1490	1390	395	177	116	52	445146
1986	155687	76720	49962	68931	42735	45241	18395	7118	3393	1580	811	881	167	83	76	471780
1987	191957	89722	44915	31411	41835	22321	23805	9384	3545	1519	781	389	524	58	47	462213
1988	163878	110223	52636	28438	19493	23141	10277	11306	4025	1616	616	344	161	301	30	426485
1989	66488	89423	65482	33207	16850	10944	12012	3850	5194	1507	698	200	106	55	195	306211
1990	48986	26715	51930	40852	19003	7459	4463	5151	1449	2373	614	302	103	47	25	209472
1991	51953	22889	12350	31853	24296	9057	2589	1494	938	242	730	147	92	24	19	158673
1992	32740	24157	10613	6631	17941	10734	2891	1091	398	361	112	136	42	9	8	107864
1993	32643	11972	12201	5841	1993	4996	2191	447	133	115	9	7	3	1	0	72552
1994	35817	13171	4570	7483	3233	683	2633	990	159	53	71	0	1	0	0	68864
1995	35068	13021	4636	2421	4673	1936	328	1641	613	103	35	47	0	1	0	64523
1996	39826	11174	4237	2642	1318	2910	1144	134	1044	404	68	23	32	0	0	64956
1997	39826	9581	2427	2335	1424	681	1828	694	50	699	270	45	16	21	0	59897

Table 13. Population biomass (mt) for 4VsW cod from full model run.

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Ages 5-15
1970	2309	10213	13757	44386	52217	27903	12261	11522	4063	2125	2240	3212	957	478	129	117107
1971	2287	7022	18186	18659	32179	33119	20511	10356	10211	2768	1369	1937	1647	633	532	115262
1972	1307	9914	18140	28917	19998	24625	24590	13228	4949	6541	644	428	506	244	88	95841
1973	2557	7485	22948	23182	24121	9986	13124	15736	6902	3051	2995	159	324	176	254	76828
1974	4120	8991	14871	25348	20879	13513	4805	5116	3630	1625	906	526	68	90	0	51158
1975	9190	12520	15326	13181	14509	12629	10910	3512	2507	3181	1215	778	614	63	99	50017
1976	4571	11817	17079	17325	12452	8643	6726	4060	1734	1043	678	335	108	190	0	35969
1977	3649	9797	25566	25407	18348	9866	5566	3877	2587	1281	721	573	121	112	136	43188
1978	9724	16826	26328	43983	33901	19357	9765	4730	3012	1987	1146	490	262	91	47	74788
1979	3331	16256	28518	38044	47060	31242	14640	7251	3554	2383	1725	1046	422	58	0	109381
1980	2355	14785	43729	34351	32864	35800	22744	11956	5739	3117	2157	1719	867	350	57	117370
1981	4745	22531	45963	56174	37274	28056	25628	14340	8042	4714	2587	1769	1556	619	240	124825
1982	3935	30242	58345	49686	52087	29724	19498	18563	9242	6102	3914	1877	1461	1077	606	144151
1983	7715	18669	73401	63011	46843	41624	23495	13028	13190	5803	3510	2437	1237	780	350	152297
1984	2482	22021	38496	78584	60841	41330	31006	17766	9156	9621	4176	2168	1647	875	522	179108
1985	4214	17907	53926	48929	80473	53585	30258	20136	11606	6707	7959	2605	1612	1174	565	216680
1986	9475	12606	33974	56612	48684	69977	39830	18176	11443	6915	4186	5804	1319	807	880	208021
1987	12942	13308	16169	24979	46133	31093	41815	23388	11102	6042	4447	2250	3694	632	514	171110
1988	8760	20621	19596	19404	21101	34436	17671	23801	10861	5859	2835	2326	1117	2708	355	123070
1989	3904	15228	33994	26489	18775	15343	23381	7931	12643	4992	3019	1007	823	536	1825	90275
1990	3303	3962	24380	35847	21180	9985	7226	11484	3181	5527	2548	1699	680	485	280	64275
1991	2422	4909	5083	26049	25941	12137	3838	2711	2175	541	1829	579	467	251	206	50675
1992	2375	3330	5713	5172	16915	13117	4634	1854	779	916	268	372	189	64	101	39209
1993	2201	1776	4015	4299	1815	5920	3355	882	362	310	40	22	14	11	0	12731
1994	2415	1954	1780	6391	3708	946	4165	1929	388	180	272	0	8	1	0	11597
1995	2364	1931	1769	1935	6287	3266	699	3597	1667	355	159	299	0	7	1	16337
1996	2685	1657	1469	1920	1290	4810	2206	382	3380	1754	332	148	246	0	5	14553
1997	2685	1421	926	1660	1512	944	4002	1604	170	2908	1705	335	116	165	0	13461

Table 14. Seal exploitation mortality at age in 4VsW cod from full model run.

	Age								
Year	1	2	3	4	5	6	7	8	Age 1-8
1970	0.03	0.02	0.01	0.01	0	0	0.01	0.01	0.01
1971	0.02	0.02	0.01	0.01	0.01	0	0.01	0.01	0.01
1972	0.03	0.02	0.01	0.01	0.01	0.01	0	0.01	0.01
1973	0.04	0.03	0.01	0.01	0.01	0.02	0.01	0.01	0.02
1974	0.05	0.04	0.02	0.01	0.01	0.01	0.02	0.02	0.02
1975	0.08	0.05	0.01	0.02	0.01	0.01	0.01	0.03	0.03
1976	0.07	0.03	0.01	0.01	0.01	0.02	0.02	0.02	0.02
1977	0.06	0.04	0.01	0.01	0.01	0.02	0.03	0.04	0.03
1978	0.07	0.06	0.02	0.01	0.01	0.02	0.03	0.05	0.03
1979	0.07	0.04	0.02	0.02	0.01	0.01	0.02	0.03	0.03
1980	0.06	0.04	0.02	0.02	0.01	0.01	0.02	0.03	0.03
1981	0.06	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.03
1982	0.12	0.05	0.02	0.02	0.01	0.02	0.02	0.02	0.04
1983	0.1	0.08	0.02	0.02	0.02	0.02	0.02	0.03	0.04
1984	0.16	0.06	0.04	0.01	0.01	0.02	0.02	0.03	0.04
1985	0.16	0.12	0.03	0.03	0.01	0.01	0.02	0.03	0.05
1986	0.15	0.14	0.06	0.02	0.02	0.01	0.02	0.03	0.06
1987	0.15	0.13	0.06	0.04	0.02	0.02	0.01	0.02	0.06
1988	0.2	0.12	0.06	0.05	0.04	0.02	0.03	0.02	0.07
1989	0.51	0.14	0.06	0.06	0.05	0.05	0.03	0.06	0.12
1990	0.36	0.37	0.08	0.05	0.05	0.08	0.08	0.06	0.14
1991	0.36	0.36	0.19	0.04	0.03	0.06	0.11	0.14	0.16
1992	0.6	0.27	0.12	0.16	0.04	0.04	0.1	0.18	0.19
1993	0.5	0.54	0.08	0.09	0.16	0.03	0.05	0.15	0.20
1994	0.59	0.6	0.22	0.06	0.08	0.27	0.03	0.06	0.24
1995	0.7	0.65	0.14	0.18	0.06	0.08	0.39	0.03	0.28
1996	0.37	0.88	0.15	0.15	0.17	0.05	0.07	0.49	0.29
1997	0.17	0.27	0.15	0.14	0.15	0.19	0.05	0.07	0.15

Table 15. Fishing mortality at age in 4VsW cod due to fishery only from full model run (excludes removals by seals).

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Ages 5-15
1970	0.02	0.12	0.27	0.42	0.47	0.34	0.39	0.24	0.34	0.24	0.37	0.21	0.08	0.14	0.29	0.28
1971	0.02	0.22	0.2	0.25	0.33	0.32	0.47	0.9	0.38	1.48	1.32	1.19	1.63	2.15	0.93	1.01
1972	0.03	0.29	0.34	0.41	0.7	0.65	0.36	0.52	0.38	0.46	1.45	0.18	0.88	0	0.42	0.55
1973	0.02	0.23	0.24	0.28	0.71	0.82	0.88	1.43	1.36	1.02	1.91	0.64	1.04	5.25	1.19	1.48
1974	0.02	0.17	0.54	0.65	0.63	0.35	0.39	0.74	0.18	0.39	0.08	0.03	0	0	0.28	0.28
1975	0.02	0.16	0.26	0.23	0.63	0.74	1.13	0.79	1.08	1.76	1.05	2.31	1.07	4	1.42	1.45
1976	0.01	0.04	0.08	0.27	0.52	0.64	0.76	0.5	0.4	0.29	0.11	0.98	0	0.26	0.35	0.44
1977	0	0	0.01	0.04	0.14	0.2	0.31	0.25	0.24	0.16	0.4	0.72	0.64	0.4	0.2	0.33
1978	0	0	0.03	0.1	0.24	0.35	0.29	0.26	0.21	0.23	0.21	0.49	1.68	4.51	0.22	0.79
1979	0	0	0.04	0.2	0.37	0.43	0.28	0.23	0.12	0.06	0.04	0.04	0.09	0	0.09	0.16
1980	0	0	0.03	0.15	0.34	0.44	0.51	0.48	0.31	0.21	0.19	0.15	0.05	0	0.26	0.27
1981	0	0	0.05	0.19	0.36	0.42	0.4	0.49	0.31	0.22	0.24	0.18	0.19	0.03	0.26	0.28
1982	0	0	0.03	0.17	0.33	0.32	0.44	0.32	0.46	0.45	0.41	0.38	0.54	1	0.45	0.46
1983	0	0	0.04	0.15	0.25	0.36	0.28	0.32	0.25	0.27	0.39	0.23	0.23	0.27	0.26	0.28
1984	0	0	0.01	0.08	0.23	0.32	0.4	0.31	0.29	0.17	0.3	0.28	0.24	0.26	0.23	0.28
1985	0	0	0	0.05	0.15	0.31	0.43	0.49	0.48	0.41	0.26	0.66	0.55	0.21	0.44	0.40
1986	0	0	0	0.08	0.23	0.23	0.26	0.27	0.4	0.3	0.34	0.12	0.66	0.18	0.35	0.30
1987	0	0	0	0.03	0.17	0.35	0.33	0.43	0.39	0.5	0.42	0.48	0.15	0.26	0.44	0.36
1988	0	0	0	0.07	0.14	0.23	0.55	0.36	0.58	0.44	0.73	0.78	0.67	0.04	0.51	0.46
1989	0	0	0.01	0.1	0.36	0.44	0.42	0.52	0.38	0.5	0.44	0.26	0.41	0.4	0.44	0.42
1990	0	0	0.01	0.07	0.29	0.58	0.61	1.25	1.39	0.78	1.03	0.79	1.06	0.49	1.08	0.85
1991	0	0	0.03	0.13	0.39	0.69	0.36	0.78	0.55	0.37	1.28	0.85	1.98	0.72	0.46	0.77
1992	0	0	0.07	0.64	0.82	1.13	1.35	1.51	0.81	3.33	2.45	3.56	3.09	4.05	2.07	2.20
1993	0	0	0	0.09	0.51	0.19	0.33	0.45	0.49	0.08	4.06	1.35	2.85	2.15	0.28	1.16
1994	0	0	0	0	0.03	0.06	0.03	0.02	0.03	0.02	0	-0.4	0	-0.38	0.03	-0.05
1995	0	0	0	0.01	0.01	0.03	0.1	0.01	0.01	0.02	0	0	-0.4	0	0.02	-0.02
1996	0	0	0.01	0.04	0.05	0.01	0.02	0.06	0	0	0	0	0	-0.4	0	-0.02
1997	0	0	0	0.01	0.02	0.02	0.01	0.03	0.16	0	0.01	0.02	0.03	0.05	0.08	0.04

Table 16. Summary of 4VsW cod population analyses.

		Population responses						Diagnostics		
Run name	Scenario	SSB at start of 1998	Change in SSB with no fishing		Yield for no change in SSB	Recruitment 94 y.c.	GM recruits 90-94 y.c.	MSR	Retrospective Metric	Mean bias
Full model	Excludes 1997 March survey, RV adjusted by 1.7, constrained seal diet model, M=.4 after 1985	12301	-2147	-18%	N/A	35068	39826	0.673	-0.02	15.0%
Includes M97	**Includes 1997 March survey**, RV adjusted by 1.7, constrained seal diet model, M=.4 after 1985	22123	3405	15%	2400	67908	48964	0.839	-0.04	13.9%
Constant seal	Excludes 1997 March survey, RV adjusted by 1.7, **constant seal diet model**, M=.4 after 1985	3820	-835	-22%	N/A	105946	102420	0.536	-0.08	25.5%
Variable seal	Excludes 1997 March survey, RV adjusted by 1.7, **unconstrained variable seal diet model**, M=.4 after 1985	12451	-2170	17%	N/A	35098	39942	0.675	-0.03	15.0%
No seals	Excludes 1997 March survey, RV adjusted by 1.7, **no seal predation**, M=.4 after 1985	16988	-2123	13%	N/A	4120	12485	0.745	-0.05	14.0%
M=.2	Excludes 1997 March survey, RV adjusted by 1.7, constrained seal model, **M=.2 throughout time series**	34781	7893	23%	8050	14094	7529	0.883	0.35	13.0%
Old RV	Excludes 1997 March survey, **RV adjusted by 0.8**, constrained seal model, M=.4 after 1985	30525	4490	15%	5300	78043	55319	0.814	0.49	13.5%

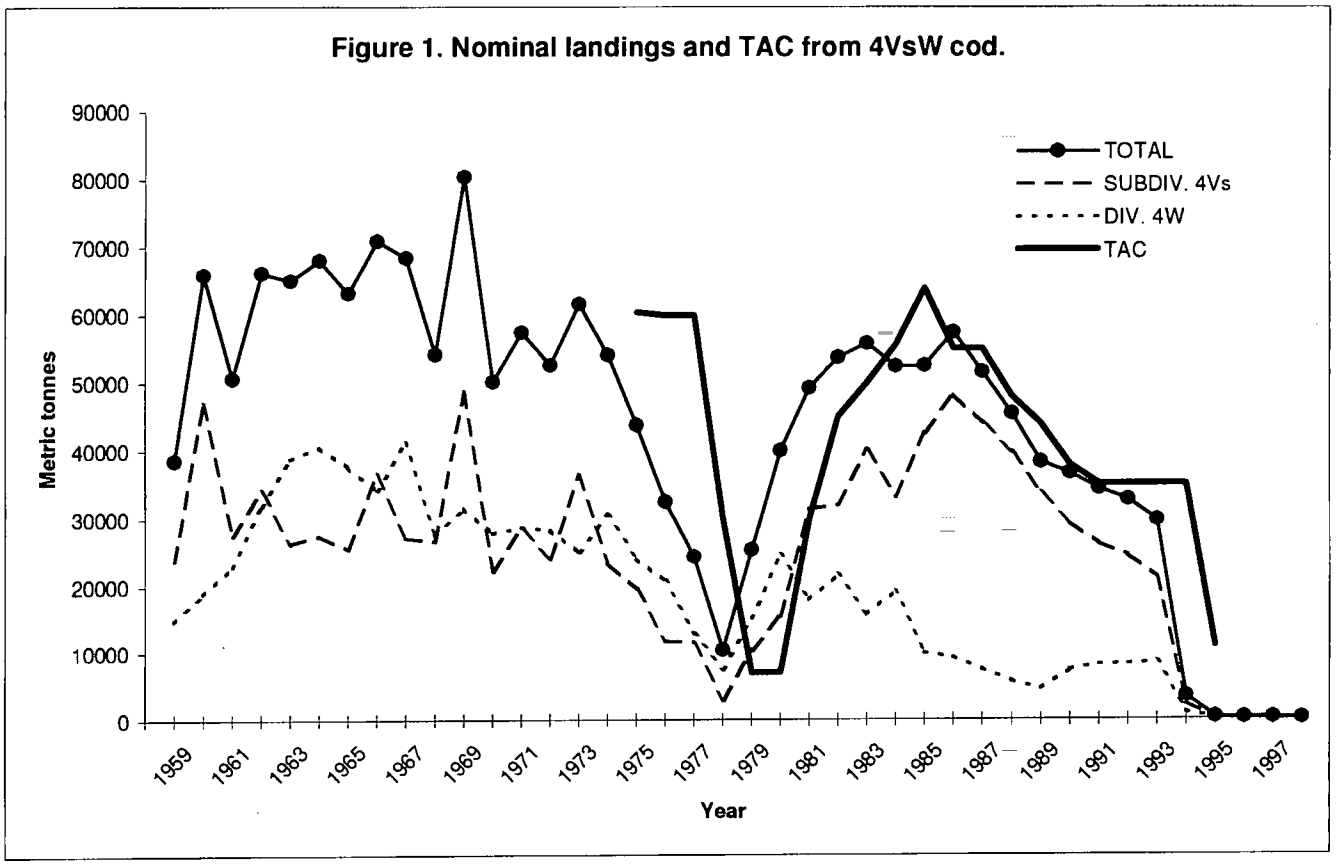


Figure 1. Nominal landings and TAC from 4VsW cod.
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Metric tonnes
TOTAL
SUBDIV. 4Vs
DIV. 4W
TAC
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

Figure 2. 4VsW cod commercial mean weights at age

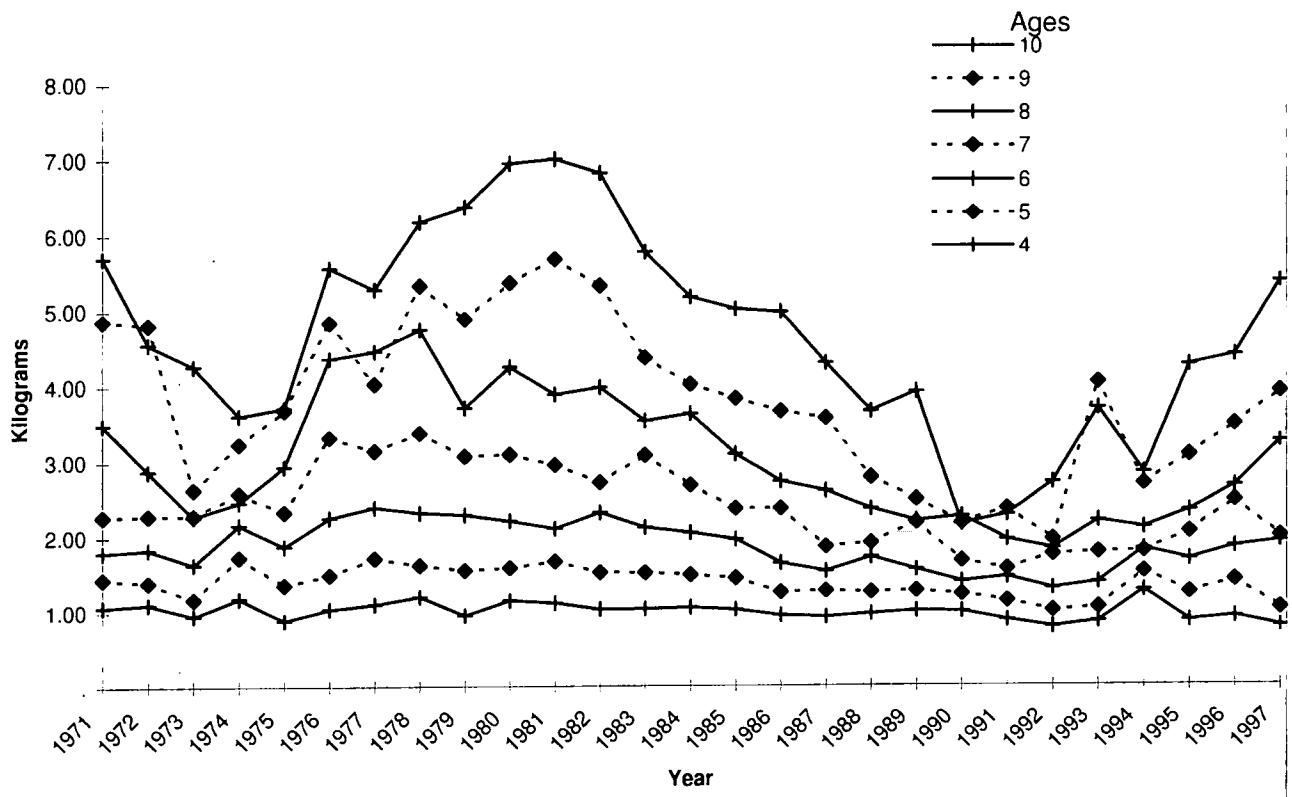


Figure 3a. Biomass of 4VsW cod consumed under three models of seal predation on cod.

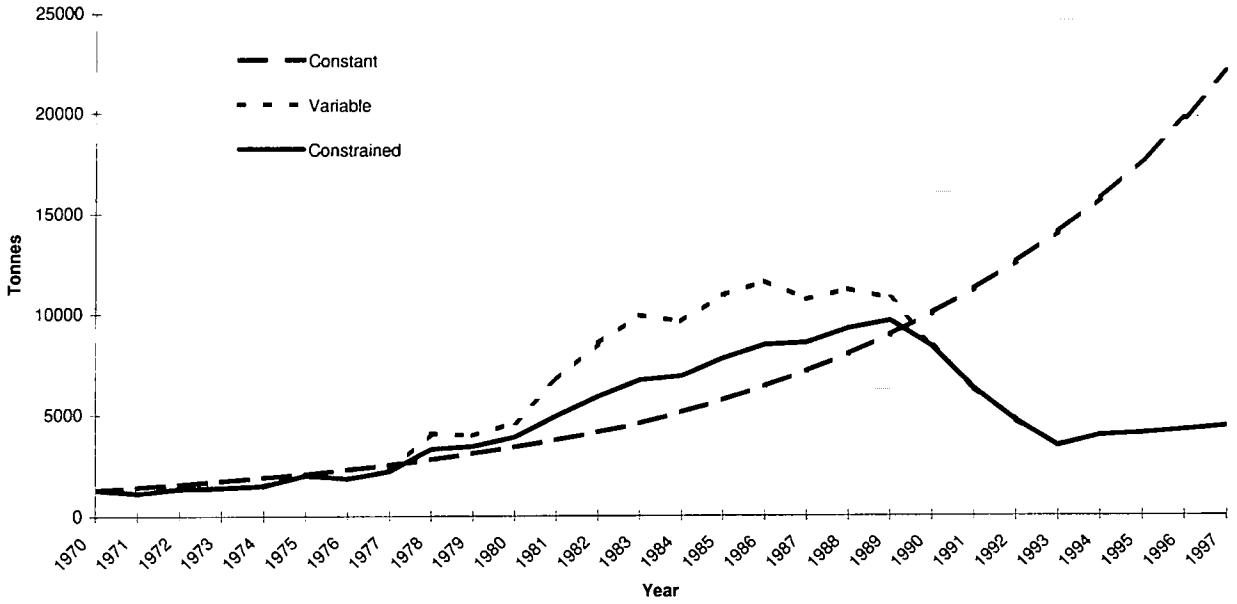
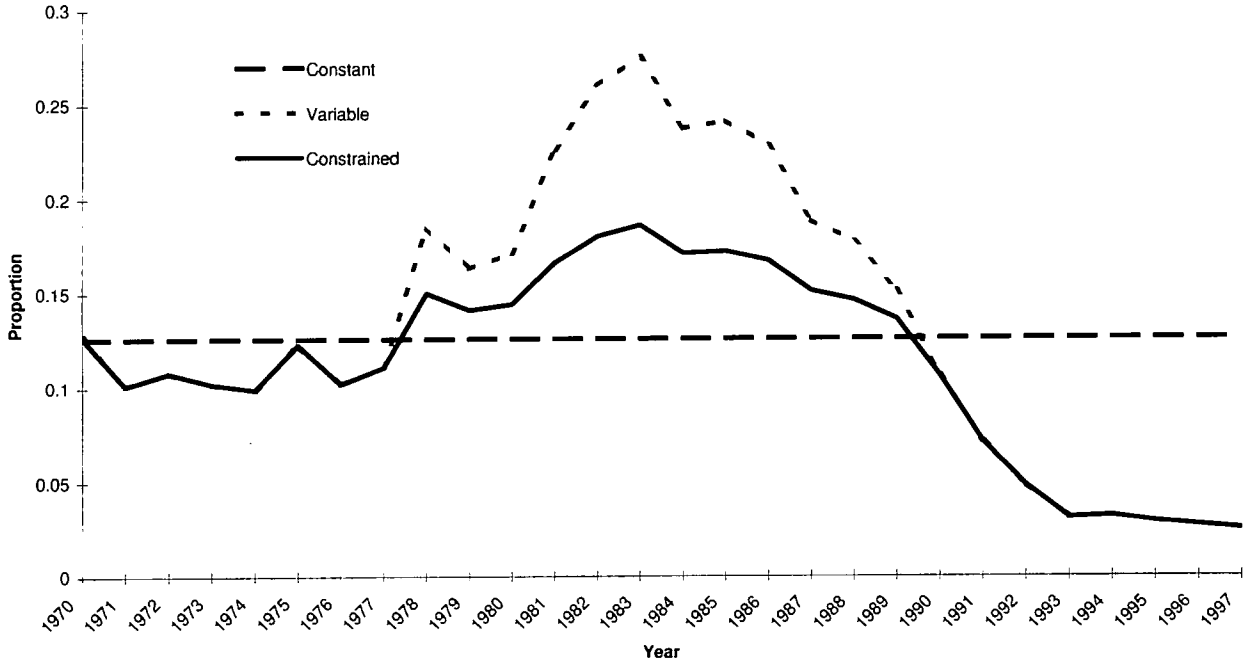


Figure 3b. Proportion of 4VsW cod in seal diet under three models of seal predation on cod.



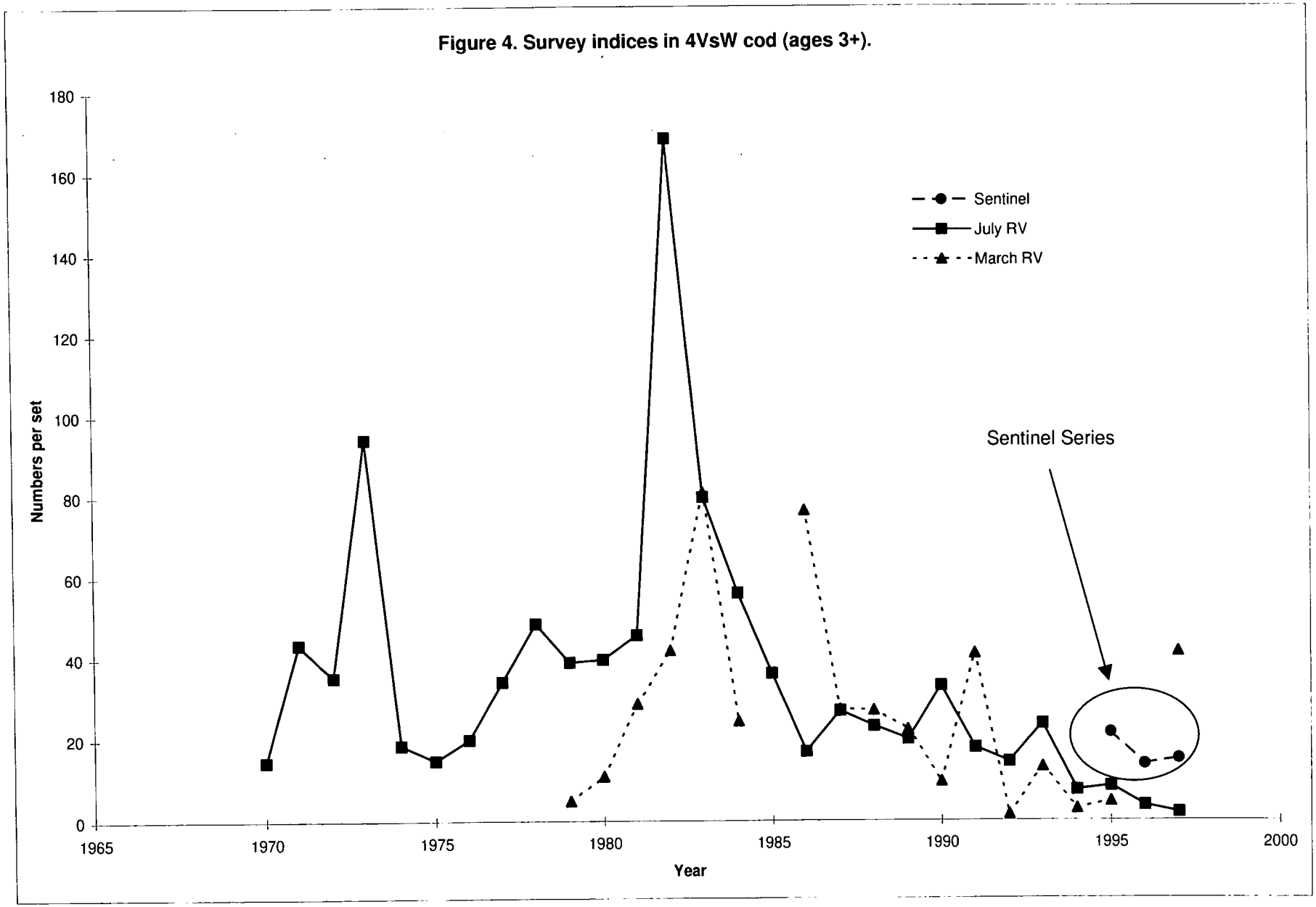


Figure 4. Survey indices in 4VsW cod (ages 3+).

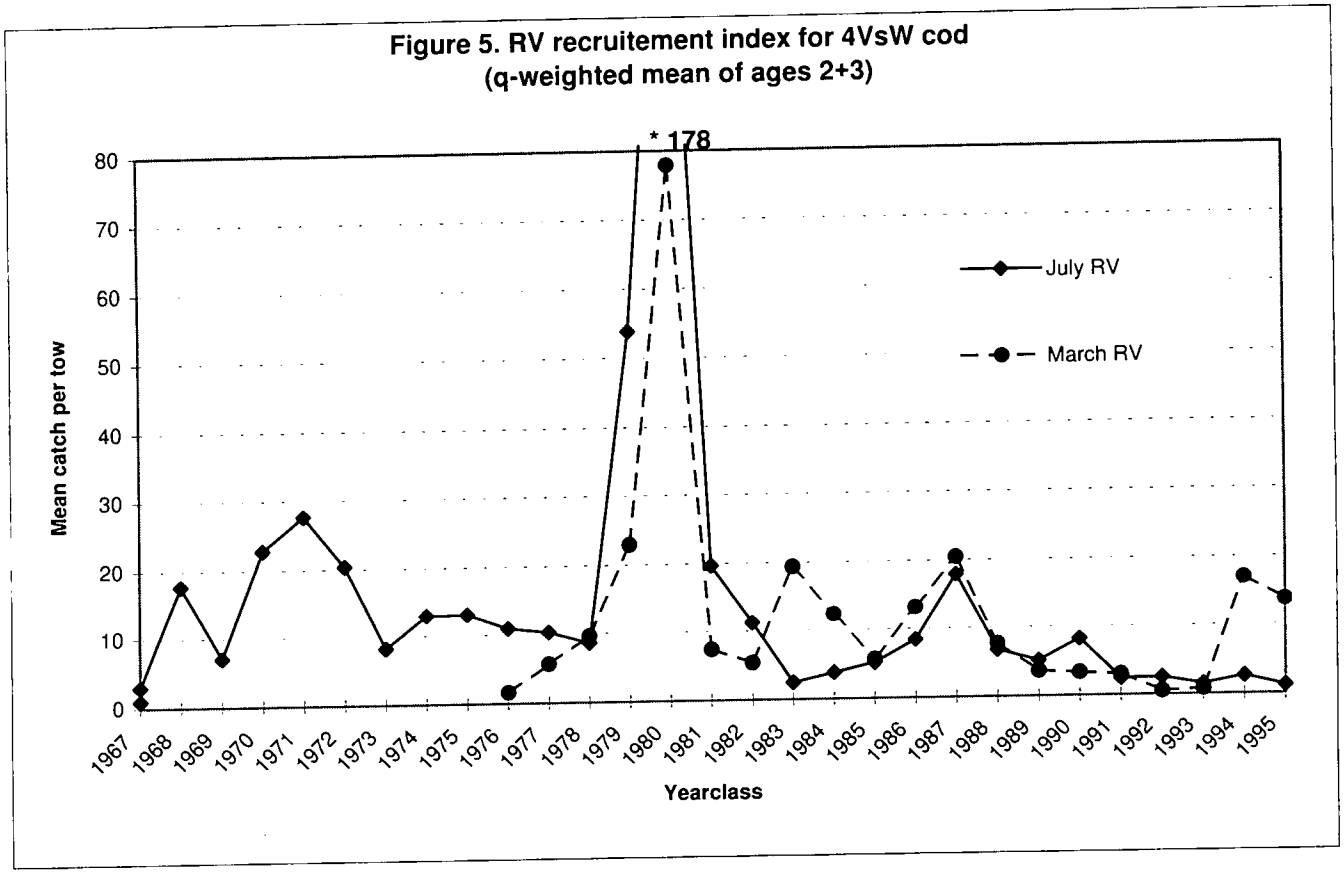
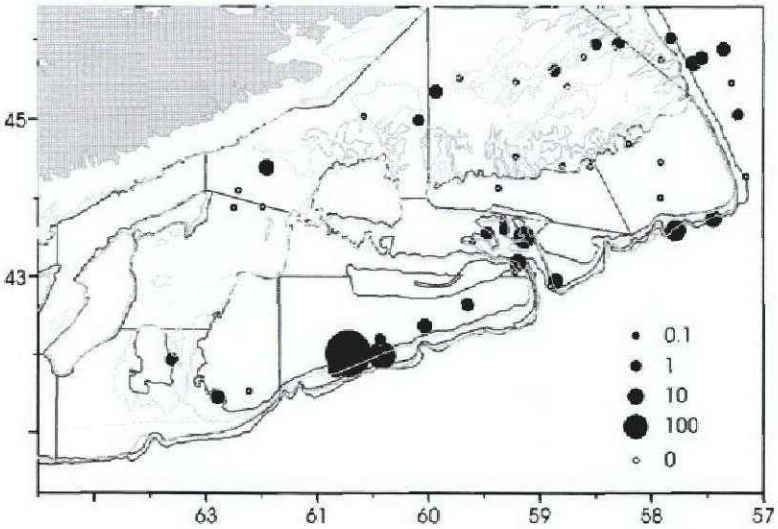


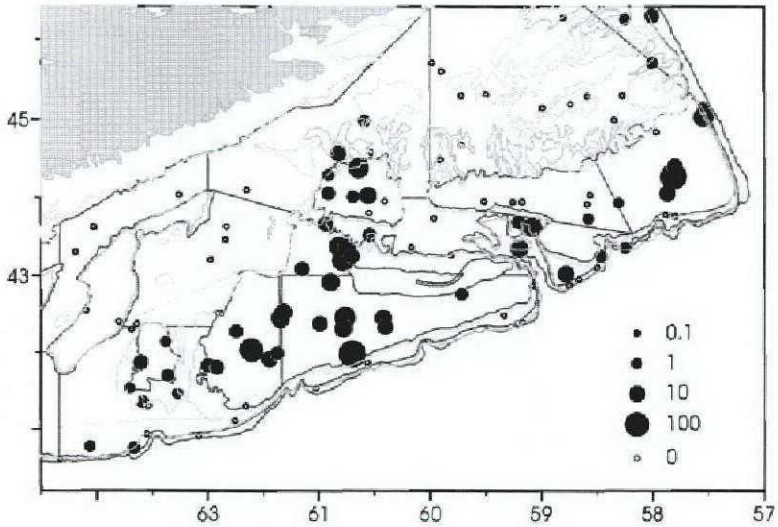
Figure 5. RV recruitement index for 4VsW cod
(q-weighted mean of ages 2+3)
* 178
80
70
60
50
40
30
20
10
0
Mean catch per tow
July RV
March RV
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Yearclass

Figure 6. Survey distributions for 4VsW cod in 1996

A.) March 1996 RV survey mean catch per tow (all ages)



B.) July 1996 RV survey mean catch per tow (all ages)



C.) September Sentinel Surveys Catch (Kgs)

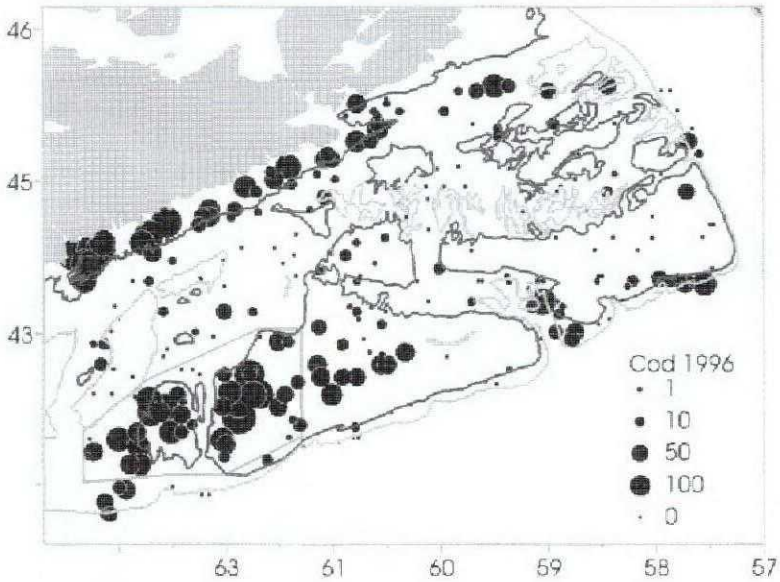
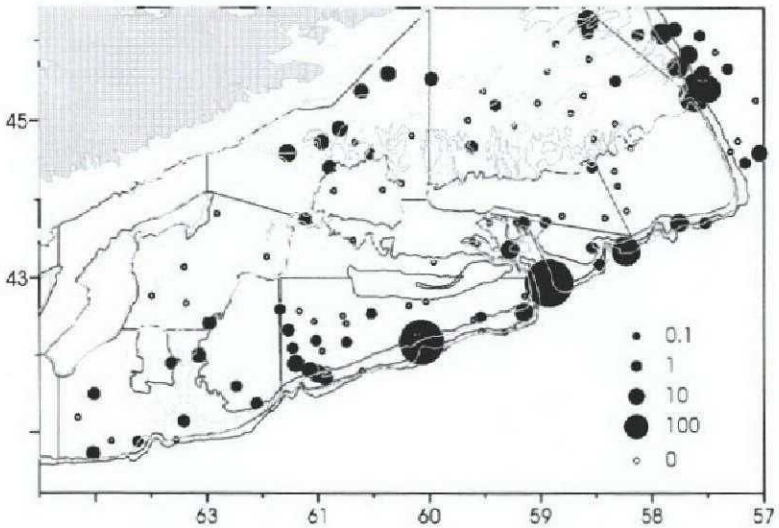
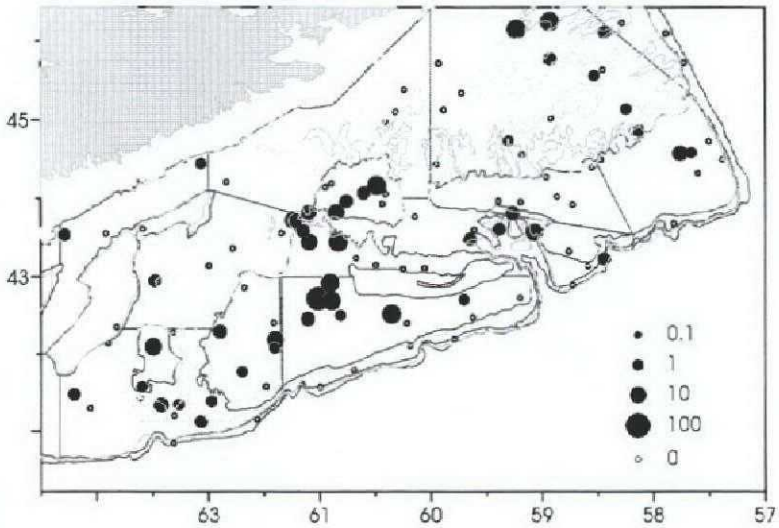


Figure 7. Survey distributions of 4VsW cod in 1997

A.) March 1997 RV survey mean catch per tow (all ages)



B.) July 1997 RV survey mean catch per tow (all ages)



C.) September Sentinel Surveys Catch (Kgs)

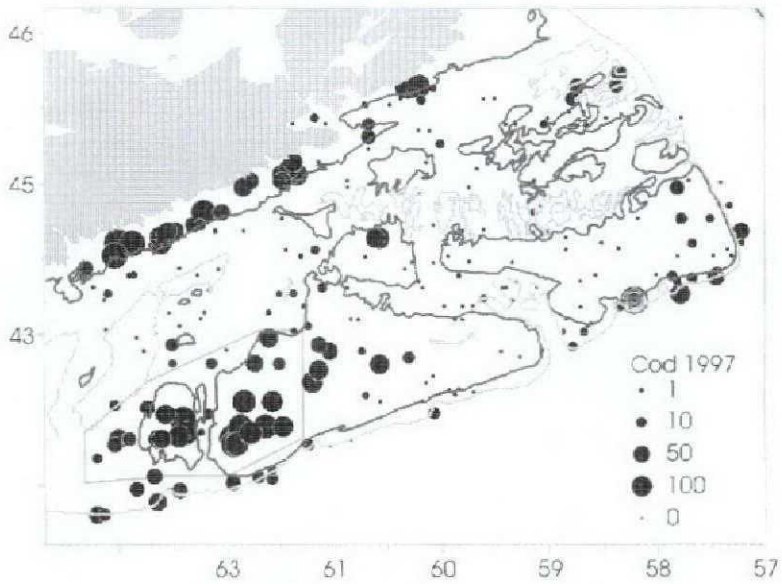


Figure 8. Total mortality estimates for 4VsW cod from RV surveys

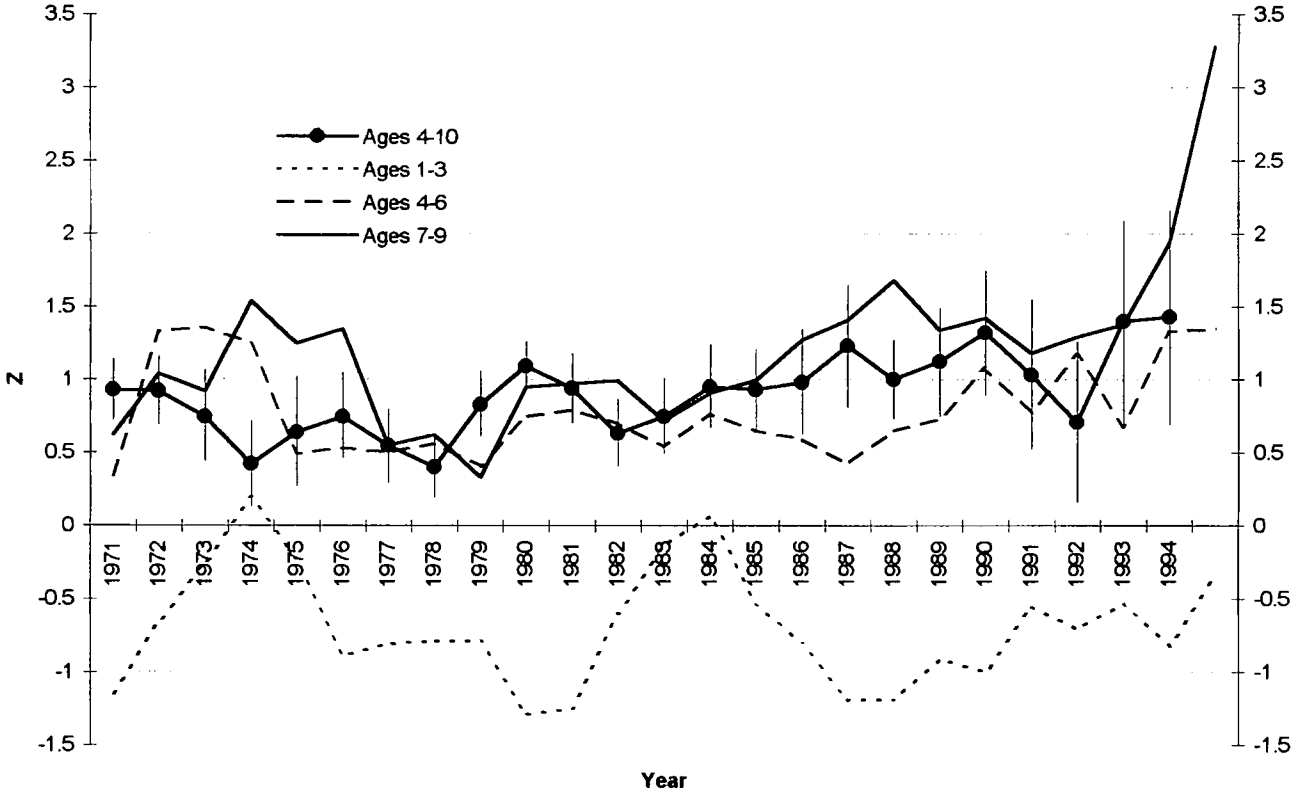


Figure 9. Residuals from full run of 4VsW cod ADAPT
(Positive residuals with crosses, negative with circles)

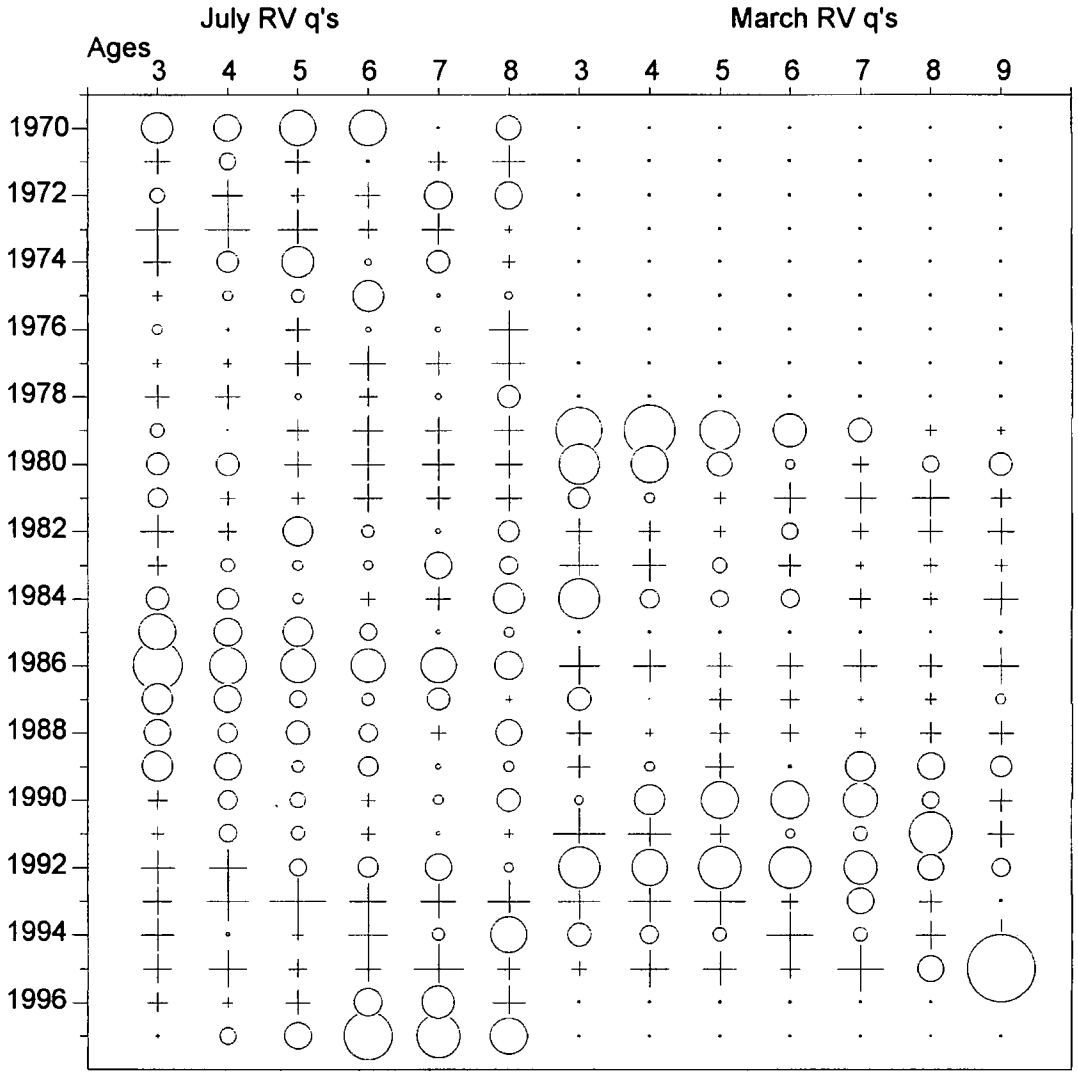


Figure 10. Observed q-adjusted survey and SPA population numbers for 4VsW cod from the full model run.

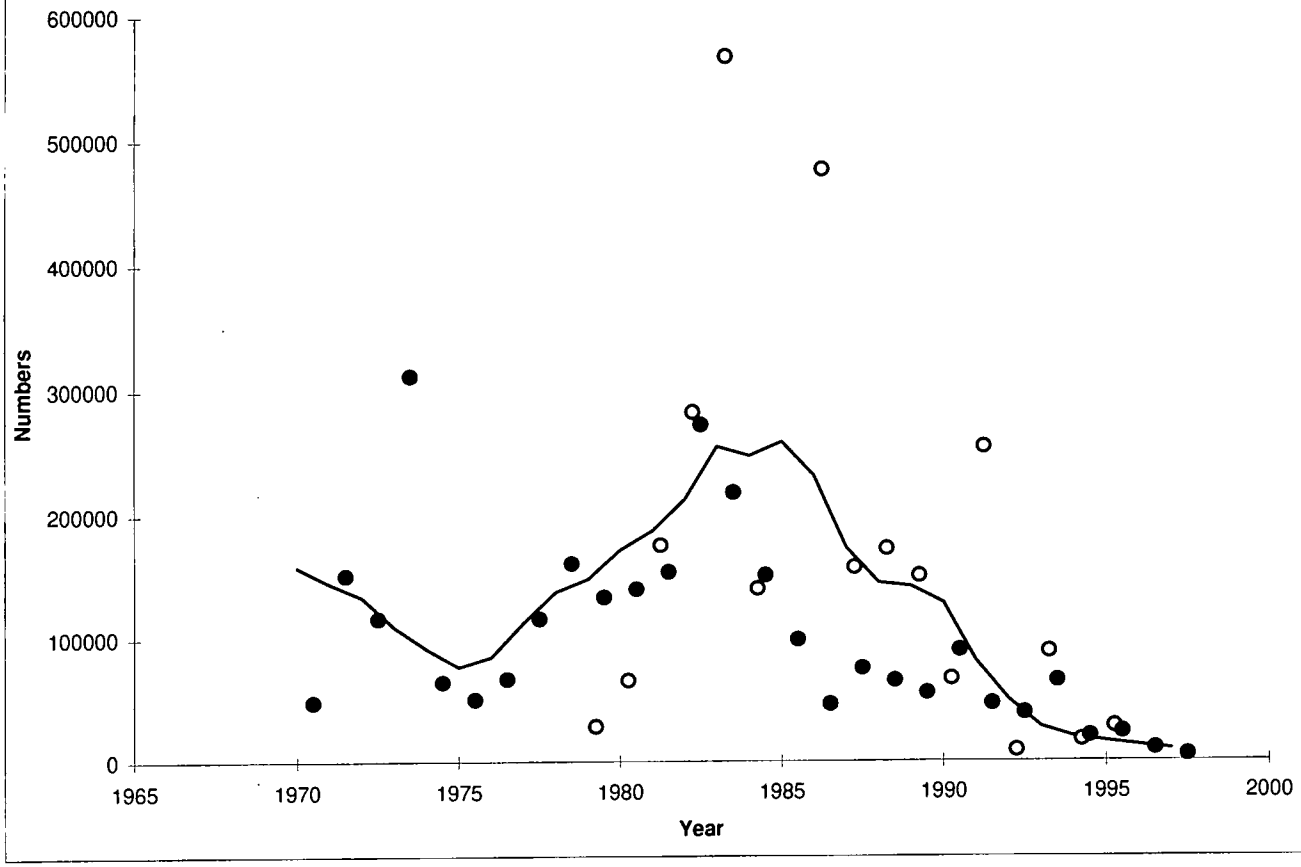


Figure 11. Retrospective analysis of 4VsW cod biomass

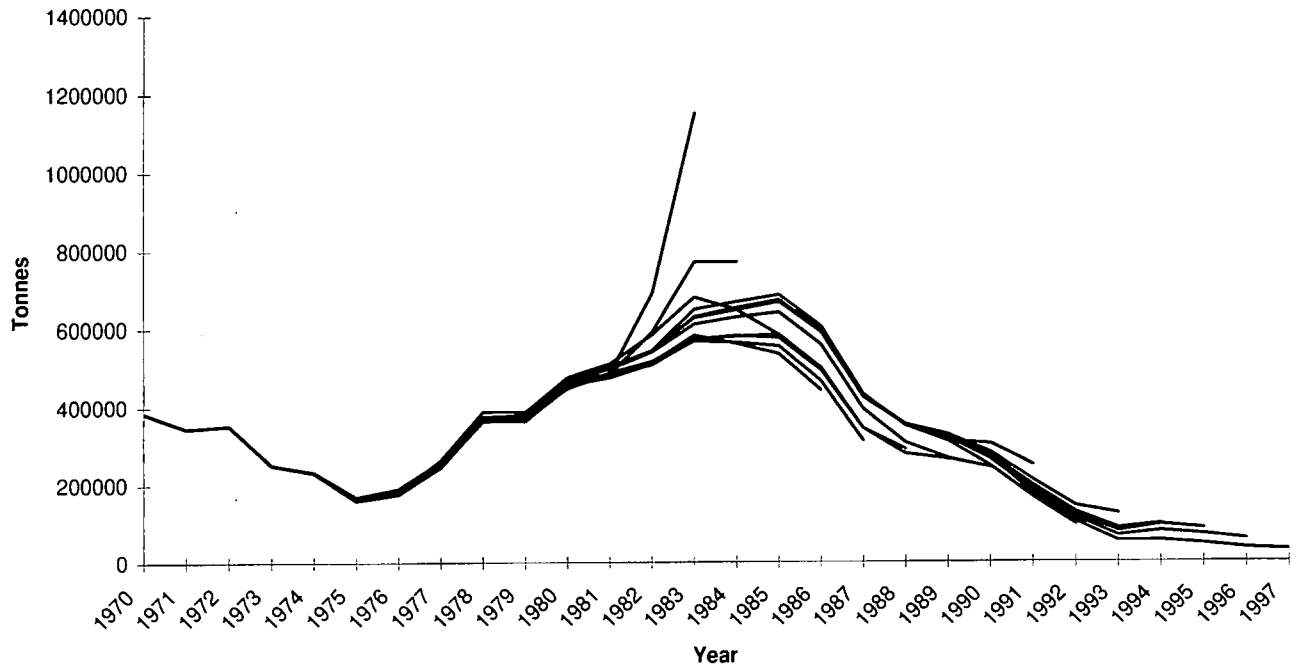


Figure 12. Total and spawning stock biomass and Age 1 recruitment numbers for 4VsW cod.

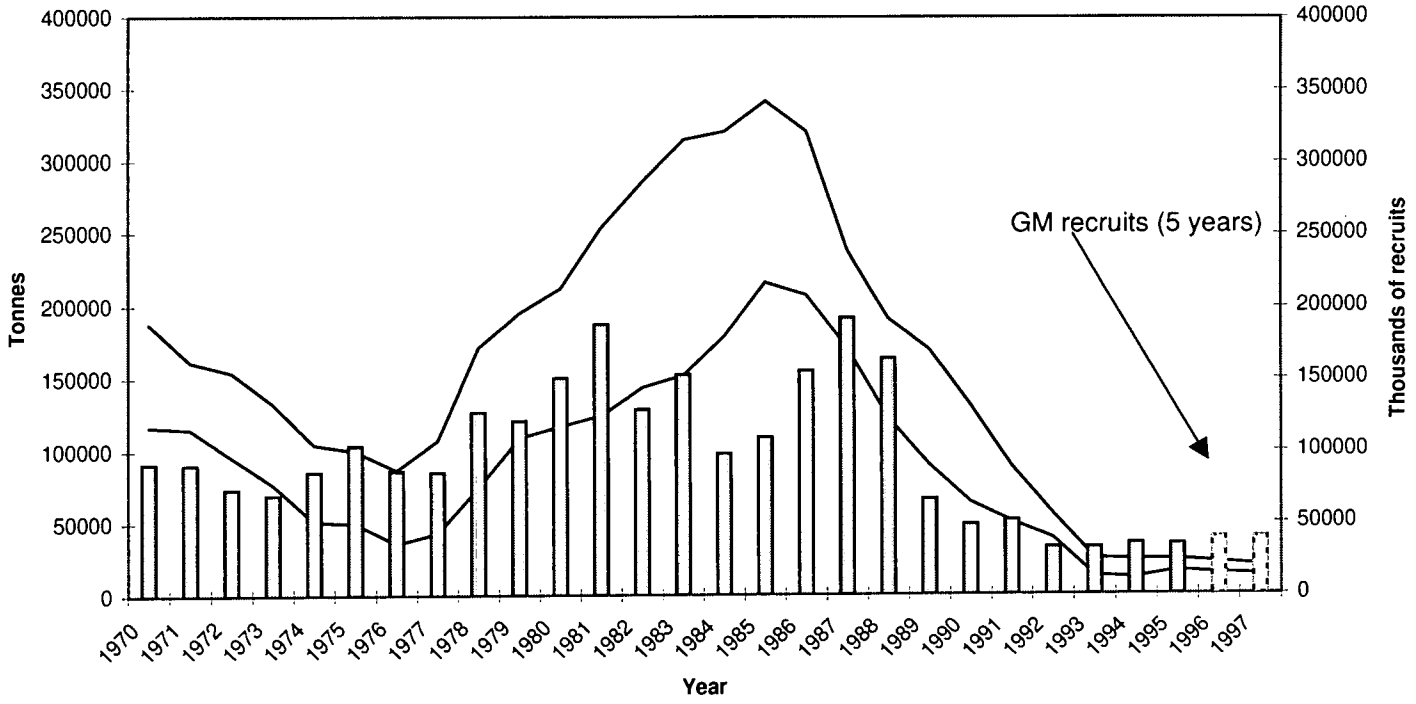


Figure 13. Exploitation rates of 4VsW cod by seals and fishery combined

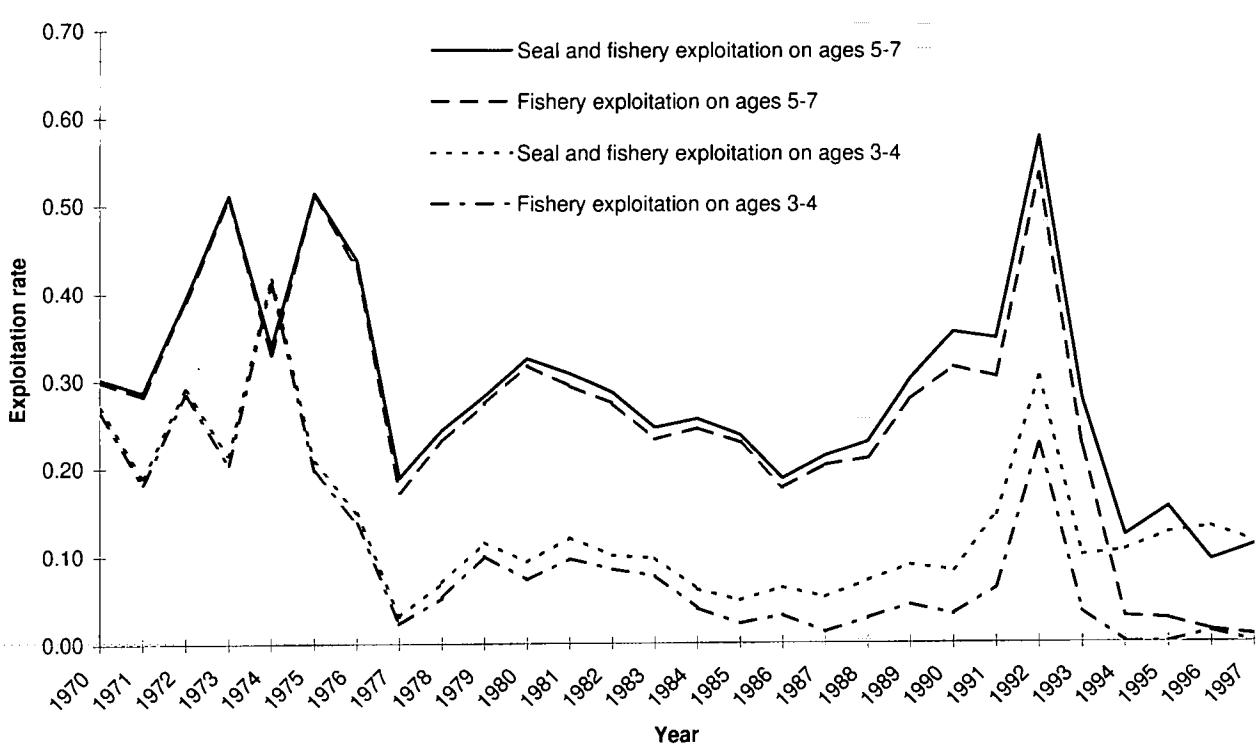


Figure 14. Long-term stock recruit (age 1) relationship in 4VsW cod

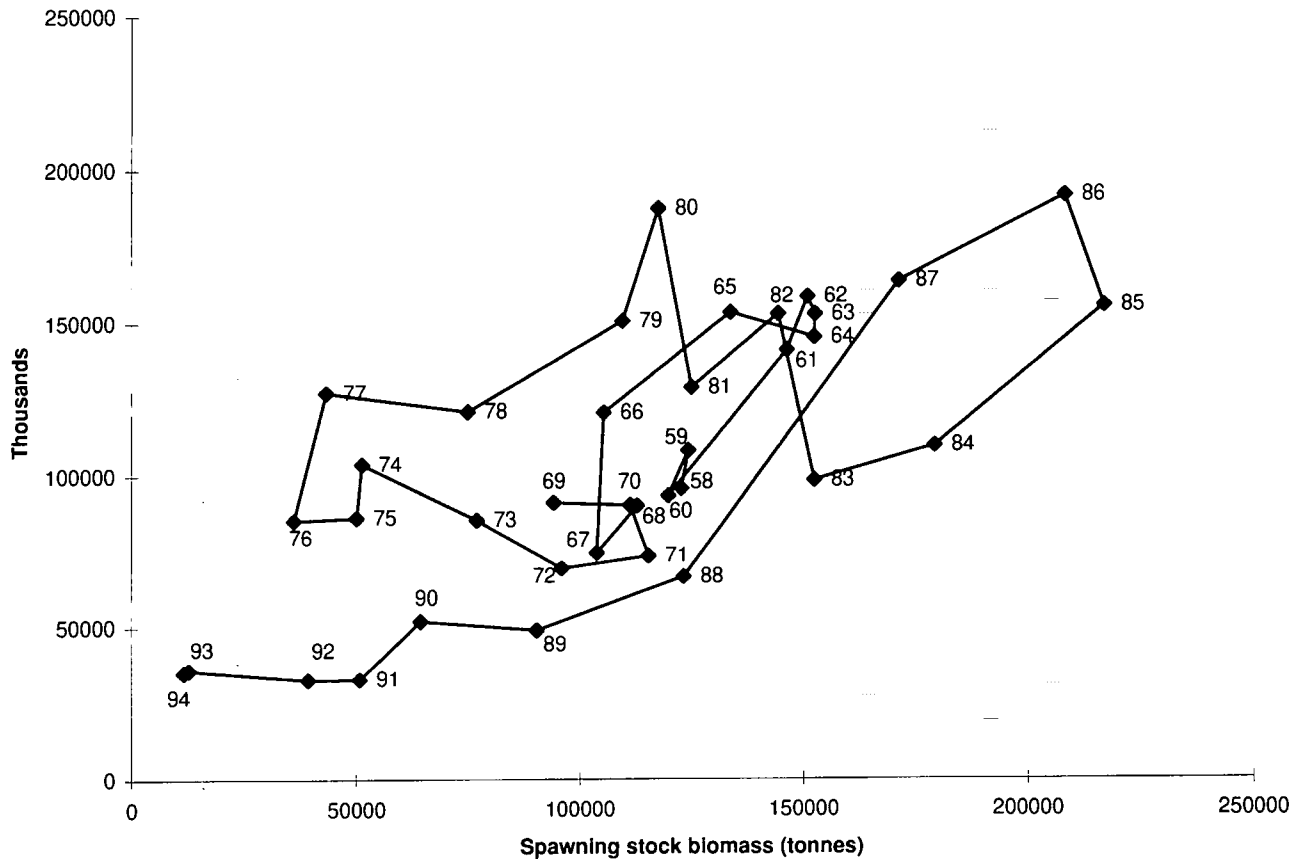


Figure 15. Production (gross and net) of 4VsW cod, including component due to seal consumption, and production to biomass ratio (P/B).

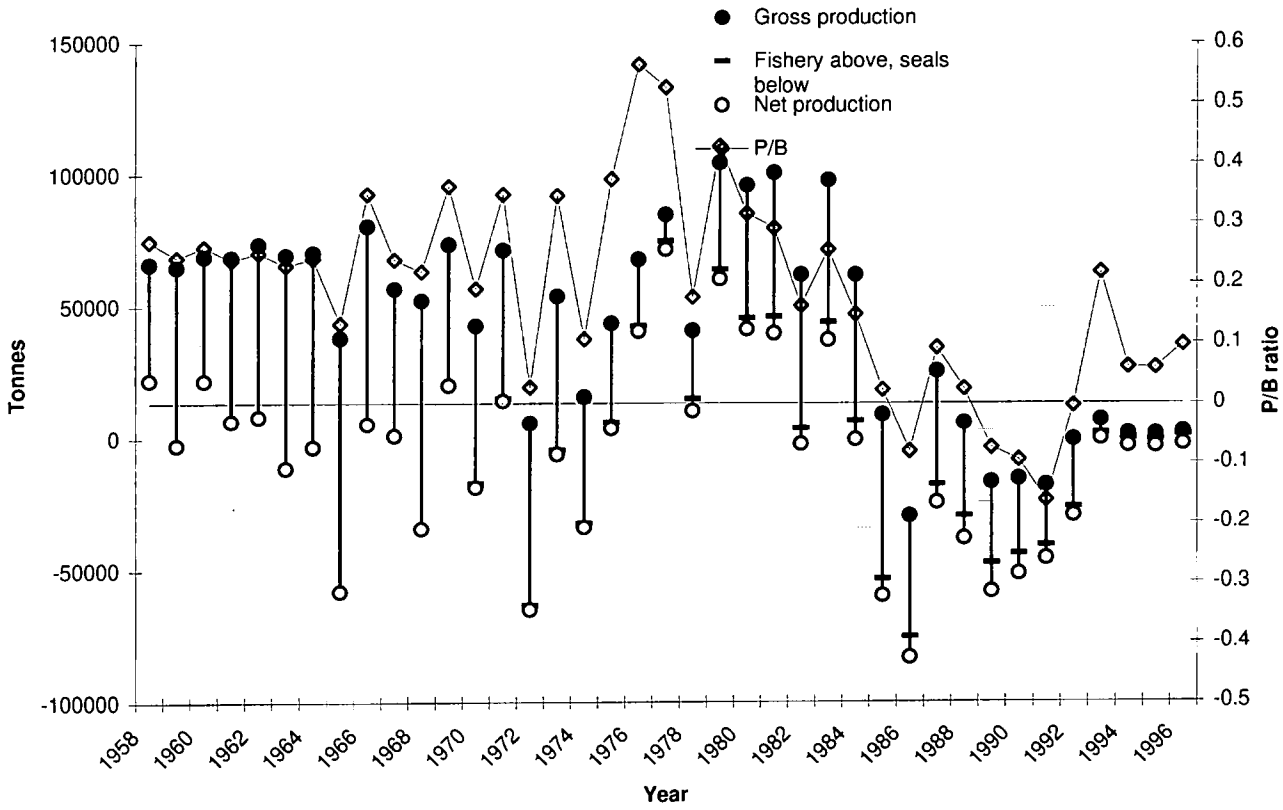


Figure 16. Yield and change in biomass projections for 4VsW cod over a range of catch levels.

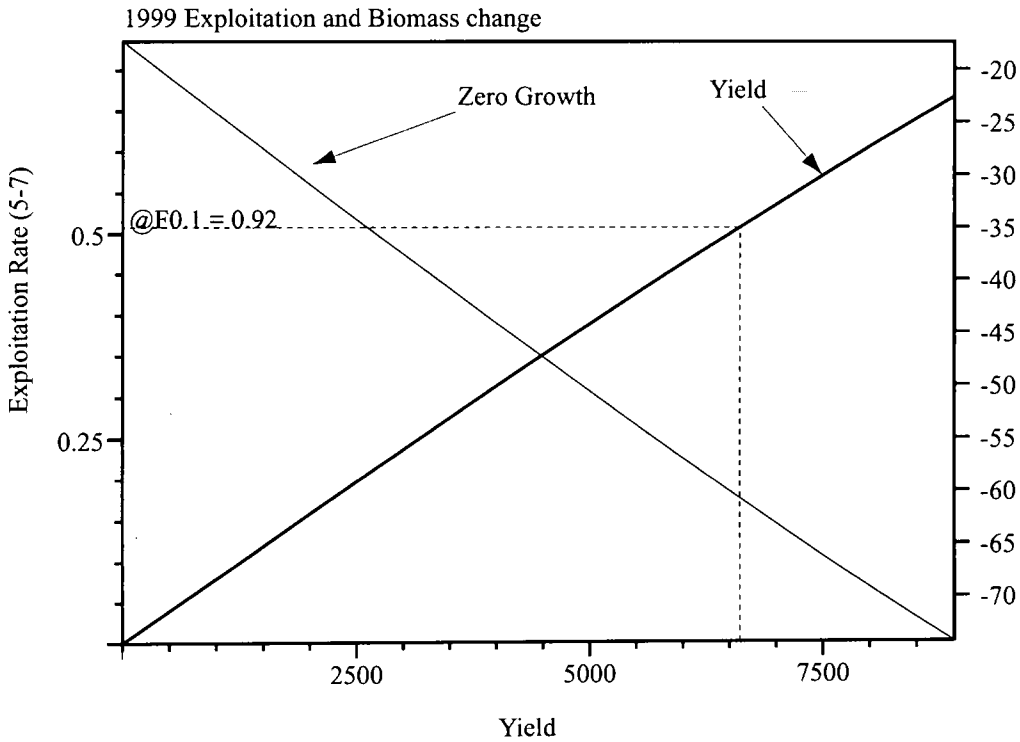


Figure 17. Sensitivity of 4VsW cod biomass to model assumptions

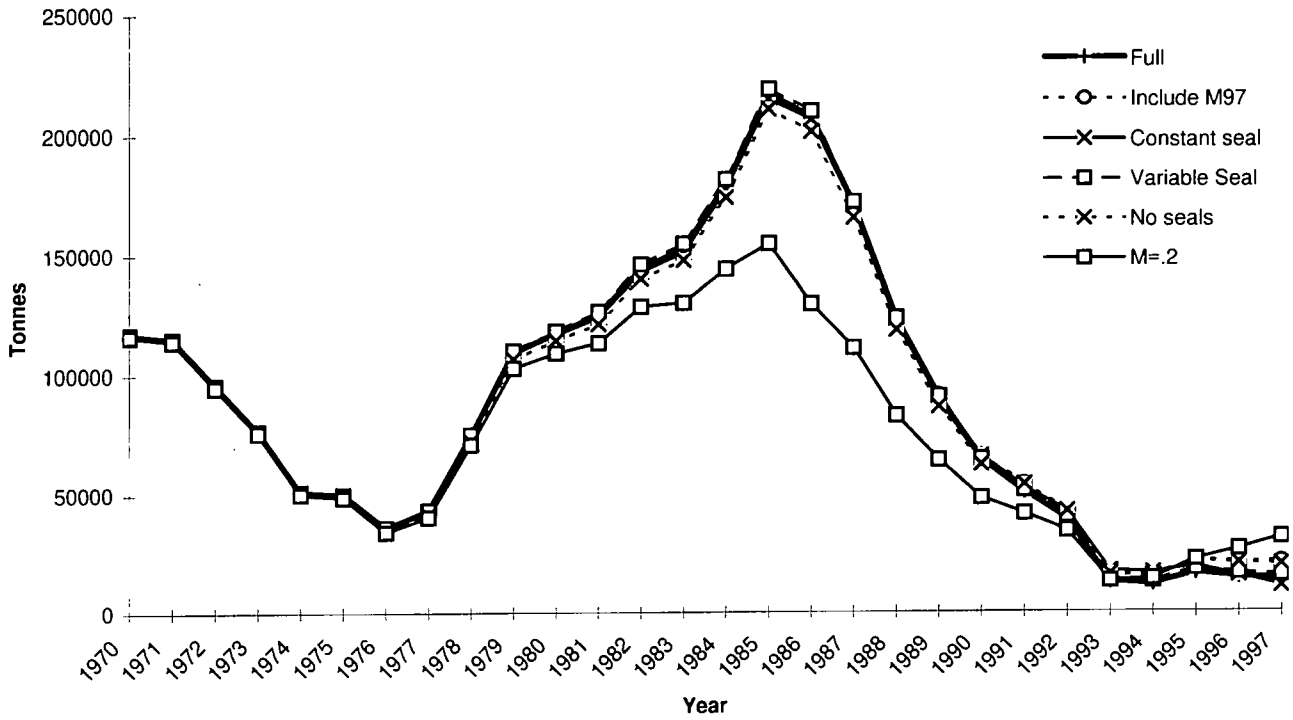


Figure 18. Sensitivity of 4VsW cod exploitation (seals+fishing) mortality to model assumptions

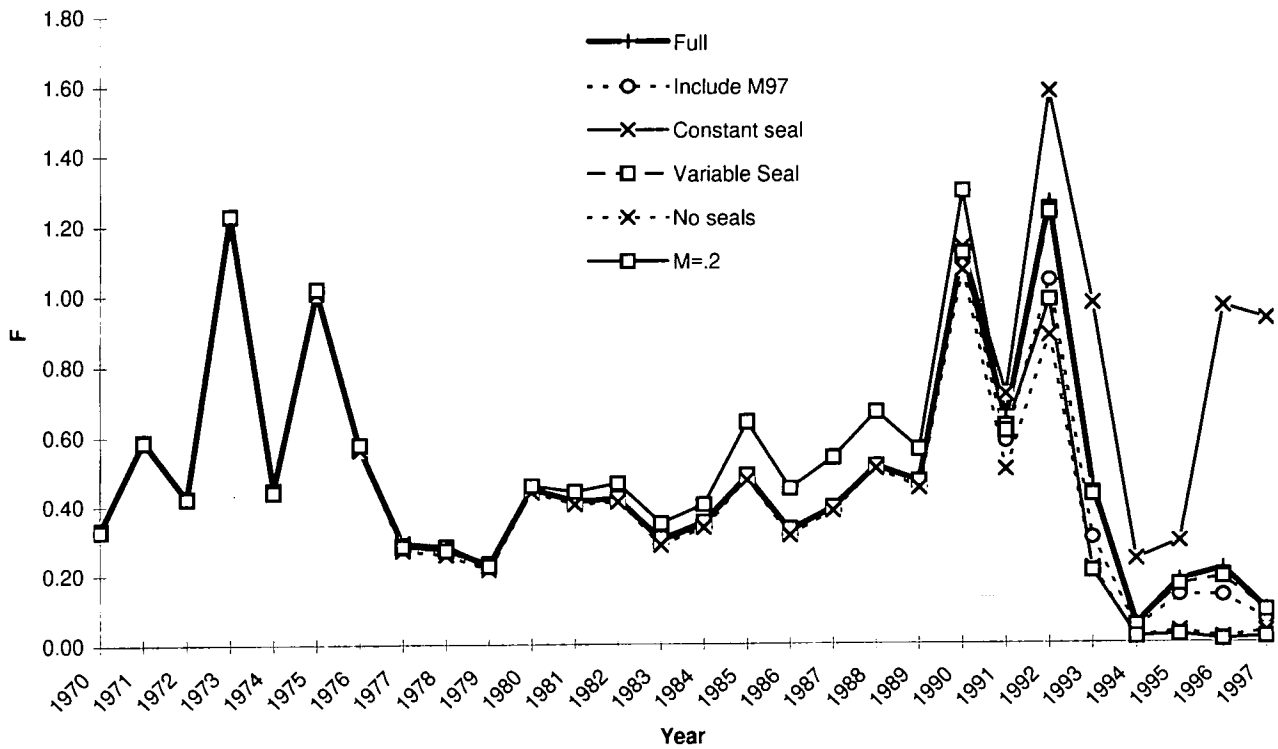


Figure 19. Sensitivity of 4VsW cod recruitment to model assumptions

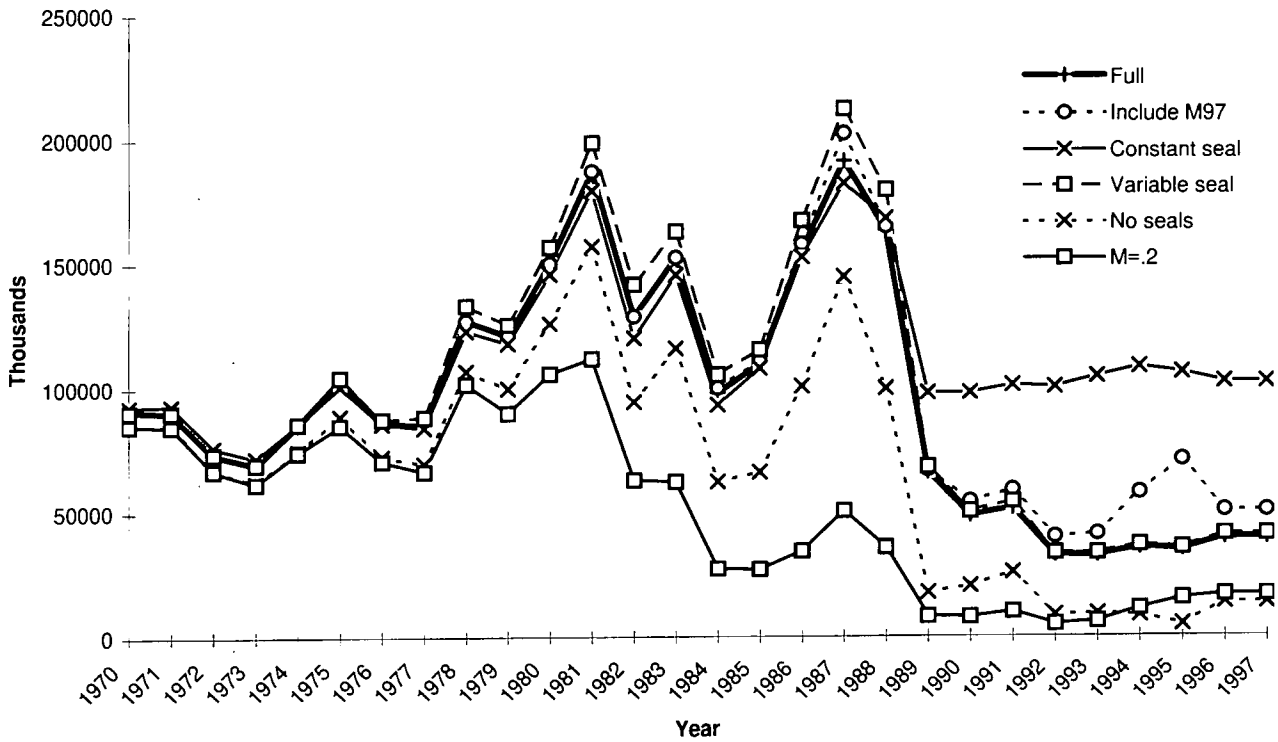
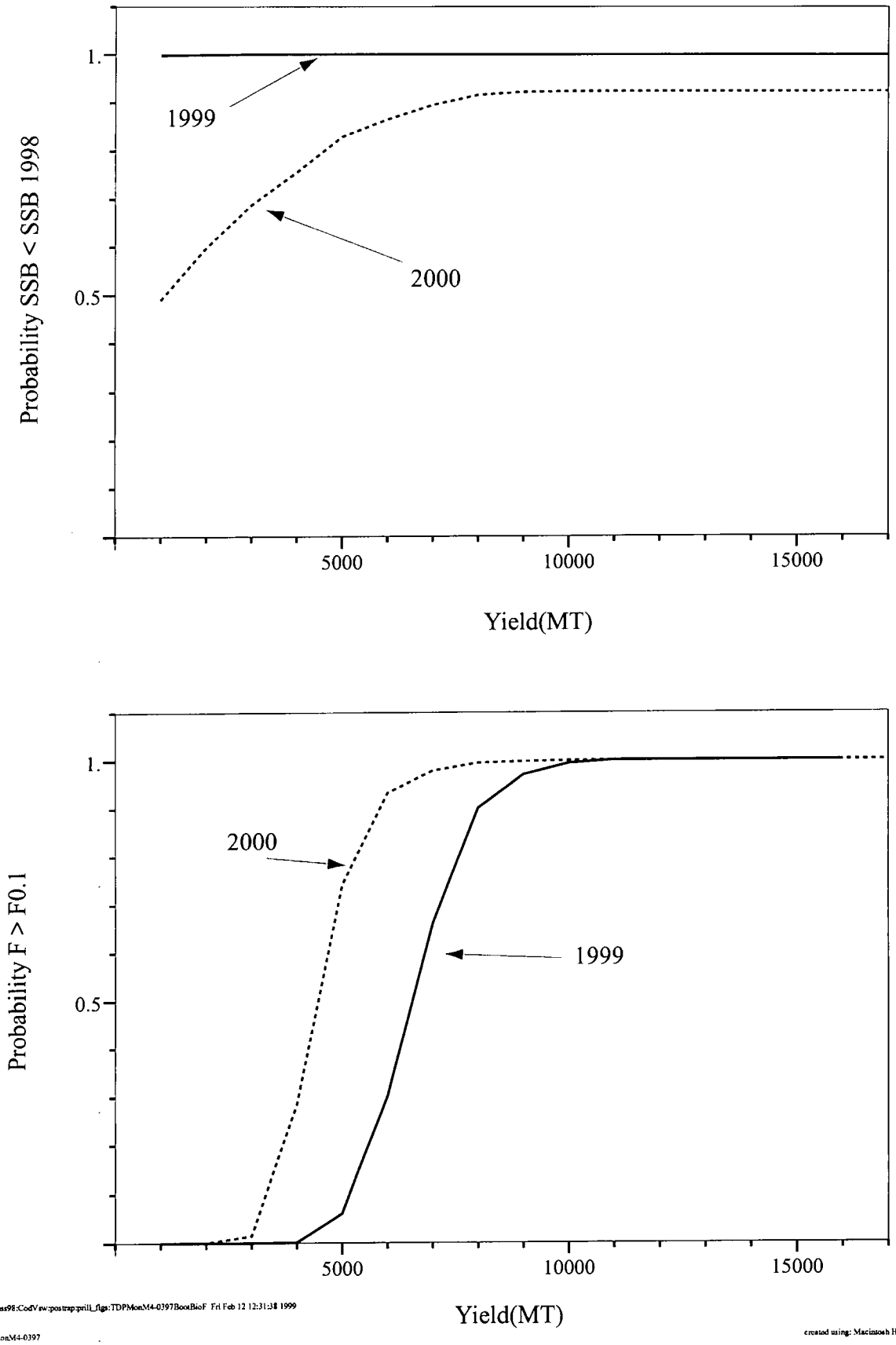


Figure 20. Risk of decline in biomass (upper panel) and fishing mortality exceeding target for 4VsW cod for 1999 and 2000.

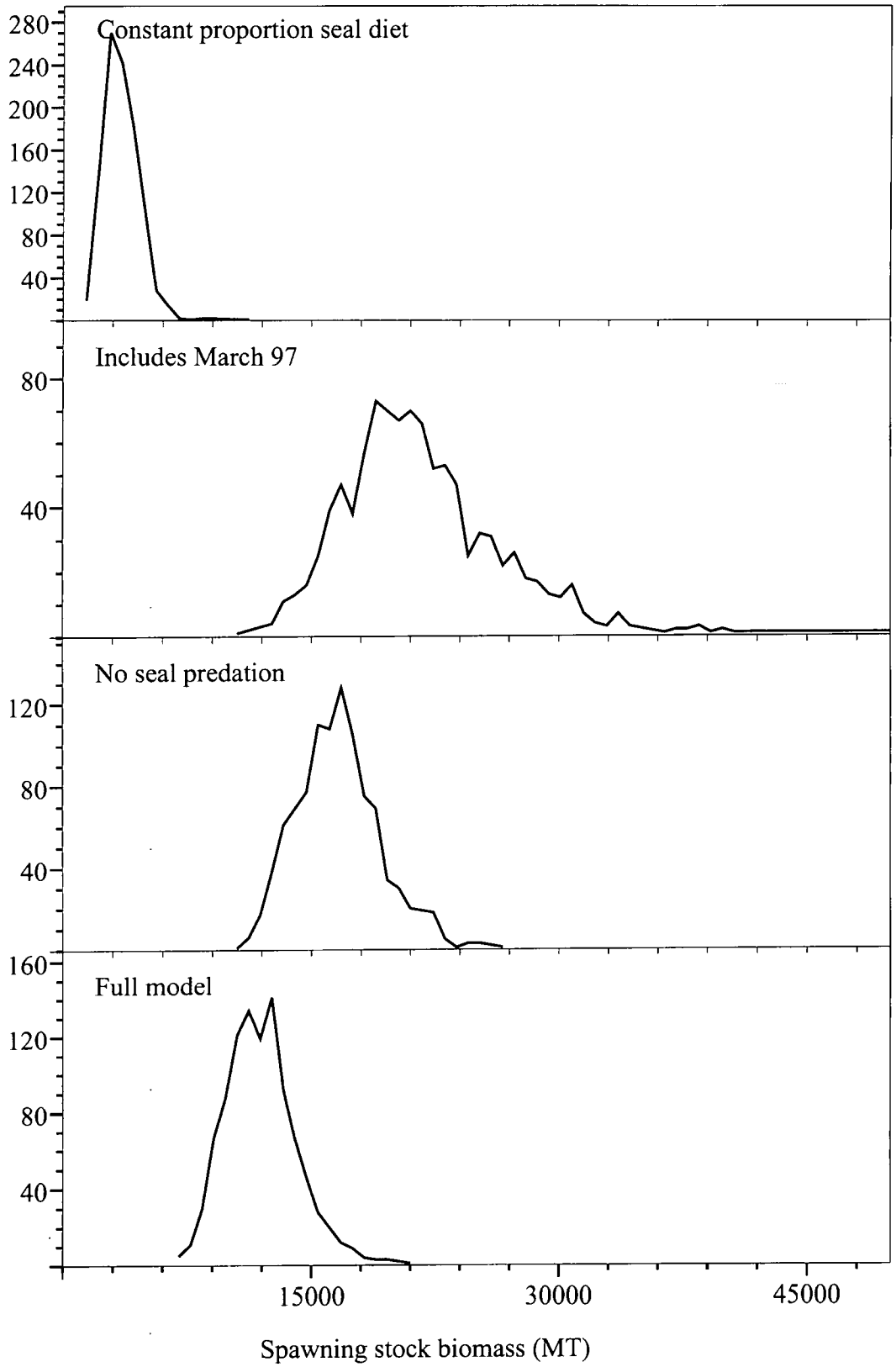


Macintosh HD:Projects98:Assess98:CodVsw:postrap:prill_figs:TDPMonM4-0397BootBioF Fri Feb 12 12:31:38 1999

stock 4VsW cod model TDPMonM4-0397

created using: Macintosh HD:util_scripts:Cod4vsw98_7.scn

Figure 21. Comparison of parameter uncertainty (distributions) with model uncertainty (panels)



Appendix A. Comparative Base Run Results for 4VsW cod in 1997.

The comparative base run results are presented here for reference and comparison with both the full model results reported in the main assessment and with previous assessments. The model is essentially the same as that used in the last several assessments. Generally, results are presented here without discussion as methods and interpretations are as given for the full model in the assessment.

Summary statistics from the NLLS fit are given in Table A1. Also included in Table A1 are the bootstrap bias correction results based on 1000 replicates. The bootstrap CV's are generally higher than those implied by the model fit statistics (i.e. log standard errors). The residuals (Table A2 and Figure A1) are highly patterned with the July RV almost all positive after 1982 except for strong year effects in 1986, 1996 and 1997. The March RV has a very large year effect in 1997, opposite to the July RV. The observed (q-adjusted survey) and estimated population numbers for ages three to eight (Figure A2) clearly show runs of residuals, first mostly negative, later mostly positive. A strong retrospective effect is present (retrospective metric = 1.54) and is clearly visible (Figure A3) which has been the reason to reject the analytical assessment of this stock in the past. This effect has essentially died out by the early 1990's.

Basic results of the population analysis given are numbers at age (Table A3), recruitment (Figure A4), biomass at age (Table A4), spawning stock (age 5+) biomass (Figure A5), fishing mortality (Table A5) and exploitation rate (Figure A6).

Table A1. Statistics from ADAPT model fit for 4VsW cod base run.

Log survivor estimates			Survey q's	
Age	Estimate	SE	July	March
3	9.5727	0.6447	1.04	0.93
4	8.8831	0.5263	0.87	1.17
5	7.9934	0.4147	1.13	0.94
6	7.5279	0.3524	1.08	1.08
7	8.0218	0.3094	1.16	0.91
8	7.3010	0.2965	1.01	1.22
9	6.6885	0.2658		1.27
10	6.8829	0.3710		

Bootstrap estimates of bias and bias adjustments						
Ages	Survivors	Bootstrap mean	Bias	Relative bias	Adjusted survivors	Bootstrap CV
1	0	0	0	1	0	1
2	8252	8452	200	0.02	8052	0.19
3	6756	6920	164	0.02	6593	0.19
4	14367	18864	4498	0.31	9869	0.84
5	7209	8324	1115	0.15	6095	0.6
6	2961	3299	338	0.11	2623	0.44
7	1859	1996	136	0.07	1723	0.38
8	3047	3202	155	0.05	2891	0.32
9	1482	1587	105	0.07	1376	0.29
10	803	838	35	0.04	768	0.28
11	975	1018	42	0.04	933	0.31
12	508	511	3	0.01	505	0.22
13	169	170	1	0.01	168	0.22
14	68	68	0	0.01	67	0.22
15	169	170	1	0.01	168	0.22

Table A2. Residuals from 4VsW cod ADAPT base run.

	July RV						March RV							
	Age						Age							
Year	3	4	5	6	7	8	3	4	5	6	7	8	9	Ages 3-9
1970	0.17	0.54	-0.44	-1.44	-0.01	-1.86	.	.	.	.	.	.	.	-0.51
1971	-0.17	0.48	0.18	0.85	-0.03	-1.24	.	.	.	.	.	.	.	0.01
1972	-1.56	-0.22	-0.83	-0.3	0.8	-1.86	.	.	.	.	.	.	.	-0.66
1973	0.88	0.38	-0.05	-0.22	-0.08	-0.85	.	.	.	.	.	.	.	0.01
1974	0.06	-0.4	-0.44	0.09	0.19	0.18	.	.	.	.	.	.	.	-0.05
1975	0.98	1.22	0.28	0.41	-0.64	0.38	.	.	.	.	.	.	.	0.44
1976	0.59	0.57	-0.05	0.41	0.67	-0.29	.	.	.	.	.	.	.	0.32
1977	0.06	-0.42	2.06	-3.12	1.21	0.18	.	.	.	.	.	.	.	0.00
1978	-0.77	0.71	-0.51	0.85	1.21	0.31	.	.	.	.	.	.	.	0.30
1979	-0.14	-0.85	0.32	-0.96	0.33	0.26	-2.13	-1.65	0.73	0.75	0.53	0.38	-0.17	-0.20
1980	0.97	-0.42	0.14	1.62	0.11	-0.49	0.69	0.62	-1.50	0.39	0.52	-0.52	0.49	0.20
1981	-1.07	-0.38	0.51	0.09	0.44	-0.29	-0.49	1.41	-0.19	0.29	.	0.01	-0.48	-0.01
1982	1.2	-1.15	0.14	-1.81	0.19	0.89	1.28	-2.74	0.34	-0.19	-0.50	-0.14	0.86	-0.13
1983	0.97	-0.85	-0.04	1.62	-0.08	0.71	-1.73	0.62	0.44	0.62	0.34	-0.14	1.07	0.27
1984	-0.77	-0.53	-0.1	0.47	0.8	0.18	-1.73	1.08	-0.19	-0.41	0.52	0.57	0.49	0.03
1985	-0.57	0.37	-1.59	-0.62	-0.01	0.64	.	.	.	.	.	.	.	-0.30
1986	0.59	0.29	-0.04	0.16	0.23	0.54	-0.65	0.11	0.44	-1.22	-1.01	-0.38	-1.49	-0.19
1987	0.59	-0.11	-0.04	-0.96	-0.64	-1	0.88	-1.79	-0.57	-0.06	-0.96	0.57	-0.48	-0.35
1988	1.48	-0.11	2.05	-0.29	0.24	0.63	-1.36	-0.11	-0.19	-1.24	-0.43	0.04	-0.68	0.00
1989	-1.07	0.66	-0.16	0.84	-0.01	-1	1.77	0.12	-1.50	0.28	0.53	-0.52	0.37	0.02
1990	-0.04	-0.22	-0.62	0.13	-1.13	0.31	2.02	0.12	1.33	0.16	-1.02	0.61	0.15	0.14
1991	-0.14	-0.26	0.11	0.09	-0.67	0.52	-0.05	1.59	0.73	1.83	1.01	0.59	0.34	0.44
1992	-0.73	0.75	-0.42	0.46	0.21	0.08	-0.04	-0.41	0.66	0.15	1.01	0.56	0.47	0.21
1993	0.11	0.31	0.2	-0.13	0.31	1.25	0.77	-1.08	-0.60	-0.08	0.25	-2.26	0.47	-0.04
1994	-0.76	-1.31	-0.34	0.86	-2.61	0.18	0.21	1.25	0.58	-1.16	0.09	0.01	-0.51	-0.27
1995	0.13	-0.09	-0.48	0.6	-0.45	0.89	0.20	0.82	0.29	0.50	-0.43	0.48	-0.51	0.15
1996	-0.63	0.48	0.17	0.03	-0.38	0.45	.	.	.	.	.	.	.	0.02
1997	-0.35	0.59	0	0.27	-0.21	0.29	0.35	0.04	-0.79	-0.61	-0.45	0.14	-0.41	-0.09

Table A3 Population numbers at age (thousands) in 4VsW cod base run.

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Ages 1-15
1970	85155	80162	40610	47554	39987	17292	6592	3858	902	373	487	323	132	101	17	323545
1971	84762	68549	57822	25209	25541	20366	10050	3640	2472	525	240	274	214	100	72	299836
1972	66998	67602	44519	38615	16002	14928	12035	5135	1204	1387	98	53	68	34	10	268688
1973	61734	53002	40993	25771	20767	6420	6316	6860	2503	672	714	19	36	23	28	225858
1974	74286	49442	34146	26322	15849	8285	2248	2122	1335	526	198	86	8	10	0	214863
1975	85190	59668	33855	15900	10969	6774	4750	1236	825	915	292	150	69	7	9	220609
1976	70831	68356	41097	21021	10156	4648	2563	1226	448	226	129	83	12	19	0	220815
1977	66637	57527	53372	31059	12951	4786	1919	934	600	244	137	95	26	10	12	230309
1978	101952	54557	47079	43216	24317	9164	3154	1128	585	384	170	74	38	11	5	285834
1979	90245	83441	44582	37488	31692	15551	5166	1888	700	382	247	111	36	5	0	311534
1980	106034	73875	68231	34907	24758	17329	8157	3135	1205	504	292	193	87	27	4	338738
1981	112030	86785	60401	54266	24170	13993	8598	3919	1552	703	330	194	134	68	22	367165
1982	63268	91720	70820	46556	36163	13200	7248	4364	1922	912	454	207	130	90	54	337108
1983	62633	51797	74969	55745	31180	20448	7477	3611	2383	960	459	233	111	57	24	312087
1984	29058	51280	42402	58206	37787	18756	11061	4398	2040	1386	583	241	144	69	33	257444
1985	27239	23791	41983	34327	42427	22703	10218	5591	2470	1178	872	339	140	87	41	213406
1986	34653	22301	19475	34232	26066	27361	11780	4490	2379	1060	556	457	121	53	53	185037
1987	45941	28372	18256	15832	24327	14918	15539	6597	2447	1113	561	284	301	39	34	174561
1988	37568	37614	23229	14920	12225	15031	7358	7777	3016	1164	466	260	122	191	22	160963
1989	12127	30758	30788	18851	10852	8192	8759	2861	3850	1154	527	147	76	42	148	129132
1990	9681	9929	25176	24600	13132	5205	3872	4171	1217	1927	507	248	86	36	21	99808
1991	13046	7926	8129	20349	18092	7232	1930	1717	758	190	627	123	81	20	16	80236
1992	6424	10681	6488	6408	13732	9117	2674	1030	837	325	100	122	38	8	8	57992
1993	8023	5260	8743	4798	3071	3794	2128	660	253	518	8	6	2	1	0	37265
1994	14831	6568	4306	7129	3542	1967	2420	1278	424	168	417	0	1	0	0	43051
1995	19258	12143	5378	3526	5833	2838	1584	1916	1033	343	136	341	0	1	0	54330
1996	10660[1]	15767	9942	4397	2874	4735	2278	1278	1553	839	279	112	279	0	1	44334
1997	10660[1]	8728[1]	12909	8107	3521	2305	3849	1850	1042	1270	686	229	91	229	0	36088

[1] Based on GM recruitment

Table A4. Population biomass for 4VsW cod base run.

	Age																
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Ages 5-15	Total
1970	2156	9881	13377	43832	51824	27656	12132	11448	4063	2125	2240	3212	957	478	129	116264	185510
1971	2146	6769	17837	18224	31784	32858	20360	10283	10206	2768	1368	1937	1647	633	532	114376	159352
1972	1192	9500	17617	28446	19594	24350	24434	13158	4946	6536	644	428	506	244	88	94928	151683
1973	2278	7040	22163	22568	23748	9728	12965	15675	6902	3048	2991	159	324	176	254	75970	130019
1974	3579	8311	14176	24639	20407	13236	4634	5047	3628	1625	904	522	68	89	0	50160	100865
1975	7546	11384	14510	12420	13960	12238	10705	3409	2491	3178	1215	776	609	63	99	48743	94603
1976	3751	10456	16113	16404	11744	8173	6413	3922	1691	1024	675	335	105	185	0	34267	80991
1977	2850	8610	23252	24202	17340	9078	5120	3604	2519	1234	703	570	121	109	131	40529	99443
1978	7790	13995	24037	40566	32620	18356	8997	4367	2856	1921	1097	472	259	91	45	71081	157469
1979	2481	14034	25222	35385	43530	30082	13840	6706	3380	2231	1652	991	397	54	0	102863	179985
1980	1658	11808	39239	30958	30588	32279	21781	11356	5390	2944	2009	1643	819	327	54	109190	192853
1981	2834	16810	38352	51229	33678	25731	22042	13625	7643	4322	2409	1622	1476	583	225	113356	222581
1982	1929	19257	45586	42112	47360	26125	17437	14998	8773	5689	3510	1713	1316	1010	570	128501	237385
1983	3159	10268	48895	50006	39236	36913	20062	11240	9963	5336	3138	2059	1079	647	291	129964	242292
1984	732	9970	22866	52654	47219	33266	26476	14749	7718	6607	3735	1830	1325	734	405	144064	230286
1985	1045	6204	25996	29969	52599	39026	22626	16146	9233	5305	4995	2234	1280	883	447	154774	217988
1986	2109	3664	13243	28114	29694	42321	25508	11466	8024	4640	2869	3012	955	518	610	129617	176747
1987	3097	4208	6572	12590	26826	20781	27295	16443	7665	4428	3194	1644	2121	428	371	111196	137663
1988	2008	7037	8648	10180	13233	22367	12652	16373	8140	4219	2148	1763	849	1718	264	83726	111599
1989	712	5238	15983	15037	12092	11485	17050	5893	9372	3821	2279	738	588	408	1391	65117	102087
1990	653	1473	11819	21587	14636	6968	6269	9300	2670	4489	2103	1396	567	367	236	49001	84533
1991	608	1700	3346	16642	19317	9692	2862	3116	1759	424	1570	482	412	213	167	40014	62310
1992	466	1472	3493	4998	12946	11141	4286	1751	1640	825	239	335	170	58	98	33489	43918
1993	541	780	2877	3532	2797	4495	3259	1302	692	1396	38	21	13	11	0	14024	21754
1994	1000	974	1678	6089	4063	2726	3828	2490	1035	570	1605	3	9	2	1	16332	26073
1995	1298	1801	2052	2818	7847	4787	3374	4199	2810	1183	626	2157	3	11	2	26999	34968
1996	719[1]	2339	3446	3196	2814	7828	4393	3633	5026	3639	1370	714	2174	2	9	31602	40583
1997	719[1]	1295[1]	4926	5765	3741	3198	8423	4274	3514	5284	4329	1689	680	1780	2	36914	47605

[1] Based on GM recruitment

Table A5. Fishing mortality in 4VsW cod base run.

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Ages 5-15
1970	0.02	0.13	0.28	0.42	0.47	0.34	0.39	0.25	0.34	0.24	0.37	0.21	0.08	0.14	0.29	0.28
1971	0.03	0.23	0.2	0.25	0.34	0.33	0.47	0.91	0.38	1.48	1.32	1.19	1.63	2.15	0.93	1.01
1972	0.03	0.3	0.35	0.42	0.71	0.66	0.36	0.52	0.38	0.46	1.45	0.18	0.88	0	0.42	0.55
1973	0.02	0.24	0.24	0.29	0.72	0.85	0.89	1.44	1.36	1.02	1.92	0.64	1.04	5.25	1.19	1.48
1974	0.02	0.18	0.56	0.68	0.65	0.36	0.4	0.74	0.18	0.39	0.08	0.03	0	0	0.28	0.28
1975	0.02	0.17	0.28	0.25	0.66	0.77	1.15	0.81	1.1	1.76	1.05	2.34	1.08	4	1.43	1.47
1976	0.01	0.05	0.08	0.28	0.55	0.68	0.81	0.52	0.41	0.3	0.11	0.98	0	0.26	0.35	0.45
1977	0	0	0.01	0.04	0.15	0.22	0.33	0.27	0.25	0.16	0.41	0.72	0.64	0.42	0.2	0.34
1978	0	0	0.03	0.11	0.25	0.37	0.31	0.28	0.23	0.24	0.23	0.51	1.73	4.51	0.23	0.81
1979	0	0	0.04	0.21	0.4	0.45	0.3	0.25	0.13	0.07	0.05	0.04	0.1	0	0.1	0.17
1980	0	0	0.03	0.17	0.37	0.5	0.53	0.5	0.34	0.23	0.21	0.16	0.05	0	0.28	0.29
1981	0	0	0.06	0.21	0.4	0.46	0.48	0.51	0.33	0.24	0.26	0.2	0.2	0.03	0.29	0.31
1982	0	0	0.04	0.2	0.37	0.37	0.5	0.4	0.49	0.49	0.47	0.43	0.62	1.12	0.49	0.52
1983	0	0	0.05	0.19	0.31	0.41	0.33	0.37	0.34	0.3	0.44	0.28	0.27	0.34	0.32	0.34
1984	0	0	0.01	0.12	0.31	0.41	0.48	0.38	0.35	0.26	0.34	0.34	0.3	0.32	0.31	0.35
1985	0	0	0	0.08	0.24	0.46	0.62	0.65	0.65	0.55	0.45	0.83	0.77	0.29	0.6	0.56
1986	0	0	0.01	0.14	0.36	0.37	0.38	0.41	0.56	0.44	0.47	0.22	0.92	0.26	0.5	0.44
1987	0	0	0	0.06	0.28	0.51	0.49	0.58	0.54	0.67	0.57	0.64	0.25	0.37	0.61	0.50
1988	0	0	0.01	0.12	0.2	0.34	0.74	0.5	0.76	0.59	0.96	1.04	0.87	0.05	0.68	0.61
1989	0	0	0.02	0.16	0.53	0.55	0.54	0.66	0.49	0.62	0.55	0.34	0.55	0.5	0.56	0.54
1990	0	0	0.01	0.11	0.4	0.79	0.61	1.5	1.66	0.92	1.22	0.92	1.24	0.62	1.29	1.02
1991	0	0	0.04	0.19	0.48	0.79	0.43	0.51	0.65	0.44	1.43	0.97	2.15	0.78	0.54	0.83
1992	0	0	0.1	0.52	1.06	1.24	1.19	1.19	0.27	3.47	2.6	3.71	3.21	4.15	1.87	2.18
1993	0	0	0	0.1	0.23	0.23	0.3	0.23	0.2	0.02	2.75	1.28	2.29	2.15	0.11	0.89
1994	0	0	0	0	0.02	0.01	0.03	0.01	0.01	0.01	0	0	0	0.01	0.01	0.010
1995	0	0	0	0	0.01	0.02	0.01	0.01	0.01	0	0	0	0	0	0.01	0.006
1996	0	0	0	0.02	0.02	0.01	0.01	0	0	0	0	0	0	0	0	0.004
1997	0	0	0	0	0.01	0.01	0	0.01	0.01	0	0	0	0	0	0	0.004

Figure A1. Residuals from base run of 4VsW cod ADAPT
(Positive residuals with crosses, negative with circles)

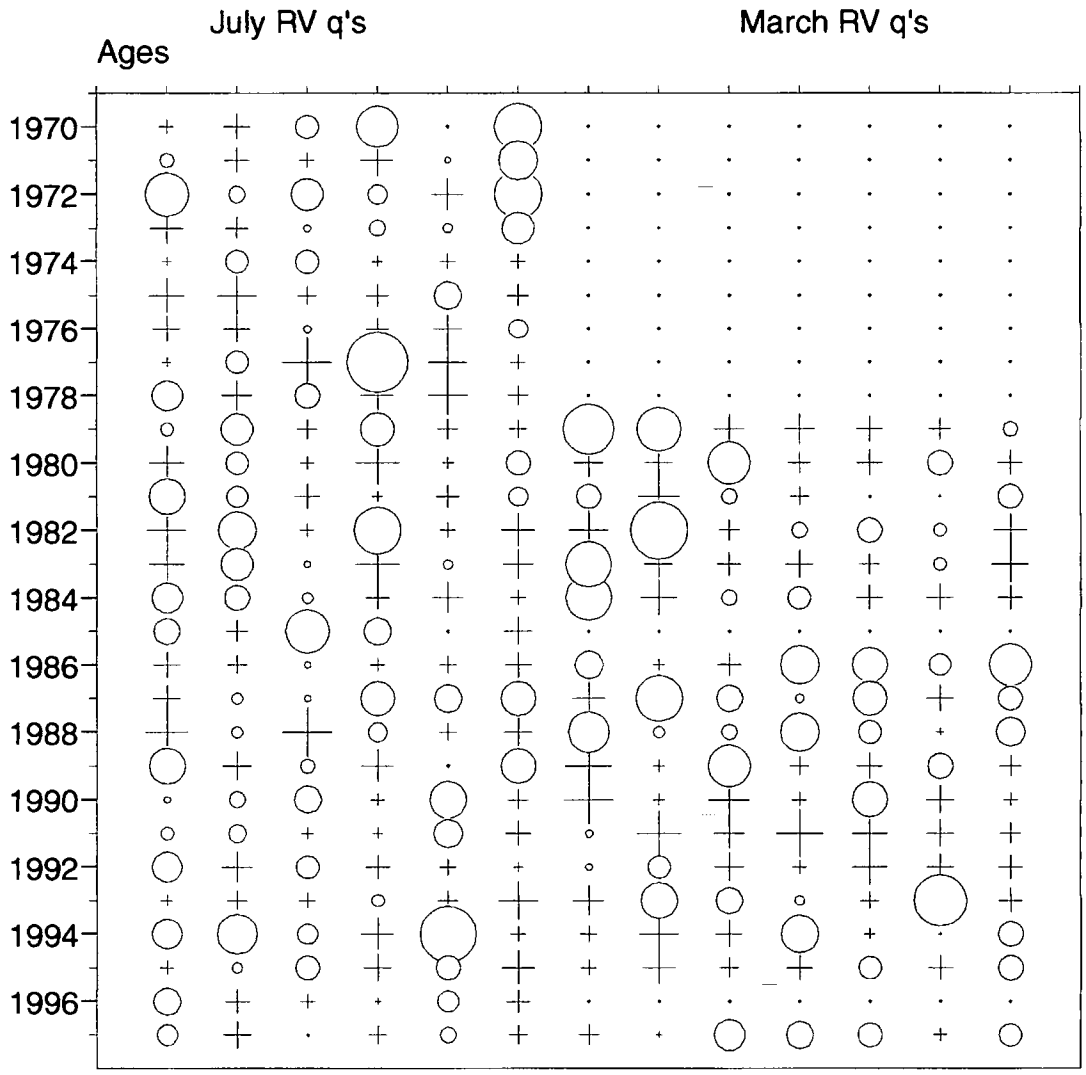


Figure A2. Observed q-adjusted survey and SPA population numbers for 4VsW cod from the base run.

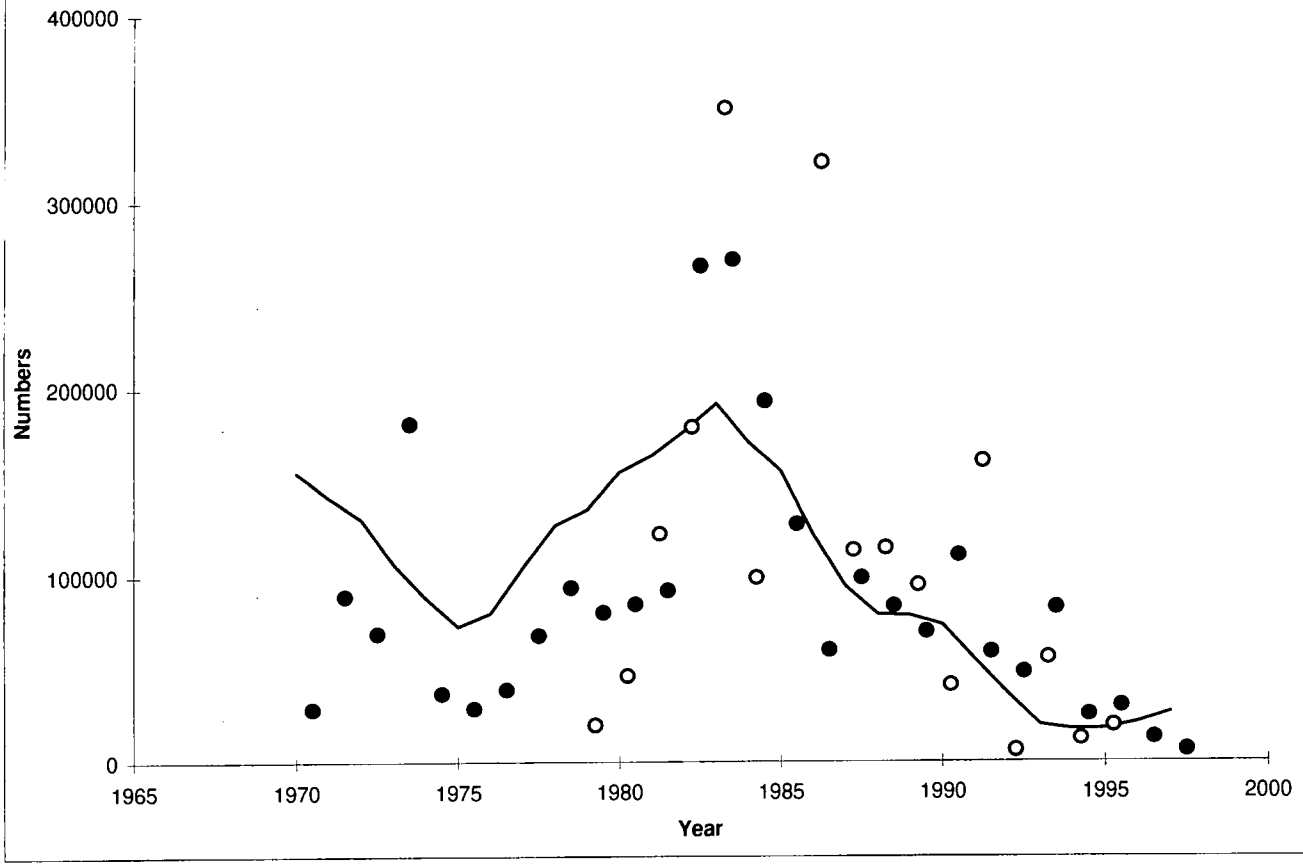
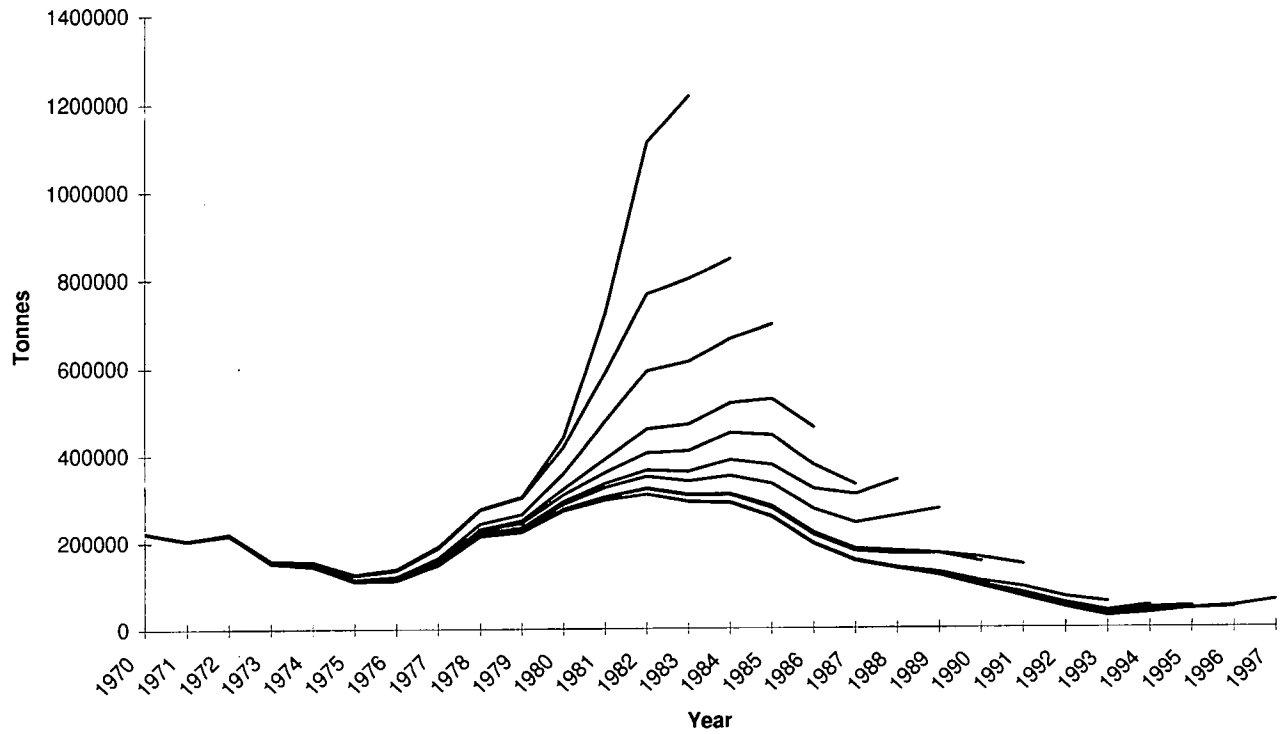


Figure A3. Retrospective estimates of 4VsW cod biomass from the comparative run.



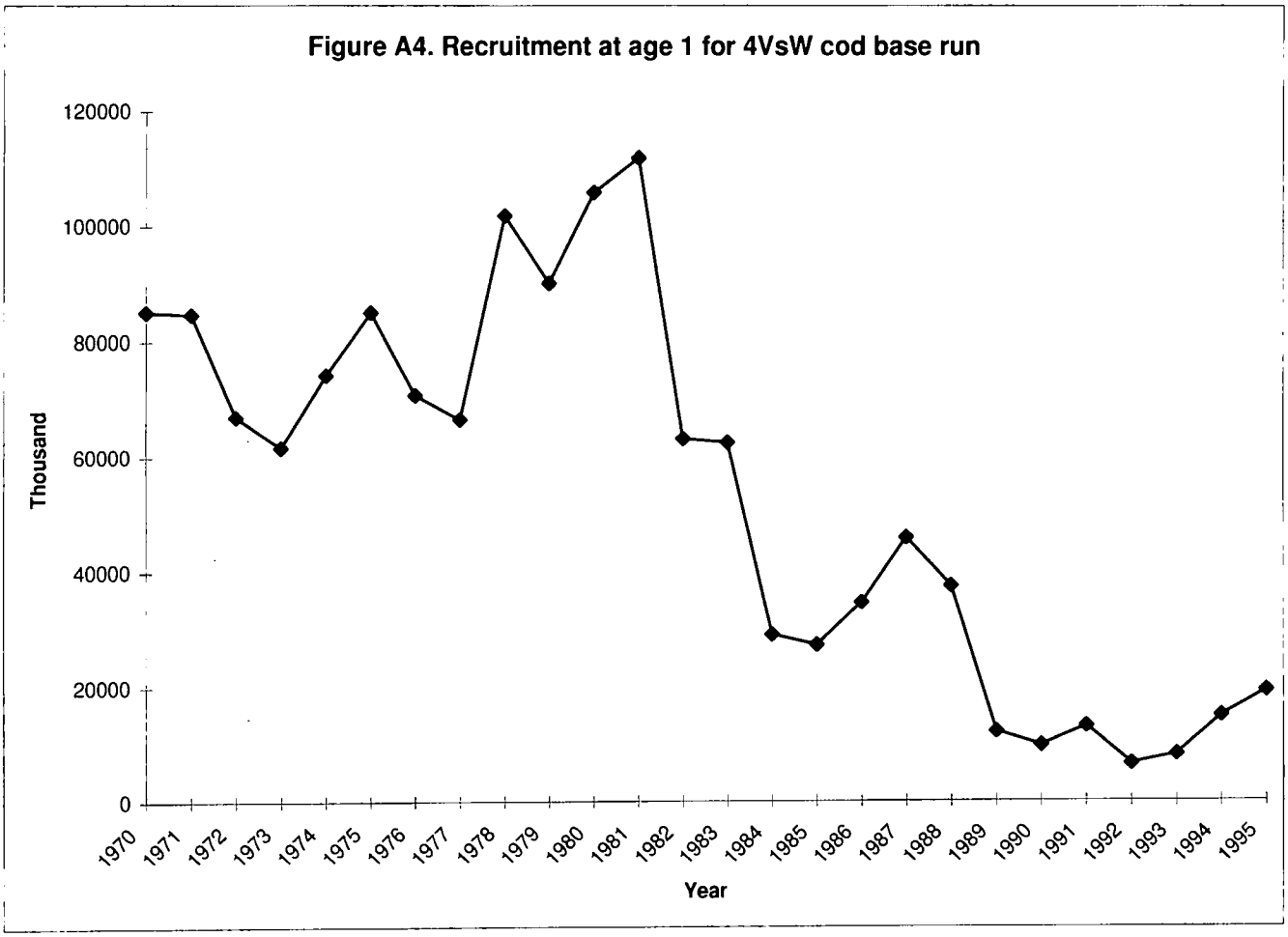


Figure A4. Recruitment at age 1 for 4VsW cod base run
120000
100000
80000
60000
40000
20000
0
Thousand
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Year

Figure A5. Total and spawning stock biomass for 4VsW cod base run.

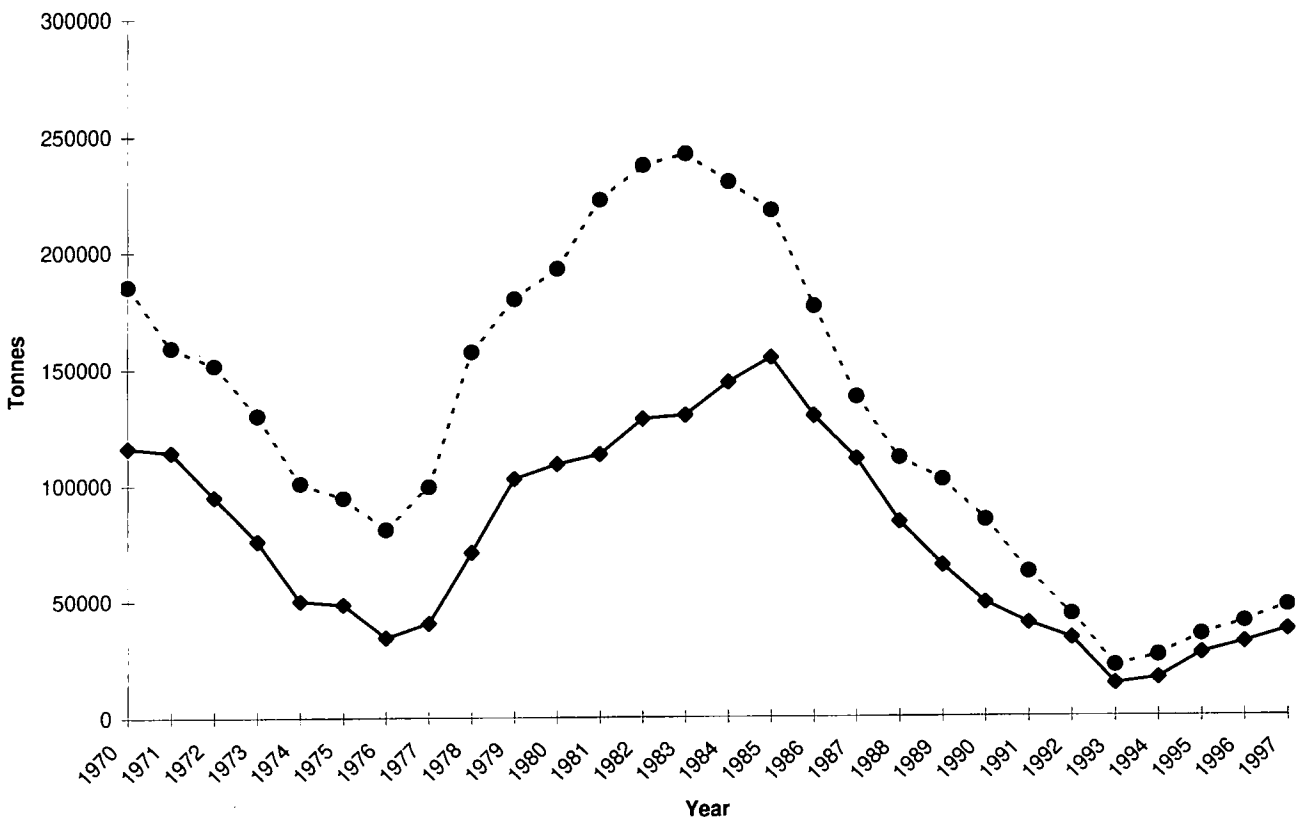


Figure A6. Exploitation rate (ages 5-7) for 4VsW cod comparative run.