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Biological information relevant to the management of 4TVW haddock

Information biologique d'intérêt pour la gestion de l'aiglefin de 4TVW

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Abstract

The current status of 4TVW haddock has been updated using the methods described in the most recent assessment (Frank et al. 2001). This fishery collapsed and was closed in 1993. Recently strong recruitment has been seen but it has been accompanied by very slow growth. The SPA reconstructed stock plus additional information has been evaluated to gain further insight into the productivity of this resource. There has been a period of steady recovery of biomass, but the population is increasingly dominated by small young fish. The 1999 yearclass is the largest seen in the 32 years summer RV series. Emphasis was placed on quantification of the productivity and production of this resource and its ability to sustain exploitation. A brief analysis of 4VW cod is also included as it is likely to be impacted by any re-opening of the haddock.

Résumé

L'information sur l'état du stock d'aiglefin de 4TVW a été mise à jour à l'aide des méthodes décrites dans la dernière évaluation (Frank et al., 2001). Après son effondrement, la pêche a été fermée en 1993. Un recrutement important a été observé récemment, mais il a été accompagné d'une croissance très lente. Les résultats d'ASP et d'autres données d'intérêt concernant la reconstitution du stock ont été évalués pour mieux connaître la productivité de cette ressource. On a noté une période de rétablissement soutenu de la biomasse, mais la population est de plus en plus dominée par des poissons jeunes et petits. La classe d'âge 1999 est la plus abondante observée dans les relevés scientifiques estivaux effectués depuis 32 ans. L'accent a été mis sur la quantification de la productivité et de la production de cette ressource ainsi que sur l'évaluation de sa capacité à soutenir une exploitation. Une brève analyse de l'état de la morue de 4VW, qui devrait être touchée par toute réouverture de la pêche de l'aiglefin, est également présentée.

Introduction

This document is intended to provide biological support to decision making for the 4TVW haddock resource. It is largely based on the most recent assessment (Frank et al. 2001), the update for this stock (DFO (2002)) and additional analysis. Where possible the analyses are carried back to 1948, using information found in Mahon et al. (1985). The purpose is to compile the available information for review and develop analysis to support of management actions.

The specific questions to be addressed are:

1) What is the productivity of the resource and how has it changed.
2) What biological references can be determined.
3) What is the probable impact of a haddock fishery on 4VsW cod.
4) Is the current productivity regime permanent (scenario analysis).

Much of this document will focus on production and productivity. We will define production as an annual change in biomass. Productivity is state variable based and reflects the current stock. Further, we define productivity as a composite of processes, which will be appropriate for longer periods of time. Productivity reflects the regime of growth, survivorship and reproduction. For example, within a given productivity regime, if the biomass falls, the production falls, but the productivity is unaffected. On the other hand if a key parameter changes, for example natural mortality increases, it will decrease both production and productivity.

1. History of stock factors from surveys and commercial sampling

In this section we will review a number of factors relevant to productivity. First will be the factors that add biomass, specifically growth and reproduction. Growth will be examined using both survey and commercial data, the latter going back to 1948. Similarly, maturity information has been compiled back to the mid-1950s. Factors that remove biomass, natural mortality and fishing mortality, will then be reviewed.

A. Growth

Although growth can be thought of as changes in length or weight, the most natural units for productivity are in terms of the annual growth rate as biomass. The weights at age that are not observed for any given year are interpolated as the average of the nearest years. For the age ranges that make up the bulk of the resource this interpolation is rarely needed. Figures 1 and 2 show the weight at age for ages 2-4 and 5-7 from the summer survey series. The reduction in growth is seen even more strongly in the older weights at age. In Figure 3, the weights at age are normalised to their mean. This shows that the older fish have changed more over the time series than the younger. However, the inflection seems to be in 1984 for all ages rather than progressing down cohorts, suggesting errors in aging.

Figure 4 shows the long-term (since 1948) weight at age for ages 3, 5 and 7 from the commercial sampling as reported in Mahon et al 1985. The weights from the same ages from the summer research vessel (RV) series are superimposed and show a good agreement up to the early 1980s, after which the RV weights tend to be smaller.

There has been a significant reduction in length at age which sees 6 year old haddock in recent years smaller than 4 year olds in the 1970s (Figure 5).

The annual growth rates for ages 3-6 from the summer RV series dropped from the early 1970s to the early 1990s, after which a levelling off is seen (Figure 3). If the long term growth is determined for a specific size fish, say 0.5 kg, the rate is seen to increase in the late 1940s then fall again in 1970s (Figure 6). Both commercial and RV data are shown. The divergence in the 1980s is consistent with the commercial sampling being dominated by faster growing fish.

B. Maturity

Figure 7 is the long term maturity data, which shows the age at 50% maturity from the March RV survey (Frank et al 2001) and commercial (Mahon et al 1985) sampling. The two sources to not agree well, but the general picture is one of reducing age of maturity.

C. Natural mortality

Figure 8 shows the annual Z (total mortality) from summer RV survey data for ages 5-10. The data have been smoothed with a 3-year running average. The survey data were not q corrected. After the closure in 1993 there was some reduction in Z, but it has increased in recent years. In the most recent assessment, Frank et al. 2001, and for this work, the recent M was set at 0.35 across all ages.

D. Environment

Figures 9 and 10 are the long-term temperature anomalies at 100 m. from Misaine Bank and Western Banks. The cold water seen on Misaine in the 1990s was not evident on Western. Both series are near the long-term means. Other authors (Drinkwater and Frank, 2001) have chosen the Misaine temperature as representative of the eastern Scotian Shelf. The Western Bank data are included, as most of the haddock biomass is concentrated in this area.

2. Stock Reconstruction from Virtual Population Analysis

A standard age-based population analysis (SPA) was used to estimate the current status and history of the stock. The SPA is tuned to the summer RV numbers at age (Table 1).

This survey also provides length at age and weight at age for subsequent analysis (Table 2,3). ACON software was used to fit the model, which is described as:

Parameters:

Log survivors - $\ln(N_{i,2001})$ i = 1 to12
Calibration coefficients - $q_{J,i}$, i = 1 to 6 for July RV survey
Calibration coefficients - $q_{S,i}$, i = 2 to 8 for Sentinel survey

Structure Imposed:

Error in catch assumed negligible

F on oldest age (12) set to the average F ages 8,9 &10
No intercept was fitted
M = 0.2 for all ages in 1970-1984, .25 in 1985, .30 in 1986, .35 thereafter

Input:

$C_{i,t}$, i = 1 to 12; t = 1981 to 1997 (May to October catch at age)
$J_{i,t}$, i = 1 to 6; t = 1970 to 2001 (July RV index)
$S_{i,t}$, i = 2 to 8; t = 1995 to 2001 (Sentinel index)

Objective function:

Minimise: $\Sigma \Sigma \{(\ln J_{i,t} - \ln(q_J N_{i,t})) + \ln S_{i,t} - \ln(q_S N_{i,t})\}^2$

Summary

Number of observations: 192 from July RV + 49 Sentinel
Number of parameters: 25; 12 estimated by NLLS, 13 algebraically

The numbers at age and biomass at age are given in Tables 4 and 5 from this base run. As was done in Frank et al. 2001, the VPA was extended back to 1948. For the earlier period the available catch at age ranged from ages 1 – 11. The resultant reconstructed populations in terms of spawning stock biomass (SSB) are summarised with the yield, recruitment and fishing mortality in Figures 11-13 respectively. Biomass has gone through two cycles over the period of analysis; a period of high SSB from the 1950-60's, a sharp reduction in the 1970's, a peak in the 1980's followed by another trough in the mid-1990's and a recent increase in the last few years (Figure 11). It is important to note that most of the loss in biomass since the late 1940s is attributable to change in weight and population structure. The average weight of a spawner in 2002 fell to about one-third of the 1948 average. Similarly Figure 13, shows the average fishing mortality over ages 5 to 7. The fishing mortality was seen to be very high in the early 1970s and again just before the collapse in 1993. The stock-recruit relationship (Figure 14) is very weak and care should be extended to the early period as there is considerable uncertainty regarding removals and their age composition.

3. Spatial Analysis

Resource distribution

When the Working Group initially examined these data in July three sets of plots were generated using different cut points between large and small fish and using two time periods. In the first set, 25 cm was chosen which represents a size beneath which there is high mortality induced by trawls. In the second, the size that represents 75% mature was chosen. The maturity at size data were analyzed to determine the size of 50% and 75 % maturity for two time periods, 1979-89 and 1990- 2001. For the earlier period the sizes are 35.8 and 40.3 cm, while for the latter they are 30.5 and 33.7 cm. These were determined by choosing the point on the average maturity nearest the target percentage and its two neighbors. A quadratic curve was fit to the three points and the point calculated on the curve to 0.01 cm. The final set examined was for above (large) and below(small) the current legal size of 43 cm and this is the scenario that will be presented here.

The distributions of haddock from the summer and March RV series are presented as pie charts divided into small and large size categories and separated into two time periods, a historical period of (1970-1989) and the more recent (1990-2001). Since the March RV begins in 1986, only one time period was used. Both the historically and more recent time periods of the summer RV surveys had similar distributions with the majority of fish in 4W. The percentage of fish within the haddock closed box was 25% of the small and 40% of the large for the historical period and 30% for both size categories in the 1990's (Figure 15,16). The distribution of haddock was more highly concentrated in the closed area during the March RV survey, with 44% of the large and 63% of the small haddock located there (Figure 17).

Loss of spawning component

The survey biomass above and below the approximate size of first spawning (35cm) was investigated to see if any inferences could be drawn on loss of a spawning component. The analysis is constrained to comparing 4W, 4Vs and 4Vn as the 4T data were not available.

Weight per tow of large haddock, greater than 35 cm., is given in Figure 18 by subdivision. Div. 4W is seen to follow a different trajectory from the other 2 areas; the fall in the late 1980s was mostly in 4Vs and 4Vn.

Weight per tow of small fish (<35cm) in 4W has been increasing in abundance over the 30-year data period (Figure 19). Some recruitment is seen in 4Vs, notably in the early 1980s. The degree to which the small fish are locally spawned as opposed to migrants is not known. Small fish are rare in 4Vn suggesting that the large fish seen in Figure 18 migrate at a later age and do not represent a resident stock.

4. Production and Yield-per-recruit Analysis

There is considerable confusion in the literature regarding the definition of production. Mertz and Myers (1998) define production as the measure of a stock to grow. This is approximated as the annual change in biomass plus the loss to fishing plus the loss to natural mortality. The usually discussed production in fisheries is the production potentially available for harvest, often called surplus production. In this MS we will add the word 'total' to denote production in the sense of Mertz & Myers. All other uses of production will be in the sense of surplus or available to harvest.

The long-term estimates from the SPA of total production averages 10 kt/year over the last 5 years while the surplus production averages 2 kt/year (Figure 20).

The total and surplus production estimates expressed as P/B ratios are given in Figure 21. The surplus production-biomass ratio was negative in the late 1980s, reflecting that even without fishing the biomass would fall. It also fell negative for the last two years as a result of the strong 1999 year-class, which is now dying faster than it is growing.

Figure 22 shows the partial recruitment, weight at age and length at age by decade for 4TVW haddock; the most significant change is growth. The partial recruitment for the 1990s, which shows a shift to older fish, is dominated by data from a closed fishery and is not well estimated. However it is worth noting that it is consistent with the small current size at age.

Natural mortality also has changed over the period of the data used in this analysis. The most recent assessment reported that natural mortality was changing over time and used values, which averaged 0.2, 0.28 and 0.35 for the 1970s, 1980s and 1990s. For recent years in which there is no fishery, these estimates are lower than suggested by the RV data alone.

A yield per recruit analysis was performed that looked at changing the age of first capture with a knife-edge recruitment and assuming that the haddock live for 16 years. This was done to make the results as compatible as possible with the analysis carried out by CAFSAC in 1989 (p69-71.) which established an $F_{0.1}$ of 0.24 with a yield of 0.46 kg/recruit.

		1970s			1980s			1990s	
Age	Length	$F_{0.1}$	$Y(F_{0.1})$	Length	$F_{0.1}$	$Y(F_{0.1})$	Length	$F_{0.1}$	$Y(F_{0.1})$
1	22.4	0.153	0.367	20.8	0.167	0.180	22.2	0.274	0.119
2	31.8	0.168	0.415	30.3	0.186	0.203	30.2	0.389	0.142
3	40.1	0.183	0.451	37.1	0.279	0.235	34.5	0.485	0.141
4	46.7	0.271	0.516	41.8	0.355	0.244	37.4	0.558	0.127
5	52.0	0.294	0.522	45.3	0.383	0.232	39.9	0.596	0.107
6	56.6	0.383	0.536	48.9	0.460	0.224	41.8	0.618	0.086

The general trend is for $F_{0.1}$ to increase as the age of first capture increases and to increase through time. More pronounced is the fall of yield at $F_{0.1}$ through time, which in the 1990's is less than a quarter of the 1970's even at higher fishing pressures. The low yield per recruit in the 1990's is true for all ages of first capture. This analysis does not include any consideration of reproduction.

5. Productivity

MSY is proposed as a metric of productivity, more productive regimes will support larger MSYs. MSY is estimated from Sissenwine-Shepherd (1987) analysis. The input data are from the latest SPA which uses catch data from 1948 to 2001, surveys from 1970 (summer) and 1986 (Industry) to 2001. The analysis uses a yield per recruit model coupled with a stock-recruit model to estimated sustainable yield. The inputs are growth, maturity, natural mortality, selectivity and stock-recruitment. The parametric recruitment is extrapolated to the origin and this gives the F that causes the (modelled) stock to crash, so-called F_{CRASH}. In the non-parametric analysis, the fit is not extrapolated below the lowest SSB observed. For convenience the use of the term F_{CRASH} is carried on, but it is not strictly correct. Figures 23 compares the parametric and non-parametric results.

When the analysis is performed on the same decadal basis from 1970 as the input data (Figure 22), considerable change from one time period to the next is seen. Figure 24 shows this analysis for parametric S-R fits. In order to get a better feeling for the timing of events affecting productivity, this analysis was extended by using moving 10 year windows and extending the analysis back to 1948 and using a non-parametric S-R. The MSYs from this analysis are shown in Figure 25. The earlier windows have an MSY of about 30 kt, the highest plateau in the series. The windows centred in late 1960s show a rapid drop, corresponding to the loss of recruitment seen at this time. The MSY then returns to above 20 kt and then falls and remains low in the late 1980s. The effect of the strong 1999 year-class can be seen in the most recent MSY estimates. The F_{MSY} (Figure 26) does not show so clear a pattern and is generally in the neighbourhood of 0.3. The F_{CRASH} has declined recently suggesting less resilience in haddock in recent years, those years of slow growth. Recall that these are not true F_{CRASH}'s as the non-parametric fits do not extrapolate to the origin from the lowest observed SSB.

As well as MSY the total biomass and spawning biomass associated with the MSY from each time window are given in Figure 27. F_{MSY} from the moving window analysis is compared to $F_{0.1}$ for each window in Figure 28. $F_{0.1}$ is seen to be much more variable in time.

Figure 29 is a sensitivity analysis of five factors which are included in this framework; growth, natural mortality, partial recruitment, maturity and stock-recruit. The stock-recruit data are seen to be quite influential. Both natural mortality and growth have the similar effects and timing. Figure 30 decomposes some of the factors of Sissenwine-Shepherd estimates of MSY into the cumulative effects of growth, growth and mortality and finally all other factors, most important of which is stock-recruitment.

A test of the affects of window size was performed in which 20 year windows were compared to the 10 year windows used in this analysis (Figure 31). The same general trend was seen in MSY but details are lost. This was done to assure that the window chosen (10 years) was adequate. Windows of a shorter duration than 10 years (results not shown) showed a similar time course to the 10 year windows but were noisier.

The relationship between the productivity (MSY) and the Misaine temperature time series is presented in Figure 32. The two were related and the r^2 was on the order of 0.6. MSY was seen to be strongly affected by recruitment (Figure 29). When both the recruitment level and the recruit/SSB were compared to the temperature time series, it is seen that the recruitment, not the R/SSB, is related to temperature (Figure 33). The recent high R/SSB in Figure 33 occurs when the average weight of a spawner is at the lowest seen in the 50 year time series (Figure 34). This is contrary to expectation that larger spawners are more efficient than smaller ones.

6. Potential implications for 4VsW cod

Haddock-cod co-occurrence

Plots of cod and haddock (greater than 43 cm) co-occurrence in the summer and March RVs are presented to address potential by-catch issues (Figure 35, 36). The bulk of the cod is seen to be east of haddock nursery area in both surveys. However, in March the cod are further west.

Of interest are the cod <43cm. The length frequencies in Figure 37 show that there appears to be a recruiting 1999 yearclass that in 2001 was about 26 cm. It does not appear to be strong though in the 2002 survey results. This is consistent with the reported high natural mortality on this resource. Mohn and Simon MS2002 shows that the smaller cod are mostly found between the haddock box and Sable Island.

Cod biomass

In 1998, when 4VsW cod was last assessed (Mohn et al. 1998), 5+ biomass was estimated to be 13.5 kt in the terminal year (1997). A re-assessment was not undertaken, but an updated biomass based on survey information was sought. In order to do this, the survey gear efficiency (q) had to be estimated. The 1998 assessment could not be exactly recreated, due to changes in assessment methods and underlying data since that time. However, using the identical model structure as Mohn et al. a provisional SPA was performed and the resultant q’s are seen to be quite similar to those q’s in Mohn et al. (1998); Figure 38. Both the published and the provisional SPAs are tuned to the mean number per tow in the summer and March survey series. However, it would be convenient to have scaling factors for trawl efficiency, which could be applied, directly to the RV estimates of total biomass and over a wider age range than was used in tuning. Once the SPA numbers at age and year, SPA[a,y] are available, q’s can be found for any survey in sufficient data are avaialble. The availability increasingly becomes a factor for older ages in more recent years.. If lognormal errors are assumed, the RV numbers at age (RV[a,y]) are matched to the respective SPA numbers and summed over years for which there are observations at a given age. a.

$$q[a] = \exp(\mathrm{sum}(\log(RV[a,y]/SPA[a,y])))$$

To account for mortality during the year, the SPA numbers must be aged ahead to the approximate time of the survey. Because of a change in research vessel and the non-stability of q's over time, this analysis was restricted to data from 1982 to 1997. The resultant q's for the areal expanded RV numbers are shown in Figure 39. These q's were then applied directly to the total biomass estimates from the survey and the results are shown in Figure 40. The estimates for 2002 are similar for either survey and are less than 1,000 t. Although precise estimates are not available, it is safe to conclude that in terms of the 5+ biomass, 4VsW cod is certainly in a worse state than at closure in 1993.

6. Synthesis

The recent productivity and production for 4TVW haddock are summarized in Figure 41. The productivity in terms of MSY fell in the late 1990s (recall these are estimates from moving windows of ten-year duration) to a plateau of about 4 kt. The advent of the strong 1999 yearclass boosted the most recent estimate to about 10 kt. Production (surplus) has been increasing and went positive in 1993 and hovers in the vicinity of 3,000 t/yr., excepting the recent spike and rebound. The most recent point is negative resulting from the rebound caused by the strong 1999 yearclass. This also is derived from the most recent biomass estimate from the SPA, which is the least reliable. If production continues at the recent average, it may be used for yield or for increasing the stock biomass. Because production is based on a difference, it is less well estimated than biomass. Except for the last two points, the standard deviation is of the order of 1,000t. determined by bootstrapping. The last two points have a standard deviation on the order of 10,000t.

The three main determinants of 4TVW haddock productivity are natural mortality, growth and recruitment. Growth is seen to be a slowly varying function and is not expected to recover quickly. Although the temperatures have improved, there may be a density dependent component keeping this rate low. As well as the ten-year averages, the most recent year's weight-at-age data are not recovering. Natural mortality is not as well estimated as the growth because it is inferred from the RV Z's (Figure 8) which are quite noisy. Nonetheless it does not show signs of improvement and is probably also slow to change. Recruitment is more volatile as was seen in the series of bad years in the late 1960s and the intermittent strong year-classes (1952, 1981, 1999). It is not possible to predict the upcoming recruitments. For these reasons, the most probable productivity for the near future is what has been seen for the last decade, on the order of 4.000 t in the absence of strong recruitment.

There are no established biomass reference points for Canadian stocks. At MSY the total biomass is 19 kt and the SSB of 9 kt in the most recent time period. These may be compared to 83 and 58 kt respectively for the long-term average. As was seen in the yield per recruit analysis the recent F_{MSY} of 0.34 is considerably higher than the long-term average of 0.18. Figure 42 shows the recent SPA total biomass and the total biomass at MSY. The recent level is considerably exceeded. It has been proposed that one criterion for re-opening would be to exceed the midpoint of the biomass at closure and biomass target (for the purposes of illustration BMSY). The total biomass would also meet this criterion but only because of the contributions of the strong 1999 year-class.

A similar plot for spawning stock biomass is shown in Figure 43. In this case the recent MSY biomass target is exceeded but the criteria of being half way from the level of the closure is not met for the long term.

On the basis of haddock alone, arguments could be made that a limited fishery could be re-opened. The current size limit of 43 cm. is no longer appropriate for this stock. For discussion, sizes 30 and 38 cm are examined. Figure 44 shows the biomass above 30, 38 and 43 cm. The following table shows the average SPA biomass for the last 10 years in each of these categories and the yield if that biomass were fished with a knife-edge at an F of 0.17, half F_{MSY}.

Size	Biomass 1992-2001 (kt)	Yield (kt)	Biomass 2001 (kt)	Yield (kt)
> 30 cm	22.1	2.9	41.3	5.5
> 38 cm	11.9	1.6	16.4	2.2
> 43 cm	3.7	.49	5.7	.76

A broad number of ages should be fished instead of focusing all the effort on the breeding population. This would also take some of the selection off the fastest growing fish. It is not known to what degree genetic influences have reduced the growth rate, but a wider spread effort would reduce the selection pressure. Any fishery would require complete monitoring and biological sampling. Any change in growth, maturity, survivorship or distribution should be monitored. The economic implications of a smaller size fish fishery are not in the scope of this review.

The 1999 year-class is included in these calculations. Because the age when gains in biomass through growth are outweighed by losses due to natural mortality is presently between ages 2 and 3, contributions of the 1999 year-class to potential yields subsequent to 2001 are not expected to exceed that in the above calculation. In other words, the short-term yield calculations presented above are thought to provide an adequate reflection of yield potentials through 2003.

Expectations regarding yields from this stock vary greatly depending on the time horizon considered. The longest horizon that can be documented is the period 1948-2001. The second time horizon of interest is that from the early to mid-1980s to present, i.e. the current low productivity regime. The immediate yield prospects are related to the status and production of the current standing stock. These are defined respectively as long-term, mid-term and short-term yield prospects.

Productivity in terms of MSY may be thought of as a potential harvest in a given regime. The long-term average MSY is 16,000t, which is achieved from an equilibrium spawning biomass of about 40,000t, fishing at an average F_{MSY} of 0.34. At times in the past, the yields of 20,000 - 30,000t associated with the high productivity period of the 1950s and early 1960s have been taken as the basis for long-term expectations. With more data, that now seems overly optimistic for the longer term. There is some evidence of a prior period of low productivity in the early 1940s, and long-term cycles in production may be a characteristic of this stock.

The fishing mortality associated with MSY of 0.34 provides a reference point different from the $F_{0.1}$ of 0.25, that has been used for this stock from the mid-980s. The F_{MSY} calculation includes information on reproduction characteristics, whereas the yield per recruit analysis used to estimate $F_{0.1}$ does not. Also, the low growth - high natural mortality regime since the mid 1980s was not included in the previous $F_{0.1}$ calculation. Including data from this recent period would result in higher $F_{0.1}$ estimates. F_{MSY}, or some fraction of it, is used for the present illustrative calculations. See Figure 28, which compares F_{MSY} and $F_{0.1}$.

The productivity calculations give an estimate of MSY in the recent (mid-term) low productivity regime of about 5,000t using an F_{MSY} of 0.34 if the contributions from the 1999 year-class are not included. This would be the yield expected if growth, natural mortality and recruitment all remain relatively stable and the stock re-builds to an equilibrium biomass of about 20,000t.

Short-term yield calculations must take into account the current size structure of the population. Much of the biomass in recent years has consisted of relatively small haddock, due to the slow growth of individuals in the population. Figure 44 showed the biomass broken into three size groups - over 30cm, over 38cm and over 43cm. These sizes were chosen because they correspond to the size at first capture that maximizes yield per recruit under present conditions (30cm), the minimum size that industry considers utilizable (38cm - DFO-Industry WG, 2002) and the current minimum fish size (43cm). Considering that the F_{MSY} of 0.34 is suitable for equilibrium conditions, a more conservative mortality rate would be appropriate for rebuilding.

The implications of re-opening a (small mesh) fishery on 4VsW cod need careful consideration. This stock is severely depressed and is showing no signs of recovery, even though current removals are on the order of 100t. The reduction in 5+ cod biomass as estimated by the survey biomass (Figure 40) corrected for gear efficiency has fallen by more than a factor of 10 since closure. Bycatch in any haddock fishery would have to be closely monitored. Similarly skates and white hake in 4VsW are low and have not shown signs of recovery since the closure in 1993. It is recommended that a more complete multi-stock analysis of any proposed fishery should be undertaken as soon as possible. Even in the absence a multi-stock analysis, 4VsW cod should at least be assessed with attention given to distributions, survivorship and potential affects of fishing activity since it has not been assessed since 1998.

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Table 1. Summer RV survey numbers at age for 4VW haddock.

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	2.7	1.7	1.3	0.5	0.4	4.8	2.8	6.1	9.9	0.1	3.5	15.7
2	1.0	3.5	0.9	1.7	2.1	0.9	3.1	11.2	11.0	9.4	0.3	9.3
3	1.8	1.2	1.3	0.5	2.8	2.0	0.5	9.1	14.8	9.8	15.0	1.0
4	2.1	1.6	0.6	0.5	0.6	1.8	0.9	1.4	8.4	10.3	13.9	7.3
5	1.0	0.6	0.5	0.2	0.5	0.5	0.9	2.0	0.5	2.9	8.5	4.7
6	0.6	0.4	0.3	0.3	0.3	0.9	0.2	0.7	0.5	0.4	2.1	2.0
7	0.6	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.3	0.3	0.3
8	0.4	0.3	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1
9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
10	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Sum 1-12	10.5	9.5	5.3	4.0	7.2	11.3	8.9	30.8	45.3	33.2	43.8	40.6

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	18.3	21.3	0.3	4.6	1.2	3.0	4.7	13.7	1.0	0.1	0.8	2.6
2	15.2	14.7	10.8	1.4	3.3	1.2	12.9	7.6	14.9	1.9	1.1	1.5
3	12.8	30.1	17.3	8.8	4.2	2.5	6.1	1.9	10.1	21.6	3.5	1.1
4	2.5	11.7	29.3	11.0	12.8	1.6	4.5	1.4	3.5	19.9	11.9	3.6
5	7.7	3.0	5.2	12.0	13.5	7.4	3.4	1.8	0.7	7.1	6.9	9.7
6	3.0	2.8	2.4	3.4	10.1	7.4	9.6	1.7	0.9	1.5	0.8	3.4
7	1.0	0.9	1.3	0.7	3.2	5.8	6.9	4.7	1.1	2.4	0.7	0.9
8	0.2	0.3	0.2	1.5	0.8	1.3	5.3	3.7	2.0	2.0	0.2	0.2
9	0.0	0.1	0.1	0.7	0.8	0.1	0.9	3.4	2.7	2.2	0.2	0.4
10	0.0	0.0	0.0	0.3	0.3	0.3	0.3	1.0	2.4	2.3	0.7	0.1
11	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	1.8	0.6	0.8	0.5
12	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.2	0.6	0.3
Sum 1-12	60.8	85.0	66.9	44.4	50.3	30.8	55.0	41.4	41.4	61.8	28.2	24.4

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	7.0	3.7	9.8	6.6	3.1	15.5	50.3	5.2	4.3
2	4.5	5.4	6.1	8.6	6.4	8.0	19.0	40.5	19.2
3	1.2	4.5	8.9	3.6	13.3	9.0	7.3	12.6	45.2
4	0.9	0.5	4.8	4.5	5.6	11.5	7.1	4.5	9.5
5	2.3	0.8	0.7	2.3	4.8	6.7	8.4	2.7	2.2
6	6.9	4.1	0.3	1.0	2.2	3.4	3.1	3.2	3.3
7	2.8	4.3	1.3	0.3	0.4	2.1	2.7	1.3	2.7
8	0.2	0.8	3.1	0.5	0.4	0.3	1.1	0.8	0.9
9	0.2	0.2	1.6	2.0	0.5	0.4	0.5	0.4	0.7
10	0.1	0.1	0.3	1.4	1.0	1.1	0.2	0.1	0.5
11	0.2	0.1	0.1	0.4	0.5	0.9	0.6	0.0	0.1
12	0.2	0.1	0.0	0.1	0.0	0.3	0.4	0.1	0.0
Sum 1-12	26.5	24.5	37.1	31.3	38.3	59.1	100.7	71.3	88.6

Table 2. Summer RV survey length(cm) at age for 4VW haddock.

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	21.9	22.6	21.1	23.2	23.5	25.1	21.4	23.3	20.3	21.2	21.0	19.7
2	31.9	31.7	29.4	32.2	34.6	28.2	32.2	32.8	33.0	31.6	28.3	30.9
3	39.7	40.0	36.5	40.4	41.6	43.2	38.4	41.9	40.0	39.3	39.6	37.0
4	45.2	45.4	45.1	47.8	47.1	48.3	47.9	47.2	46.8	45.7	45.8	44.8
5	50.8	50.5	49.3	51.4	53.5	54.7	52.4	53.9	52.5	50.7	49.7	49.1
6	54.6	54.0	56.0	57.4	58.4	59.0	56.1	56.1	57.6	56.5	55.1	54.3
7	58.1	57.0	59.6	58.1	57.9	60.7	61.2	60.8	62.8	60.2	60.5	59.3
8	62.8	62.9	57.1	63.7	60.5	63.3	63.2	64.5	56.5	64.4	64.9	60.9
9	65.1	60.5	58.8	72.5	59.1	62.2	64.5	0.0	0.0	0.0	60.5	63.2
10	67.1	0.0	68.5	72.1	67.2	67.4	54.5	68.5	72.5	69.5	0.0	66.2
11	70.1	0.0	0.0	0.0	66.1	0.0	64.5	78.5	68.5	66.5	0.0	0.0
12	69.3	0.0	0.0	0.0	0.0	72.5	72.5	0.0	0.0	0.0	0.0	0.0

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	17.8	19.0	20.9	22.2	23.1	21.6	22.7	19.9	22.7	21.5	21.9	23.3
2	28.8	25.8	29.0	31.3	32.3	31.8	32.8	31.8	29.7	32.0	33.3	31.7
3	39.6	35.8	35.3	35.4	38.6	37.1	35.3	37.5	35.9	34.8	35.2	36.4
4	44.0	42.0	40.4	40.5	39.2	39.2	39.2	42.7	39.0	38.1	37.1	39.4
5	48.2	48.1	46.2	42.9	42.2	41.4	41.9	43.4	43.3	40.2	40.5	39.6
6	53.8	51.5	51.3	47.0	44.4	43.6	43.0	44.6	43.6	42.4	43.3	41.7
7	57.4	55.2	56.2	50.2	47.2	45.5	46.3	45.4	47.1	45.7	43.2	43.9
8	62.6	59.1	61.6	51.5	51.0	47.6	45.0	47.8	46.7	45.1	47.4	42.4
9	72.0	64.6	64.0	53.0	53.4	53.6	49.7	47.5	47.6	46.5	48.4	46.0
10	64.5	60.6	66.5	58.9	56.8	53.8	47.8	50.4	47.3	47.4	47.3	47.2
11	0.0	0.0	74.5	58.7	57.4	56.1	58.1	53.5	46.9	49.2	47.8	46.5
12	0.0	66.5	0.0	0.0	55.4	49.7	57.7	52.2	54.0	49.6	48.9	49.3

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	23.7	22.0	21.7	22.6	19.6	23.6	21.6	21.4	21.2
2	29.4	29.6	29.7	27.9	29.8	28.6	28.3	27.6	27.9
3	33.6	34.1	35.1	32.8	33.2	34.1	34.1	32.6	31.2
4	38.1	36.7	36.8	37.2	36.2	35.9	37.5	36.8	35.9
5	40.0	39.2	40.1	39.4	38.7	38.5	38.6	38.8	38.4
6	40.3	41.6	42.2	40.8	41.1	41.1	41.1	39.9	40.2
7	42.5	42.7	43.8	41.9	42.8	40.9	43.4	41.9	41.2
8	47.0	45.9	44.0	43.0	40.8	45.0	44.9	43.8	43.4
9	45.6	45.0	44.9	44.7	46.6	43.8	43.4	44.2	45.2
10	48.5	45.1	43.9	44.8	46.8	45.1	45.7	45.8	45.2
11	45.9	45.4	50.3	46.8	47.4	46.0	47.8	46.9	43.9
12	48.3	49.2	49.3	47.0	50.9	44.3	47.4	47.2	52.1

Table 3. Summer RV survey weight(kg) at age for 4VW haddock.

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	0.10	0.11	0.10	0.12	0.12	0.16	0.09	0.13	0.08	0.09	0.08	0.08
2	0.33	0.32	0.27	0.33	0.41	0.23	0.33	0.37	0.35	0.31	0.20	0.31
3	0.66	0.64	0.51	0.67	0.72	0.83	0.57	0.78	0.65	0.62	0.62	0.53
4	0.98	0.94	0.98	1.13	1.06	1.16	1.14	1.12	1.07	0.99	0.99	0.95
5	1.42	1.30	1.28	1.41	1.57	1.69	1.51	1.68	1.54	1.37	1.30	1.27
6	1.78	1.59	1.88	1.99	2.06	2.13	1.87	1.89	2.06	1.92	1.82	1.72
7	2.17	1.86	2.28	2.06	2.01	2.32	2.46	2.43	2.69	2.35	2.46	2.25
8	2.76	2.50	2.00	2.74	2.30	2.64	2.72	2.90	1.93	2.89	3.11	2.45
9	3.08	2.23	2.19	4.09	2.13	2.50	2.90	0.00	0.00	0.00	2.47	2.74
10	3.39	0.00	3.47	4.03	3.17	3.19	1.71	3.48	0.00	3.68	0.00	3.16
11	3.89	0.00	0.00	0.00	3.01	0.00	2.90	5.27	0.00	3.20	0.00	0.00
12	3.75	0.00	0.00	0.00	0.00	3.98	4.18	0.00	0.00	0.00	0.00	0.00

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	0.06	0.07	0.09	0.11	0.11	0.10	0.11	0.07	0.11	0.10	0.11	0.13
2	0.25	0.17	0.24	0.30	0.31	0.32	0.34	0.31	0.26	0.33	0.37	0.32
3	0.64	0.45	0.43	0.43	0.55	0.51	0.43	0.52	0.46	0.42	0.44	0.47
4	0.88	0.74	0.65	0.64	0.58	0.60	0.60	0.77	0.59	0.55	0.52	0.58
5	1.15	1.11	0.97	0.75	0.73	0.72	0.73	0.81	0.81	0.65	0.67	0.59
6	1.58	1.36	1.34	0.99	0.85	0.84	0.80	0.88	0.83	0.77	0.82	0.69
7	1.91	1.69	1.76	1.20	1.04	0.96	1.01	0.93	1.05	0.96	0.81	0.79
8	2.47	2.08	2.34	1.30	1.32	1.10	0.92	1.09	1.03	0.92	1.07	0.72
9	3.75	2.72	2.63	1.41	1.53	1.58	1.26	1.07	1.09	1.01	1.14	0.91
10	2.71	2.24	2.95	1.93	1.85	1.60	1.12	1.29	1.06	1.07	1.06	0.98
11	0.00	0.00	4.18	1.92	1.92	1.82	2.04	1.55	1.04	1.19	1.10	0.94
12	0.00	2.97	0.00	0.00	1.72	1.26	2.01	1.44	1.60	1.22	1.17	1.11

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	0.13	0.10	0.10	0.11	0.07	0.13	0.09	0.09	0.09
2	0.24	0.25	0.25	0.21	0.26	0.23	0.21	0.20	0.21
3	0.37	0.38	0.42	0.34	0.36	0.40	0.37	0.33	0.30
4	0.53	0.48	0.48	0.50	0.47	0.47	0.49	0.48	0.45
5	0.62	0.59	0.62	0.60	0.58	0.58	0.54	0.56	0.53
6	0.64	0.70	0.73	0.67	0.70	0.71	0.66	0.61	0.62
7	0.75	0.76	0.82	0.72	0.79	0.70	0.77	0.70	0.68
8	1.01	0.94	0.83	0.78	0.68	0.93	0.86	0.80	0.78
9	0.92	0.89	0.88	0.89	1.02	0.86	0.77	0.83	0.93
10	1.11	0.90	0.82	0.89	1.03	0.94	0.91	0.92	0.95
11	0.94	0.91	1.24	1.02	1.08	1.00	1.04	0.99	0.86
12	1.10	1.16	1.17	1.03	1.34	0.89	1.02	1.01	1.28

Table 4. SPA population numbers for 4VW haddock.

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	8164	4575	8296	7755	4810	21293	28877	37357	40904
2	5466	6407	3503	6515	5909	3884	17181	23253	30392
3	7161	4358	4642	2608	4268	4627	3125	13455	18782
4	7618	5249	2765	3193	1550	2612	3363	2417	10143
5	4156	4660	2318	1584	1287	1039	1410	2528	1675
6	3322	2136	1336	1061	563	634	596	862	1606
7	3385	1485	656	490	215	191	352	317	450
8	823	1719	362	225	91	73	100	168	154
9	190	322	342	123	40	32	32	49	66
10	70	76	13	136	47	26	19	19	23
11	61	23	27	2	22	23	17	7	2
12	28	32	0	6	0	4	18	11	0
Sum 1-12	40444	31042	24259	23699	18802	34438	55090	80443	104196

Age	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	14944	38240	75731	120084	69150	15022	9099	7409	18575
2	32843	12234	31008	61216	97837	56165	12290	6989	5478
3	24491	26647	9676	25100	49728	79677	45658	9537	5105
4	14643	19669	19671	7685	19174	39733	63864	35283	6979
5	6122	10976	12182	11516	5601	12797	28768	45319	23393
6	977	4401	6056	5376	4335	2740	8464	18003	25264
7	668	656	2063	2235	2631	2032	1500	5306	9684
8	185	412	312	623	726	1675	1292	893	3057
9	71	137	220	130	317	382	1290	721	442
10	33	53	77	85	63	233	285	777	376
11	12	21	35	36	45	35	186	110	488
12	0	8	11	20	25	19	27	104	65
Sum 1-12	94987	113454	157043	234106	249630	210509	172725	130451	98907

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	17042	32373	24547	10301	9515	27246	36062	26190	45882
2	12990	11754	21157	17181	7256	6699	19192	25402	18437
3	3791	9073	7800	14438	12000	5103	4706	13515	17867
4	3530	2633	6276	5249	9561	8351	3589	3314	9506
5	4842	2389	1687	4253	2780	5259	5806	2528	2328
6	15861	3228	1445	1064	2646	783	3345	4077	1773
7	16550	10346	2054	884	591	1371	337	2336	2855
8	6294	10399	5950	1103	422	66	891	227	1619
9	2001	3852	5288	2816	509	126	8	628	150
10	271	1263	1911	1972	1186	152	24	5	441
11	234	164	600	906	708	351	34	17	2
12	332	145	63	250	393	175	142	21	10
Sum 1-12	83738	87618	78778	60415	47566	55682	74137	78260	100872

Age	1997	1998	1999	2000	2001
1	27808	21798	80947	251997	41028
2	32215	19583	15348	57040	177575
3	12952	22680	13783	10813	40192
4	12510	9105	15970	9710	7618
5	6618	8756	6406	11250	6842
6	1625	4656	6144	4506	7926
7	1241	1140	3254	4303	3172
8	1999	873	802	2285	3008
9	1126	1400	609	563	1608
10	100	781	964	424	395
11	311	67	522	674	296
12	2	217	29	365	472
Sum 1-12	98507	91057	144777	353931	290132

Table 5. SPA biomass for 4VW haddock.

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	476	267	626	407	314	1940	3211	1657	3280
2	1306	1161	613	1168	1310	650	3921	4253	6562
3	3941	2016	1880	1103	2092	2692	1122	6798	9221
4	6539	4129	2193	2433	1310	2396	3262	1930	9254
5	5582	5266	2543	1859	1715	1395	1868	3494	2199
6	5771	3205	2089	1694	960	1159	1061	1460	2987
7	6827	2700	1246	964	429	419	804	675	1017
8	2523	3997	698	561	199	167	251	449	333
9	737	797	800	353	97	77	90	108	149
10	317	187	35	404	168	67	40	61	43
11	351	59	53	6	77	56	53	20	6
12	75	85	0	11	0	12	50	26	0
Sum 3-12	32663	22441	11538	9388	7045	8440	8601	15022	25207

Age	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	575	2265	2972	5160	2476	525	428	458	1181
2	5097	1657	4800	8472	9819	7006	1968	1270	1024
3	11462	11685	3198	11107	16696	21342	14475	3843	2036
4	11728	15407	15089	5250	13124	21520	33311	17485	4023
5	7401	12438	13677	12038	5531	10836	20060	30810	15056
6	1677	6945	9055	7624	5419	3348	8319	14414	19738
7	1467	1426	4172	4053	4305	3152	1904	5377	8762
8	516	1112	766	1471	1448	3334	1958	1125	3263
9	131	365	643	393	822	893	2347	1016	638
10	84	99	214	233	182	661	644	1258	587
11	29	57	69	88	102	107	444	212	896
12	0	18	21	37	59	36	73	188	101
Sum 3-12	34494	49553	46904	42293	47687	65228	83536	75727	55101

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	882	2102	931	682	494	1701	3498	2381	3048
2	2365	2156	2879	3326	1400	1233	3441	4566	2980
3	1407	3806	2939	4771	4585	2128	1600	4139	5817
4	1954	1515	3463	2652	4470	4231	1794	1392	4101
5	3228	1661	1332	2637	1691	2910	3495	1418	1278
6	12024	2602	1185	839	1930	531	2055	2694	1162
7	15236	8926	1979	789	466	1105	242	1625	2162
8	5932	10905	5822	1083	427	50	798	190	1285
9	2353	3830	5766	2867	522	125	6	595	137
10	359	1608	2039	2126	1228	161	25	5	378
11	423	216	695	1020	767	351	32	17	3
12	634	248	99	282	465	193	144	22	10
Sum 3-12	43551	35315	25318	19066	16552	11785	10190	12098	16333

Age	1997	1998	1999	2000	2001
1	1847	1513	3281	25422	2484
2	4580	3296	1996	9359	23843
3	3794	6238	4458	3170	10588
4	5745	3652	6593	4313	3198
5	3565	4724	3354	5671	3598
6	1049	3013	3938	2780	4547
7	903	827	2268	3187	2157
8	1601	613	687	1770	2370
9	965	1255	466	479	1359
10	89	748	945	376	335
11	285	65	531	667	282
12	2	254	29	368	485
Sum 3-12	17997	21389	23270	22782	28919

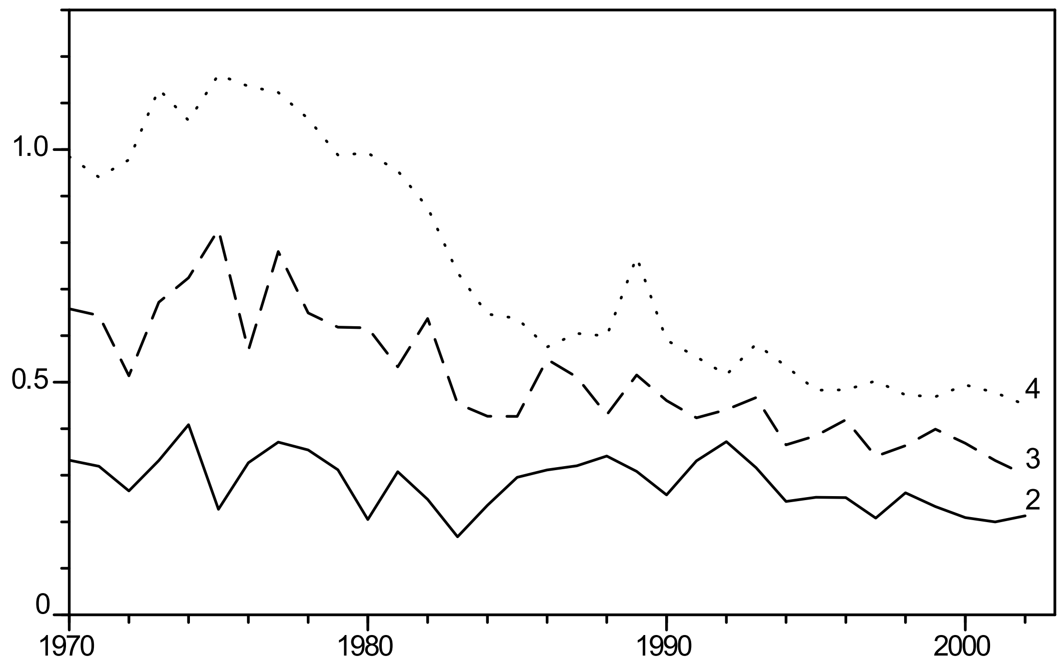

Figure 1. Haddock weight (kg) at age for ages 2-4 from the summer RV surveys.

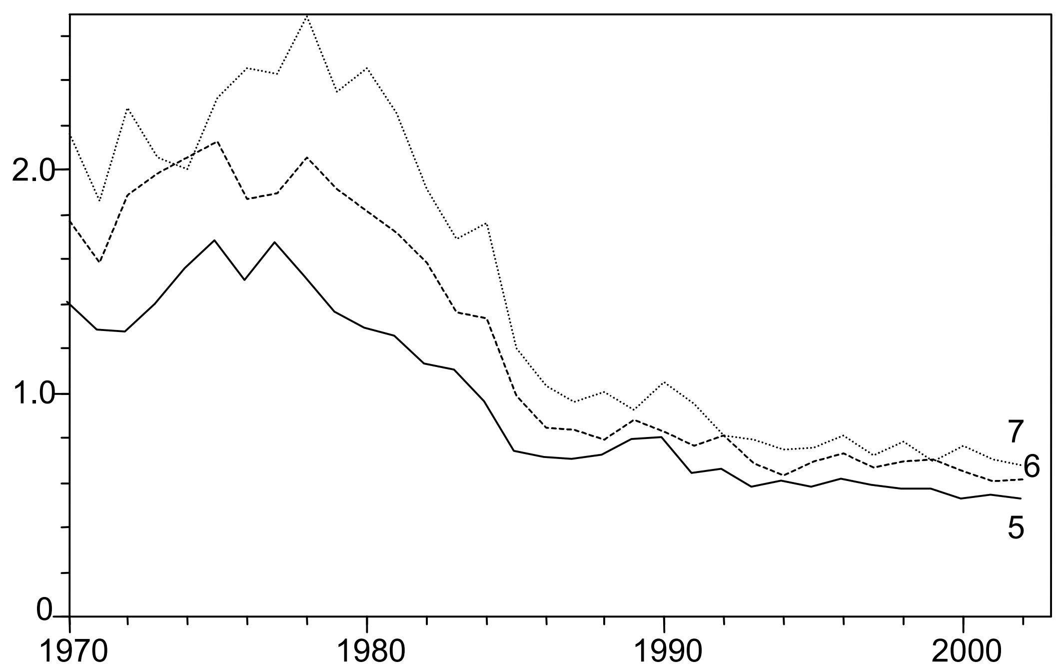

Figure 2. Haddock weight (kg) at age for ages 5-7 from the summer RV surveys.

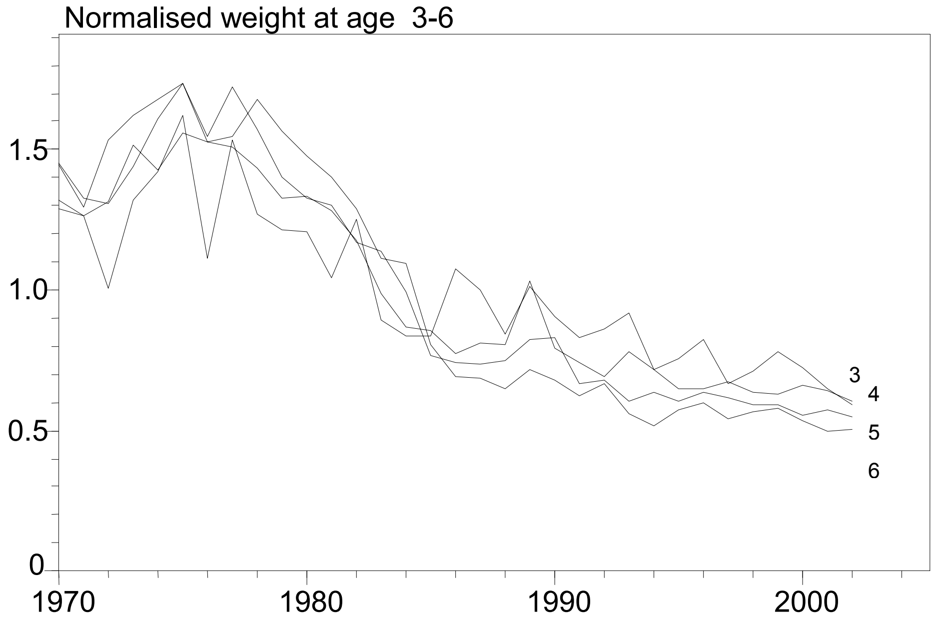

Figure 3. Normalised haddock weight at age for ages 3-6 from the summer RV surveys. The younger ages are slightly less changed than the older.

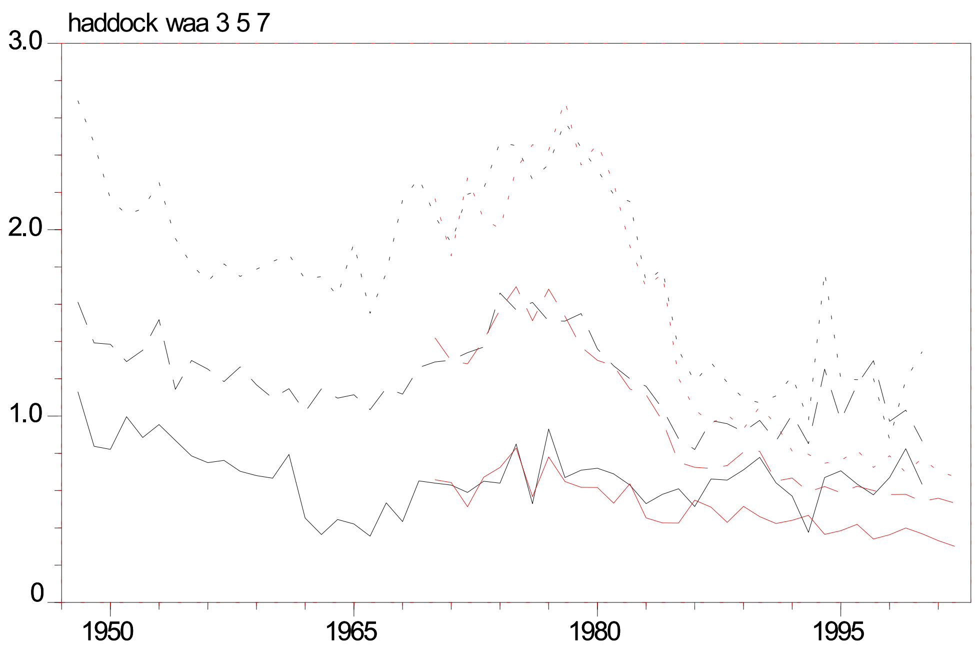

Figure 4. Long term haddock weight at age for ages 3,5, 7 from the commercial and summer RV surveys.

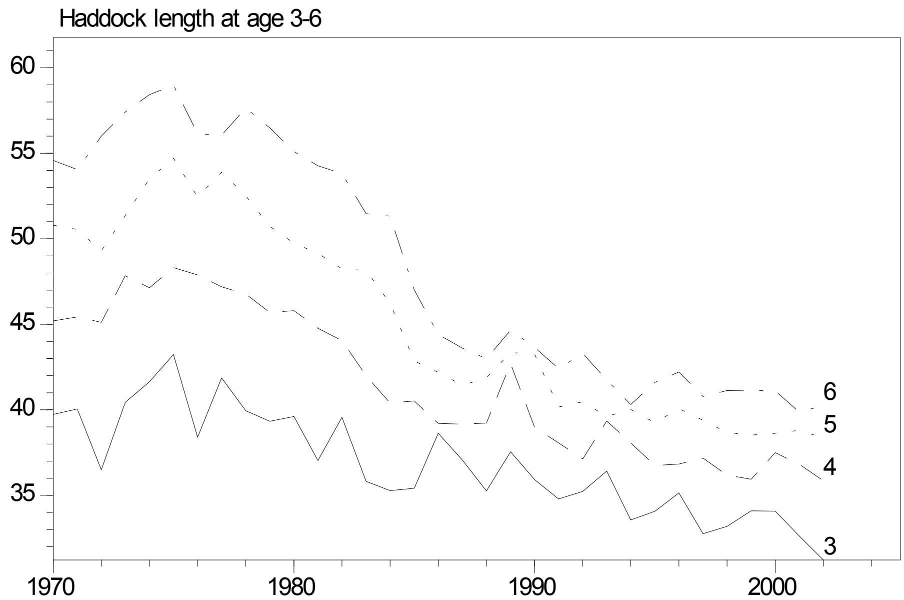

Figure 5. Haddock length at age for ages 3-6 from the summer RV surveys.

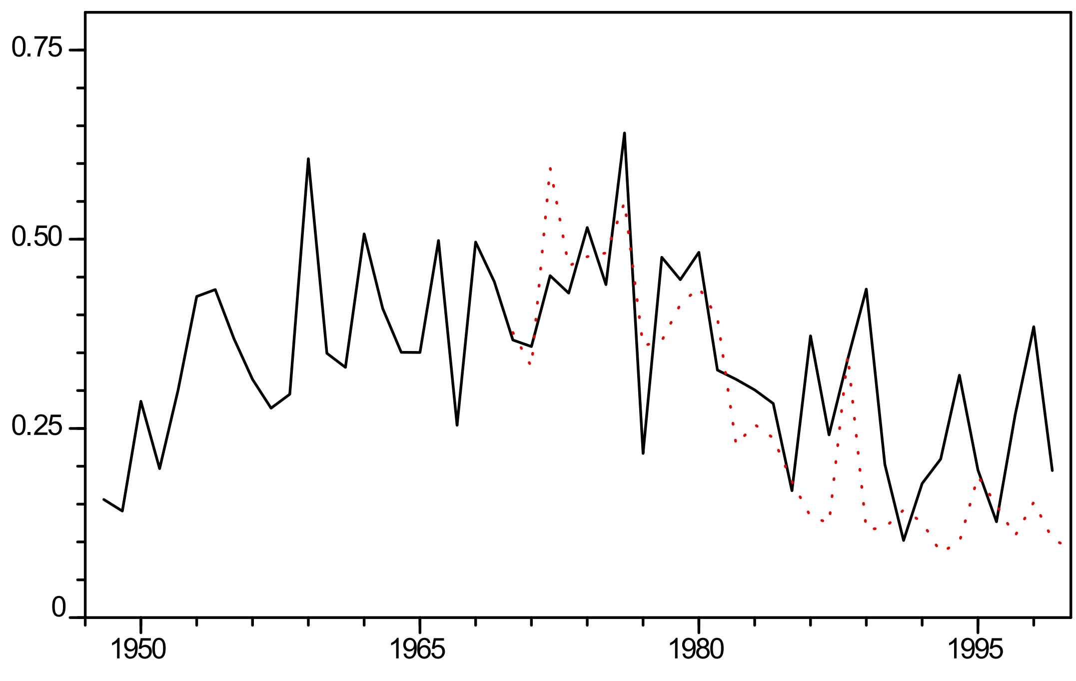

Figure 6. Long term haddock growth rate at .5 kg from the commercial (solid) and summer RV (dashed) surveys.

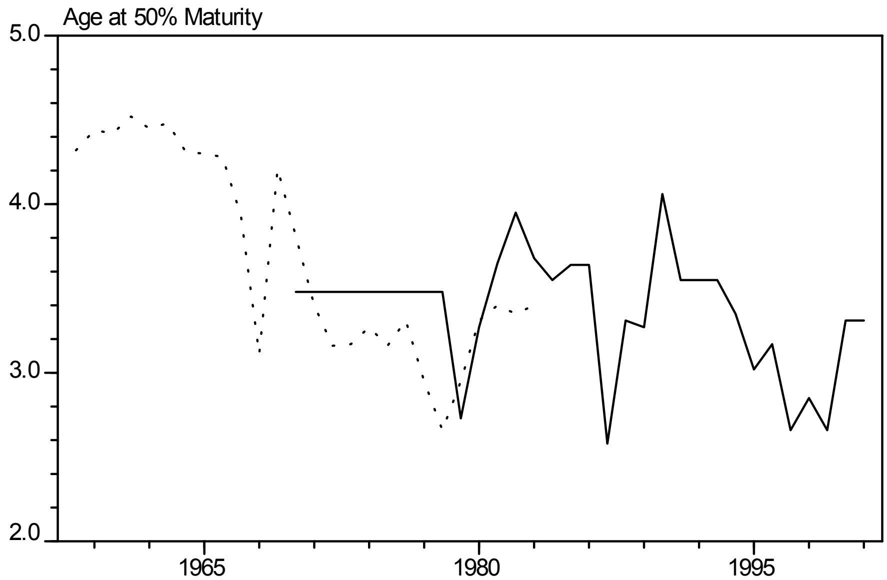

Figure 7. Age at 50% maturity from the March RV surveys (Frank et al 2001) and commercial (Mahon et al 1985) sampling.

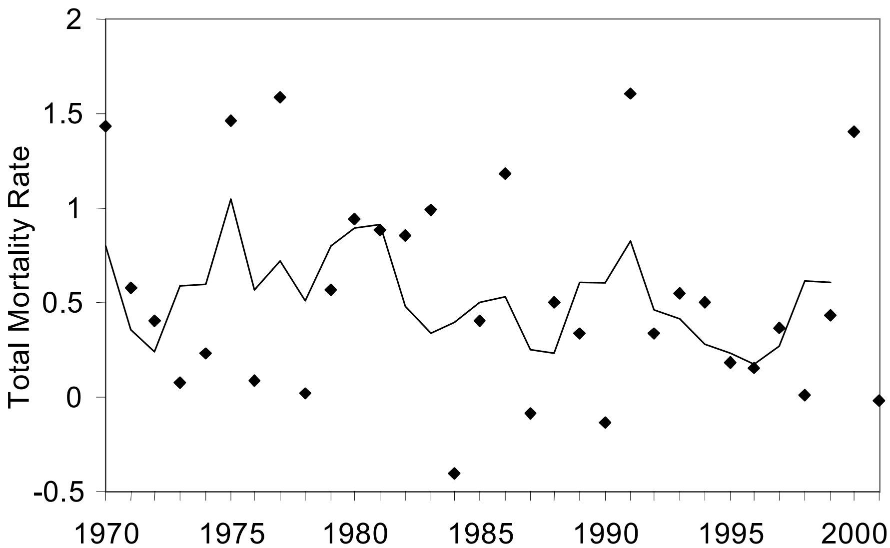

Figure 8. Estimates of total mortality (Z) for ages 5 – 10 from the summer RV survey for 4TVW haddock. Dots are annual estimates, the line is the 3-year running average.

Figure 9. The annual (points) and 5-year running mean (line) of the temperature anomalies at 100m on Misaine Bank in the northeastern Scotian Shelf (K. Drinkwater pers. comm.).

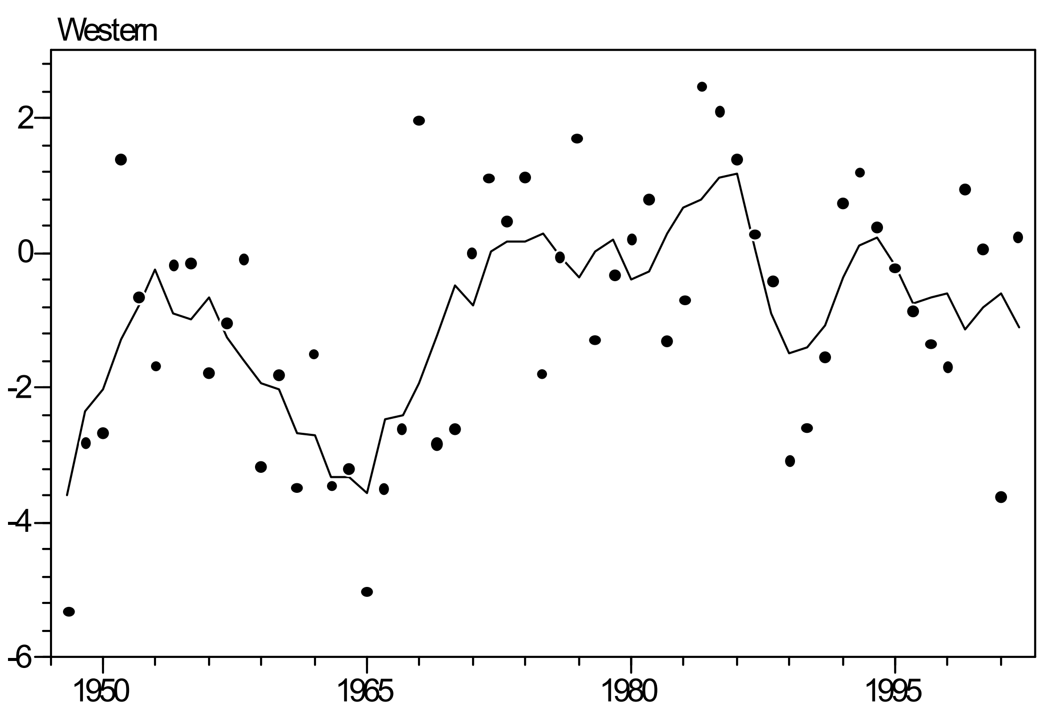

Figure 10. The annual (dots) and 5-year running mean (line) of the temperature anomalies at 100 m on Western Bank in the northeastern Scotian Shelf (K. Drinkwater pers. comm.).

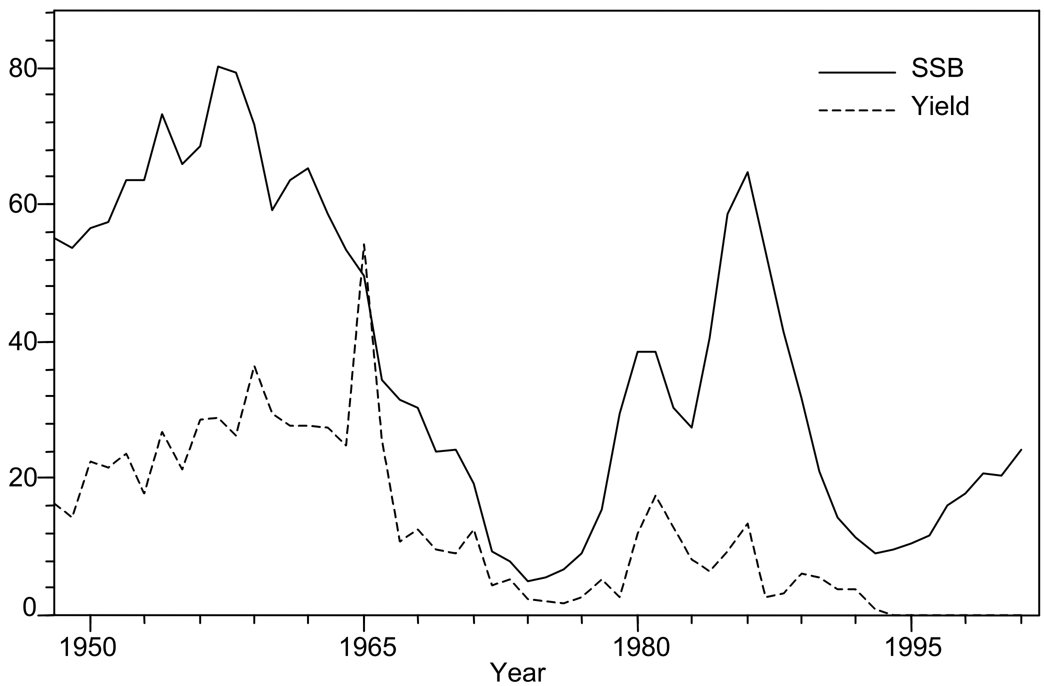

Figure 11. Yield and spawning stock biomass (SSB) in kt as estimated by the SPA for 4TVW haddock.

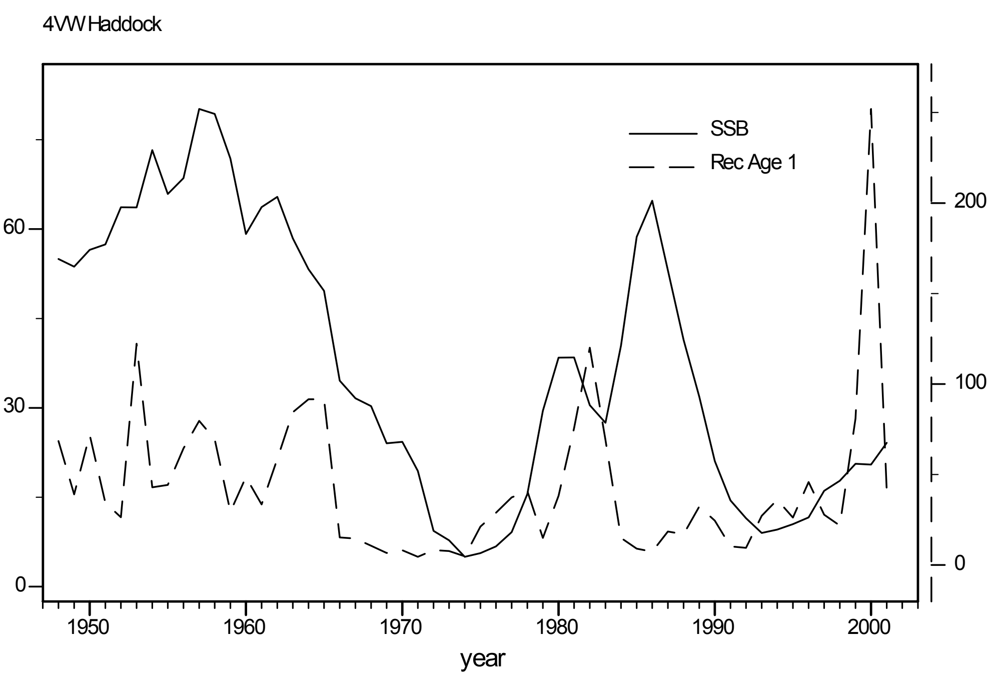

Figure 12. Recruitment in millions and spawning stock biomass (SSB) in kt for 4TVW haddock as estimated by the SPA.

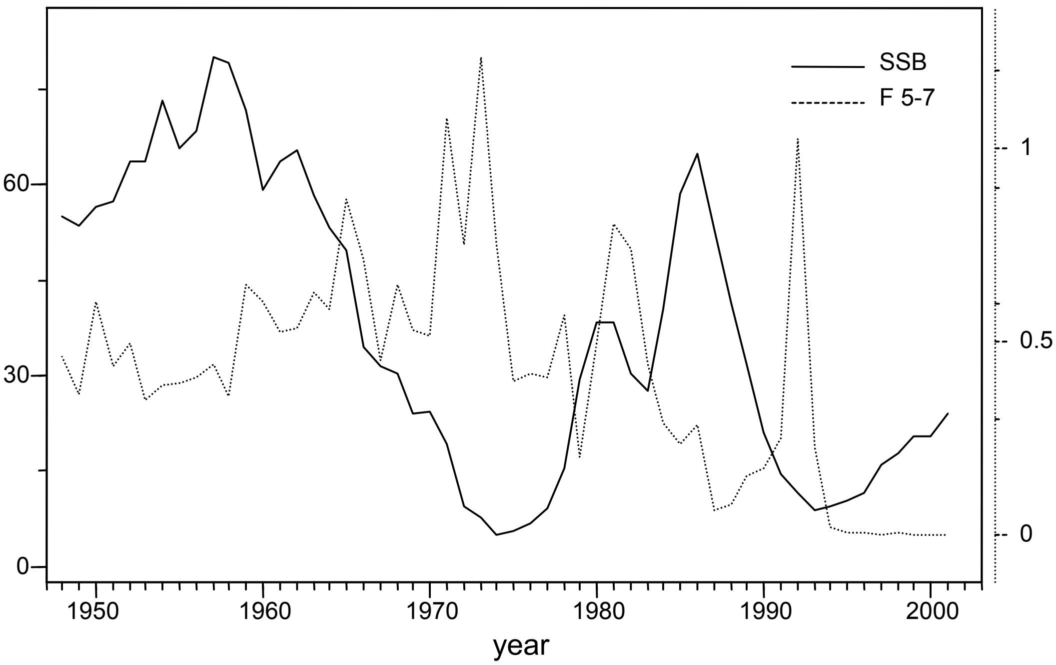

Figure 13. Average F over ages 5-7 and spawning stock biomass (SSB) in kt for 4TVW haddock as estimated by the SPA.

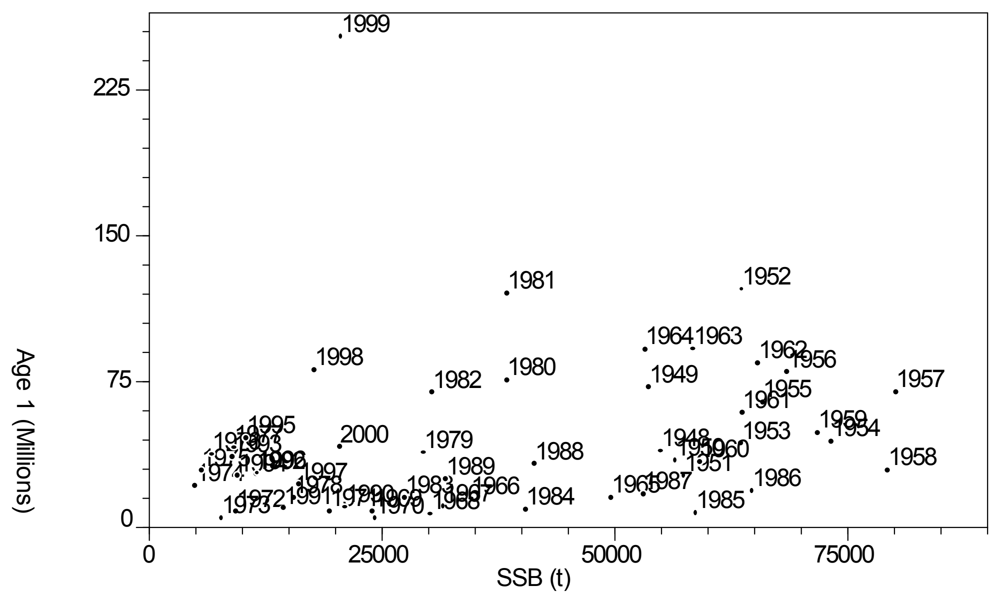

Figure 14. Stock-recruit relationship from SPA for 4TVW haddock.

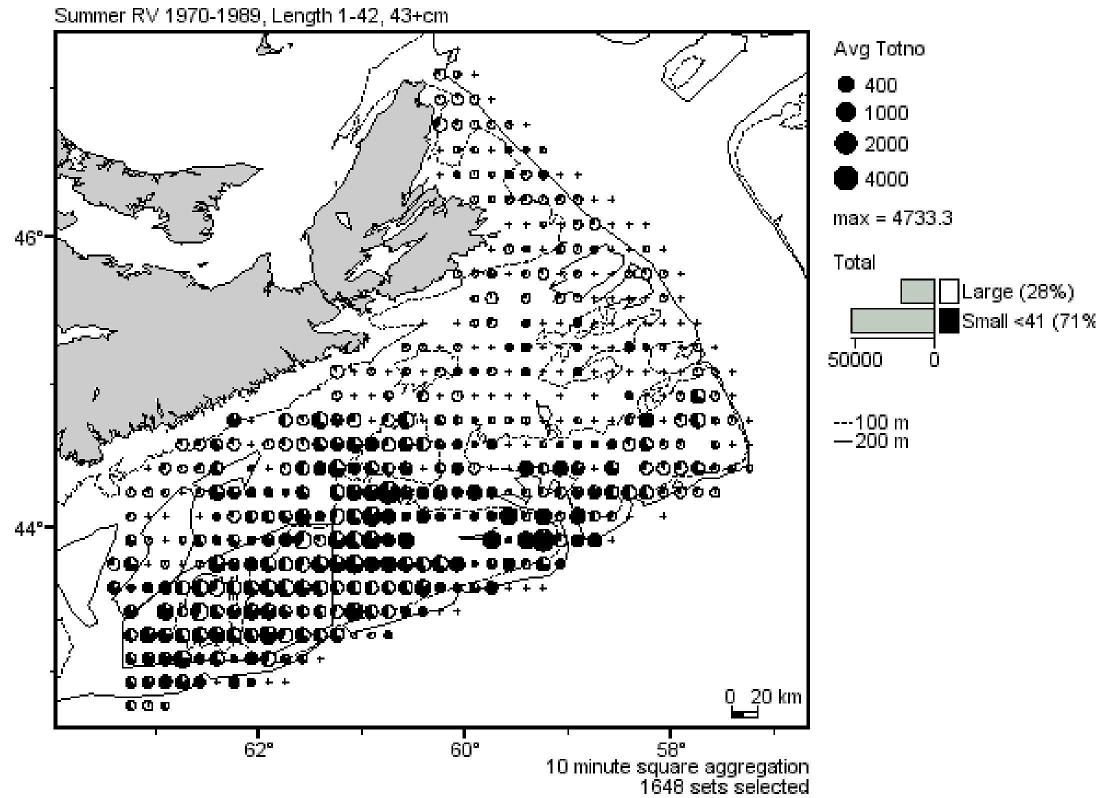

Figure 15. Pie chart for small (< 43 cm) and large haddock from historic summer RV survey, 1970-1989. 40% of the large and 25% of the small haddock are inside the haddock closed area.

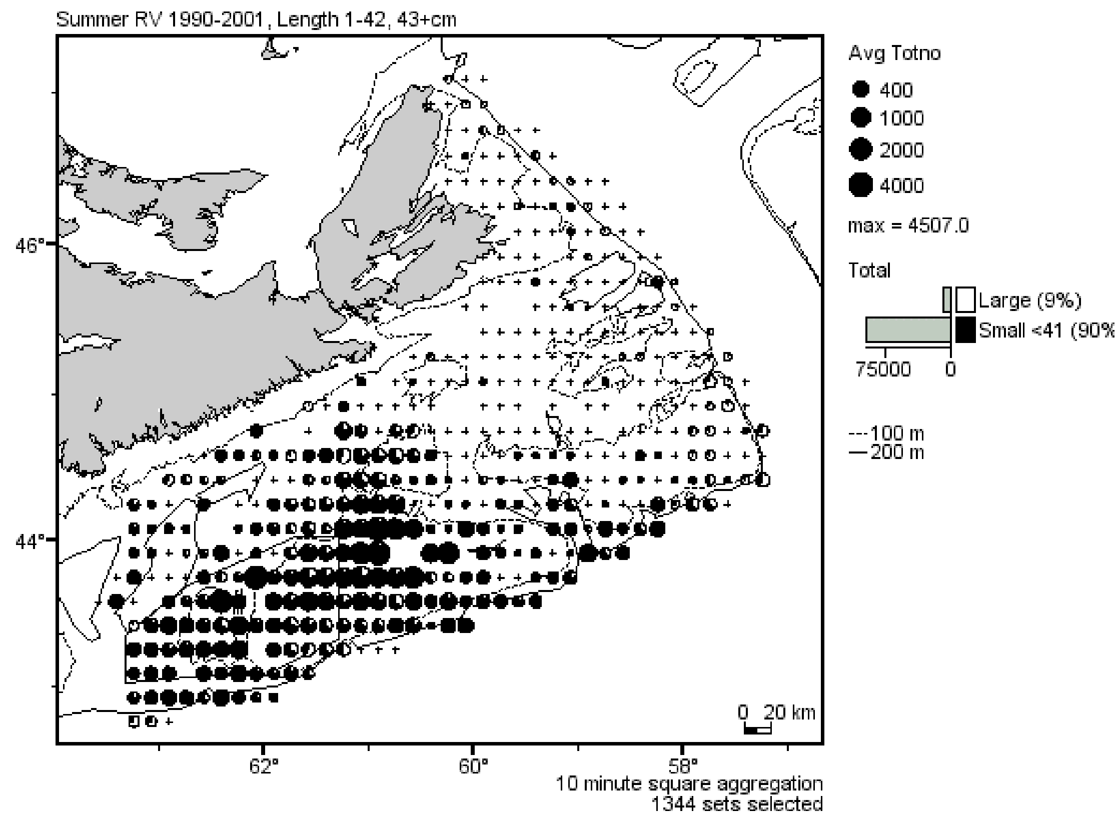

Figure 16. Pie chart for small (< 43 cm) and large haddock from the summer RV survey, 1990-2001. 30% of both the large and small haddock are inside the haddock closed area.

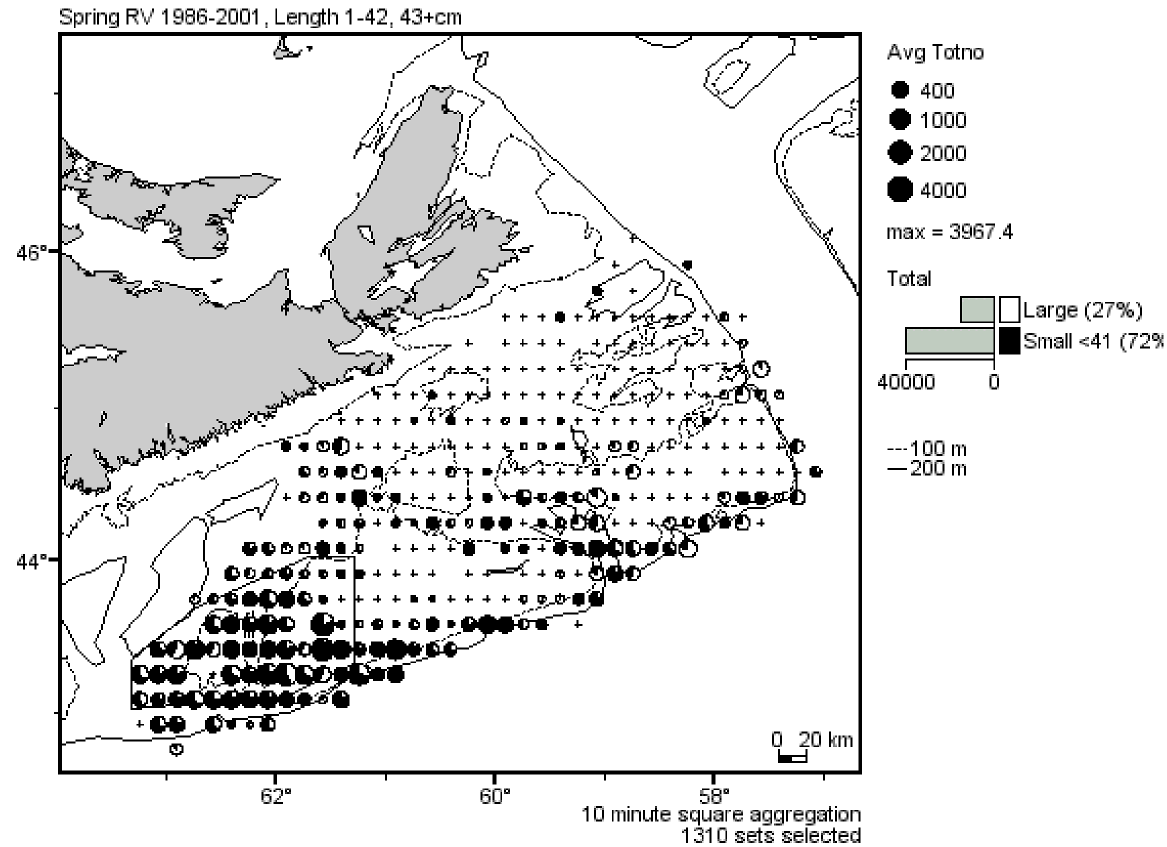

Figure 17. Pie chart for small (< 43 cm) and large haddock from March RV survey, 1986-2001. 44% of the large and 63% of the small haddock are inside the haddock closed area.

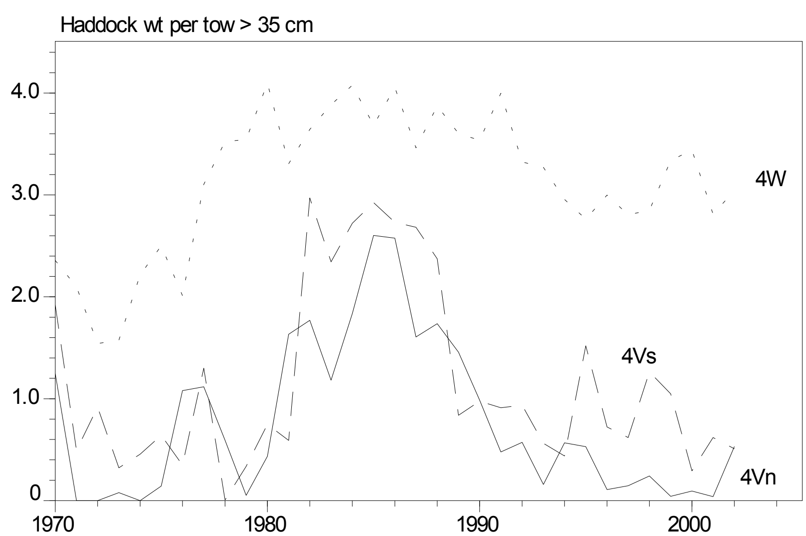

Figure 18. Weight per tow of haddock greater than 35 cm from the summer RV survey.

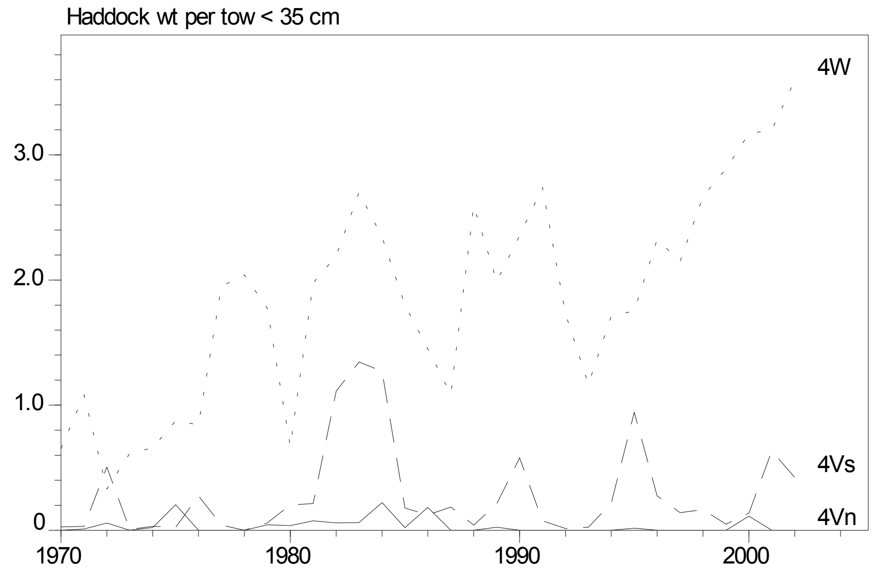

Figure 19. Weight per tow of haddock less than 35 cm from the summer RV survey.

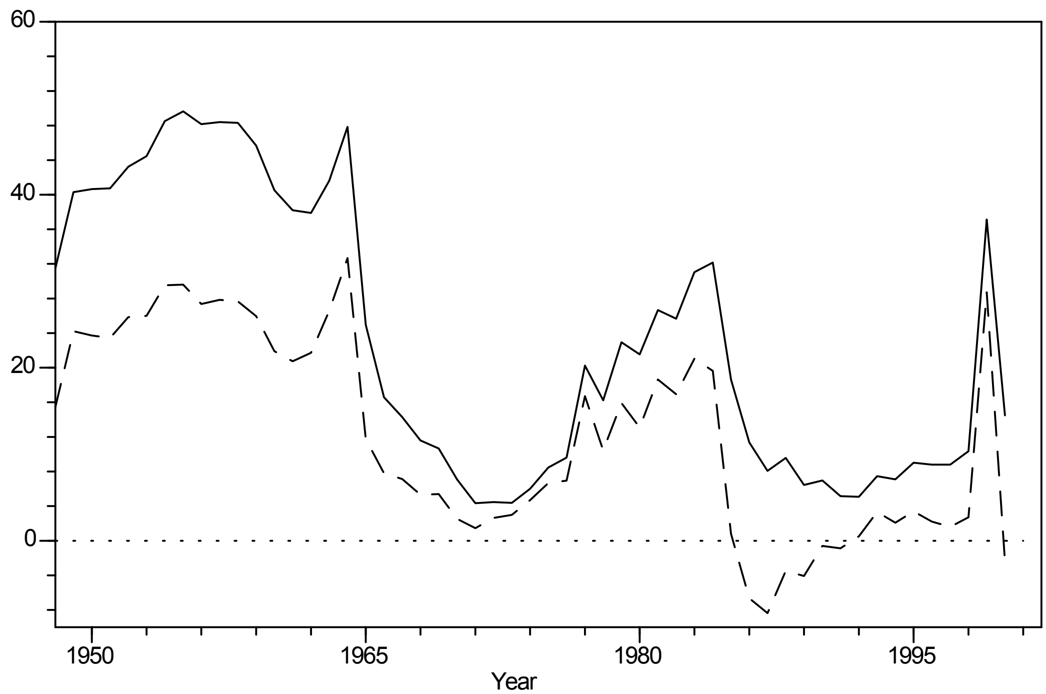

Figure 20. Total production, kt (solid line) and surplus production, kt (dashed line) from the long-term SPA.

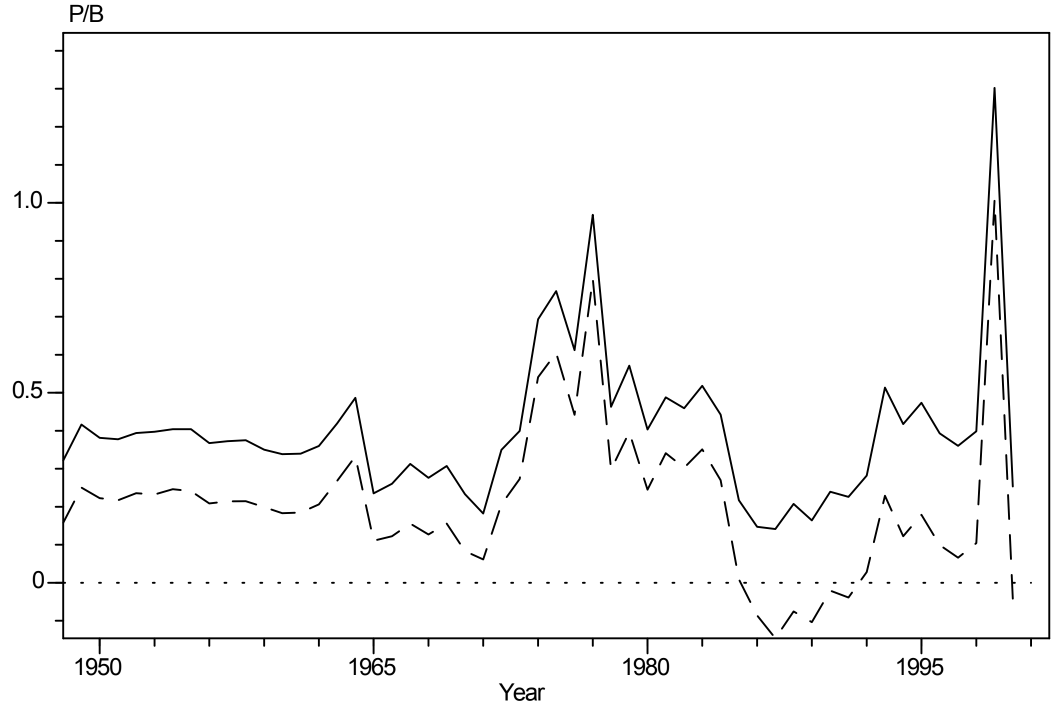

Figure 21. Total production to biomass ratio (solid line) and surplus production to biomass ratio (dashed line) from long-term SPA.

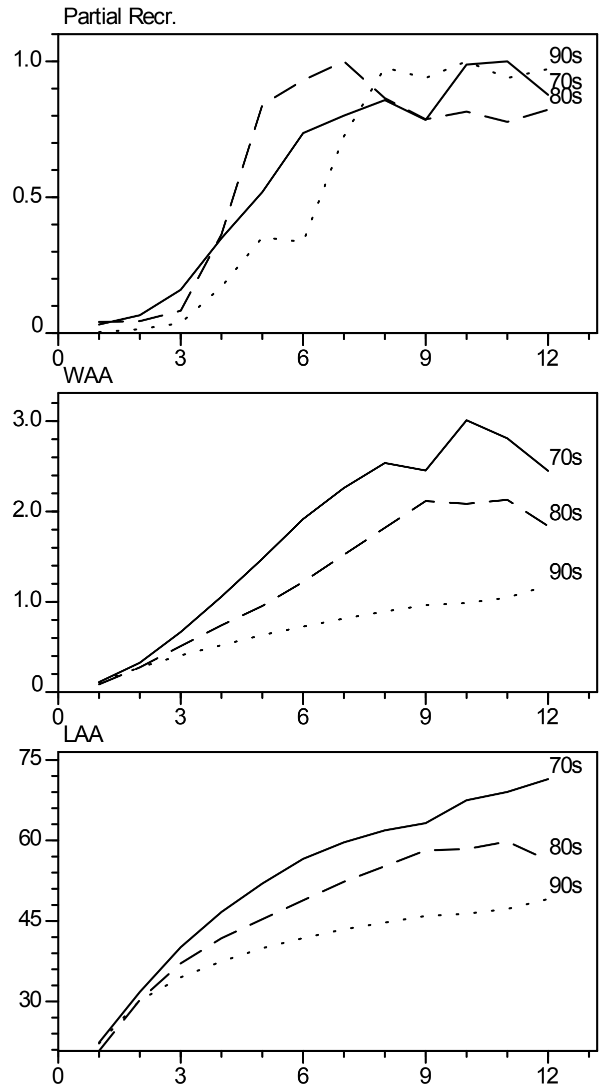

Figure 22. Comparison by decade of partial recruitment, weight at age and length at age for 4TVW haddock.

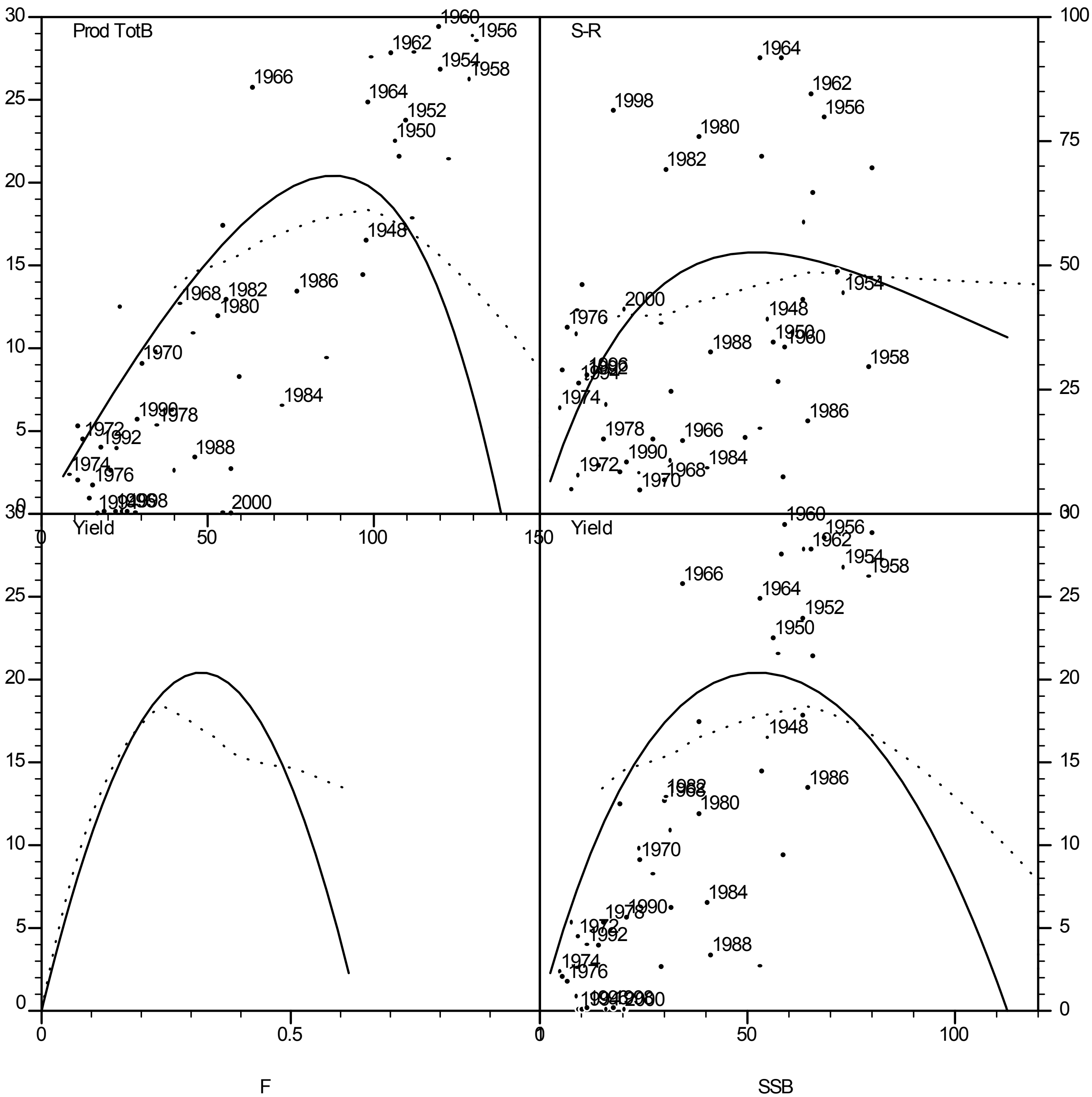

Figure 23. Sissenwine-Shepherd analysis using long term average parameters. The solid line is a parametric fit to a Ricker model; the dashed line is a non-parametric kernel fit to the stock recruit data. The upper left panel is production as a function of total biomass; the upper right is stock-recruit data with labels denoting year-class; the lower left is yield as a function of biomass weighted F and the lower right is yield as a function of SSB. The data points in the upper left are yield versus F.

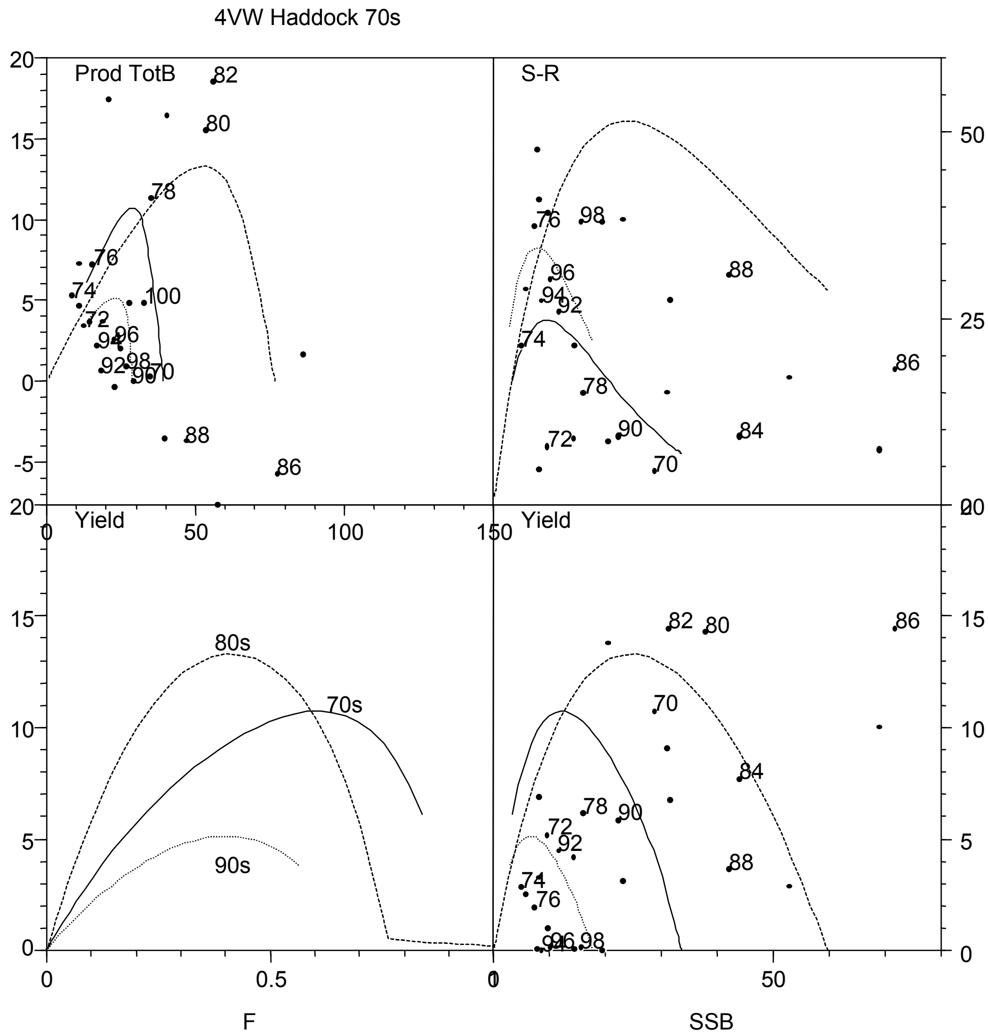

Figure 24. Productivity estimated by decade using Shepherd-Sissenwine model. The negative points in the upper right corner are annual surplus production.

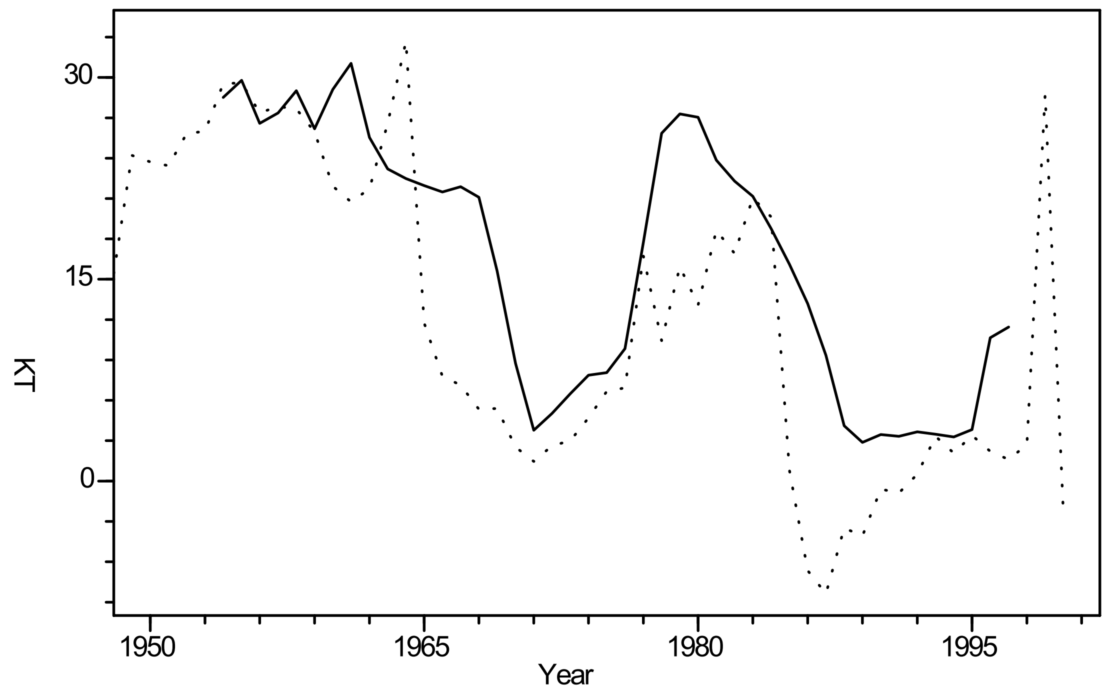

Figure 25. Estimates of MSY from 10 year moving windows (solid line). The x-axis labels denote the centre of the 10-year window. The dashed line is the annual surplus production.

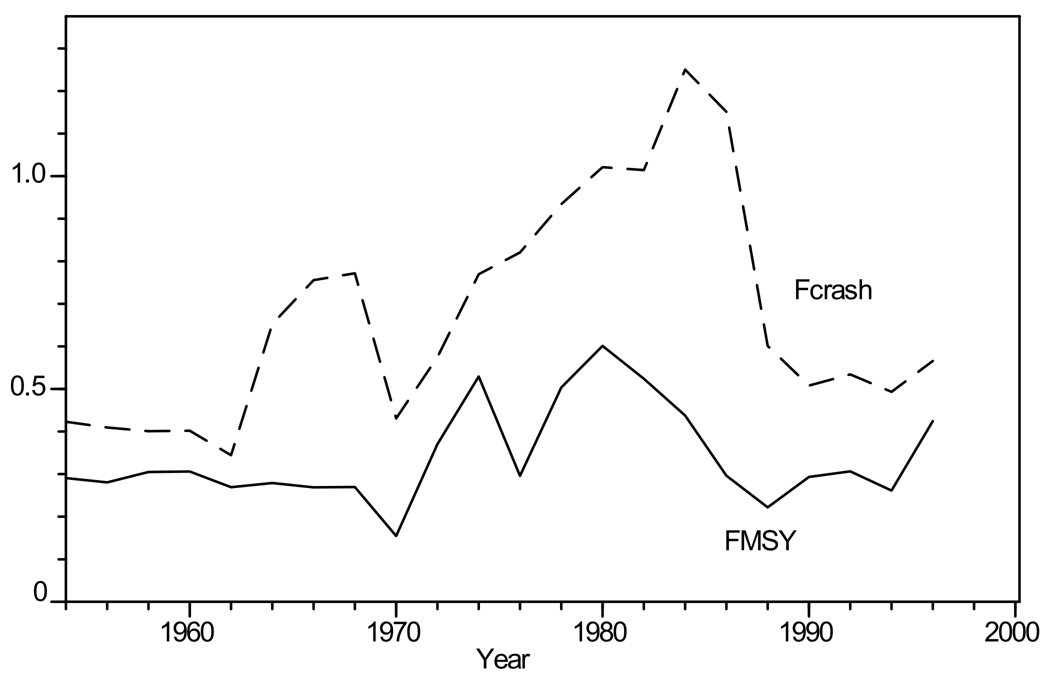

Figure 26. Estimates of F_{MSY} and F_{CRASH} from 10 year moving windows. The x-axis values denote the centre of each 10-year window.

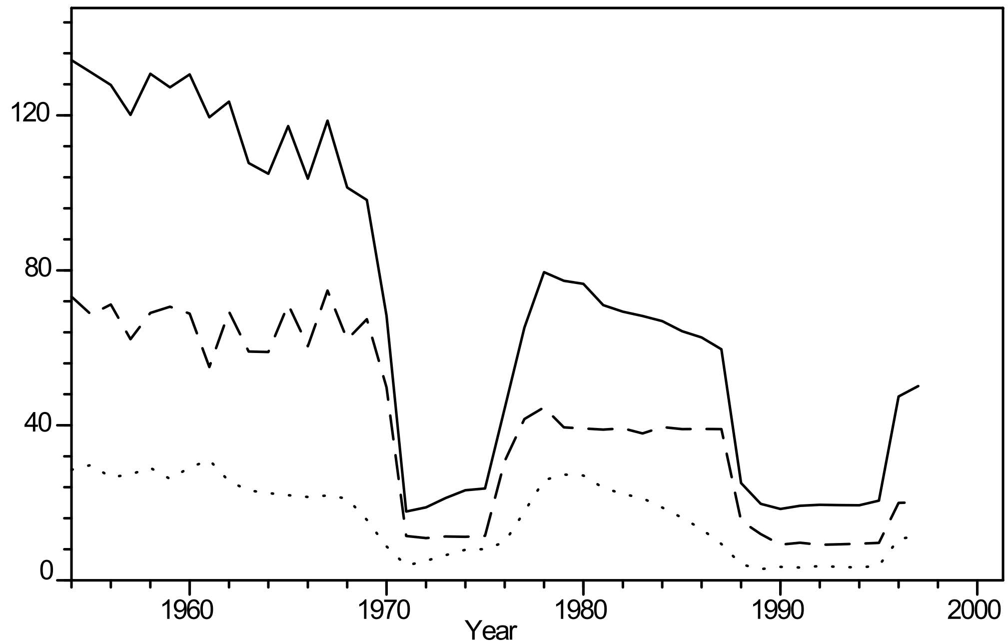

Figure 27. Sissenwine Shepherd estimates of total biomass and SSB at MSY, and MSY.

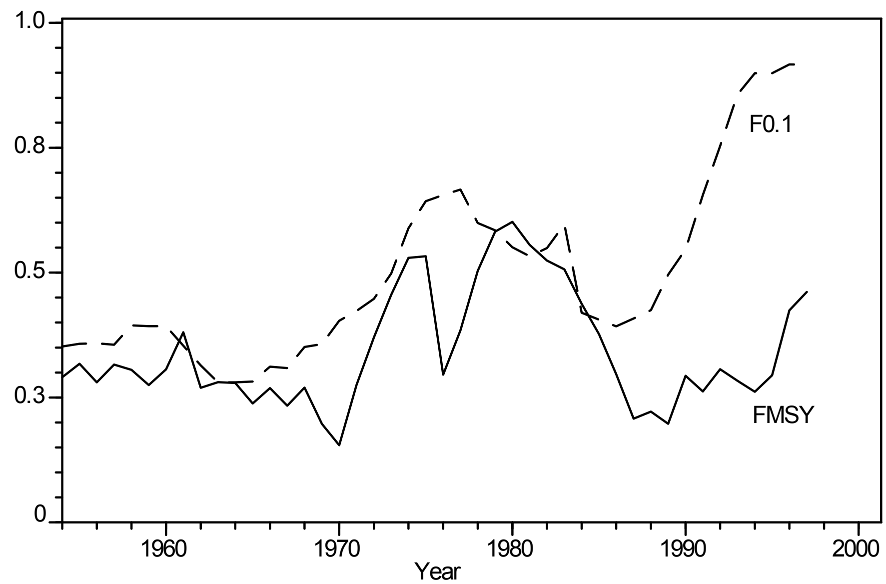

Figure 28. Comparison of Sissenwine Shepherd estimates of F_{MSY} and $F_{0.1}$.

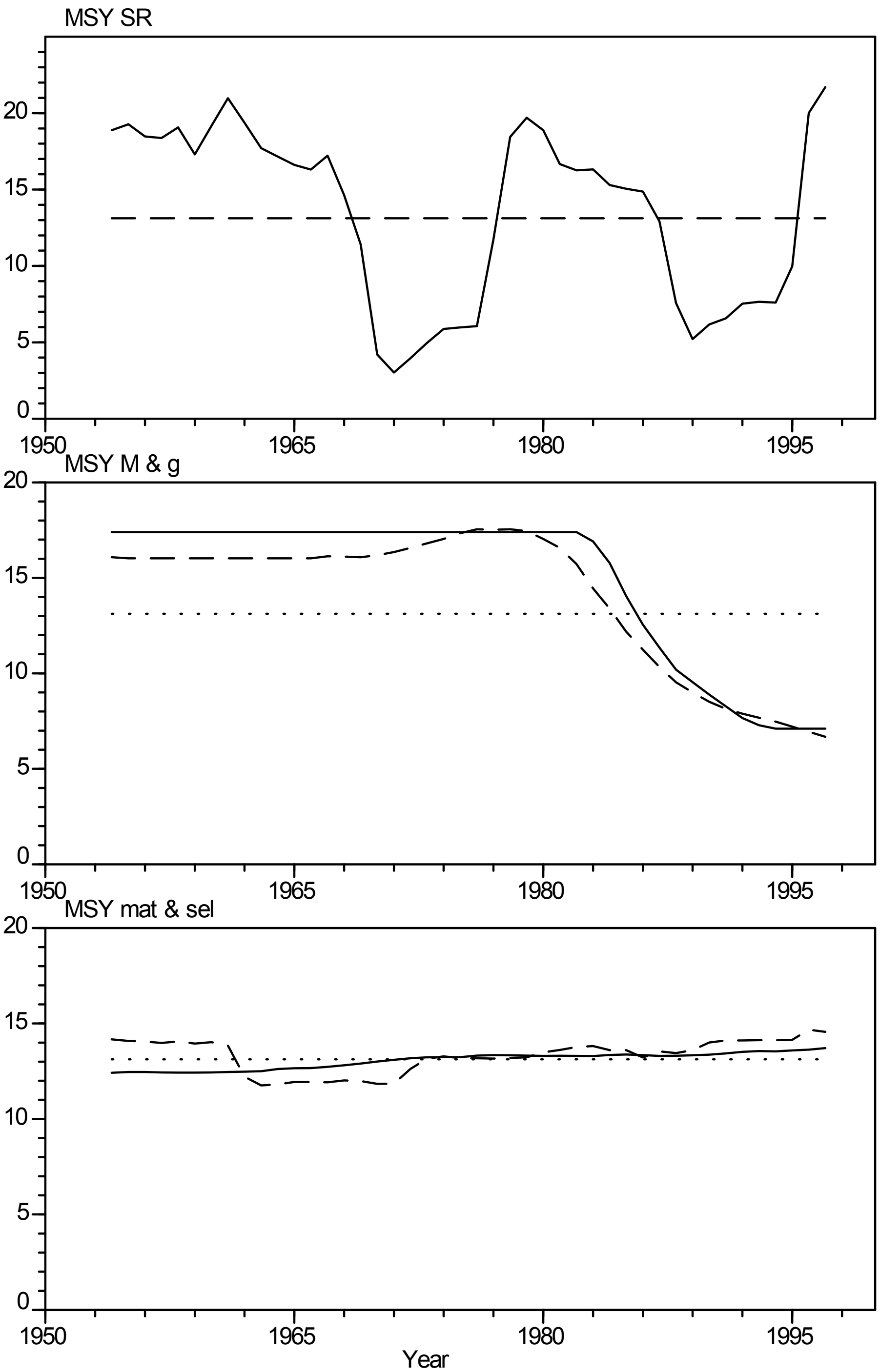

Figure 29. Sensitivity of Sissenwine-Shepherd MSY estimates to individual effects. The dotted line in all three panesl is the average MSY. The uppermost plot is the effect of the 10 year moving windows of stock-recruit data. The middle plot is the sensitivity to changes in m (solid line) and growth (dashed). The lowest pot is sensitivity to changes in maturity(solid) and selectivity (dashed).

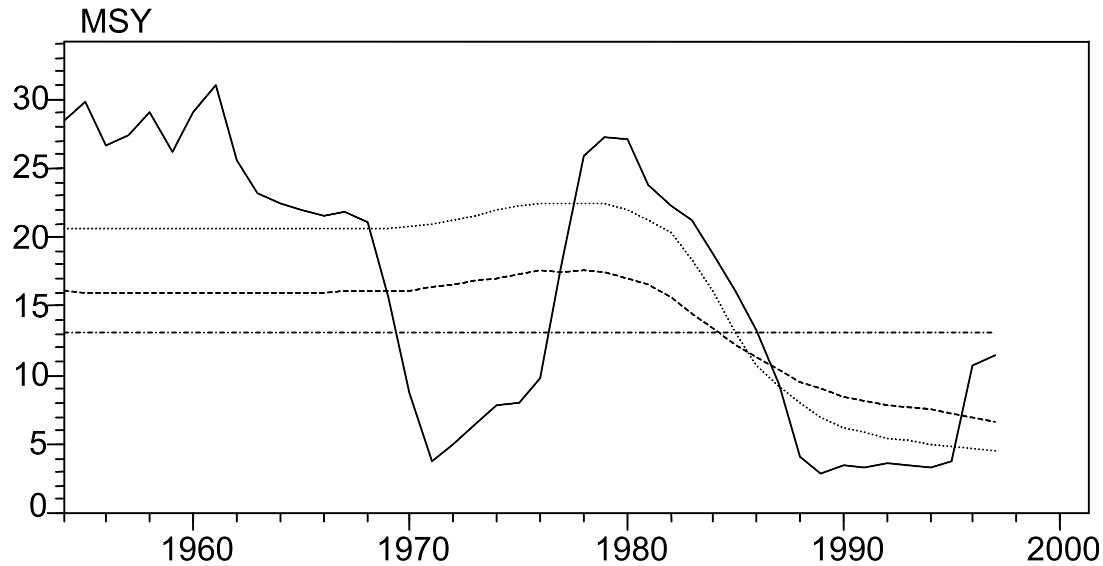

Figure 30. Cumulative sensitivity of Sissenwine-Shepherd MSY (kt)showing the cumulative effects of growth, mortality and stock-recruitment. The lkine nearest the mean is growth alone, the next one out is growth and nantural mortality and the solid line is all three, growth, M and recruitment.

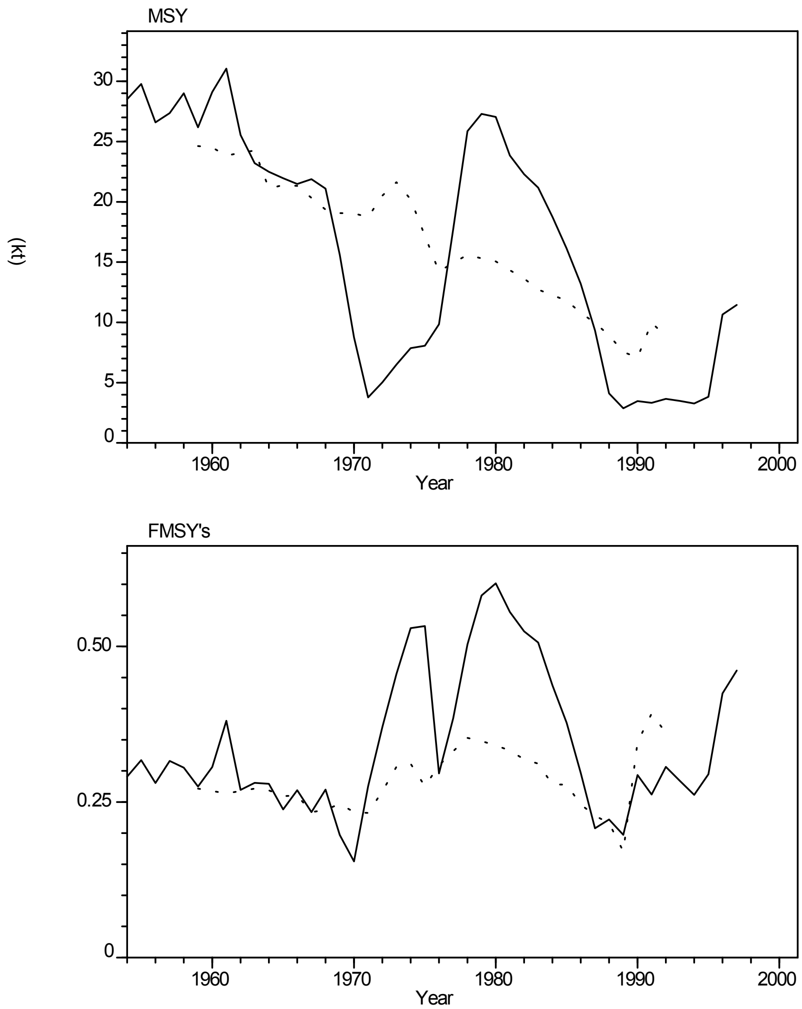

Figure 31. Comparison of MSY and F_{MSY} using 10 (solid line) and 20 (dashed) year windows.

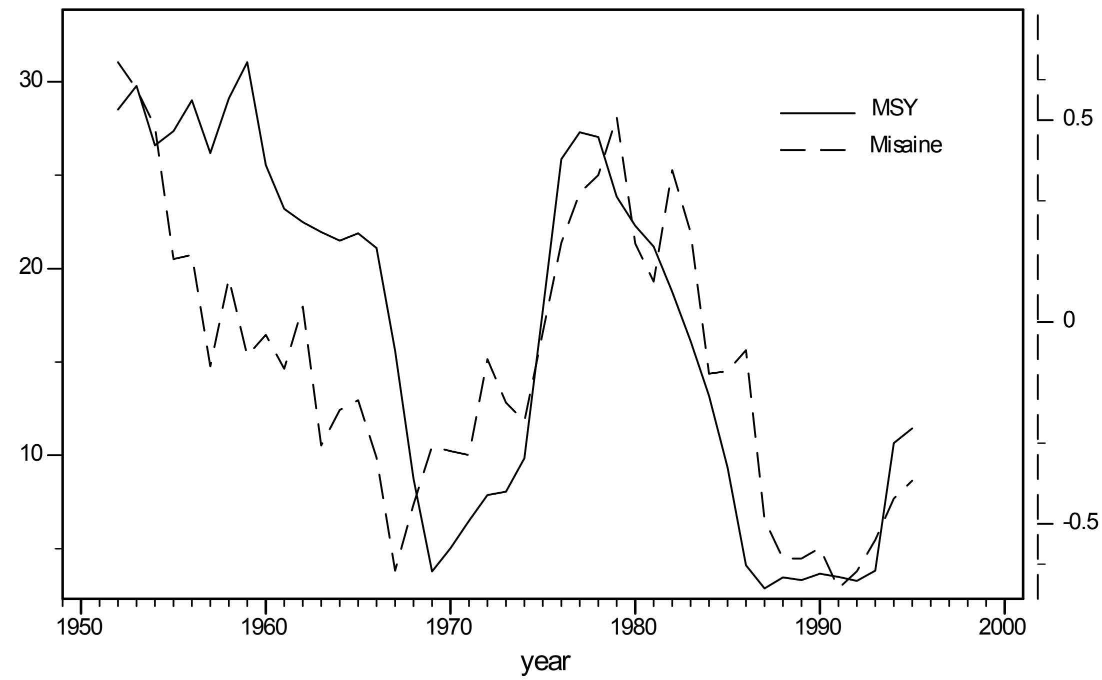

Figure 32. Time series of MSY from Sissenwine-Shepherd model and Misaine tempreature anomoly.

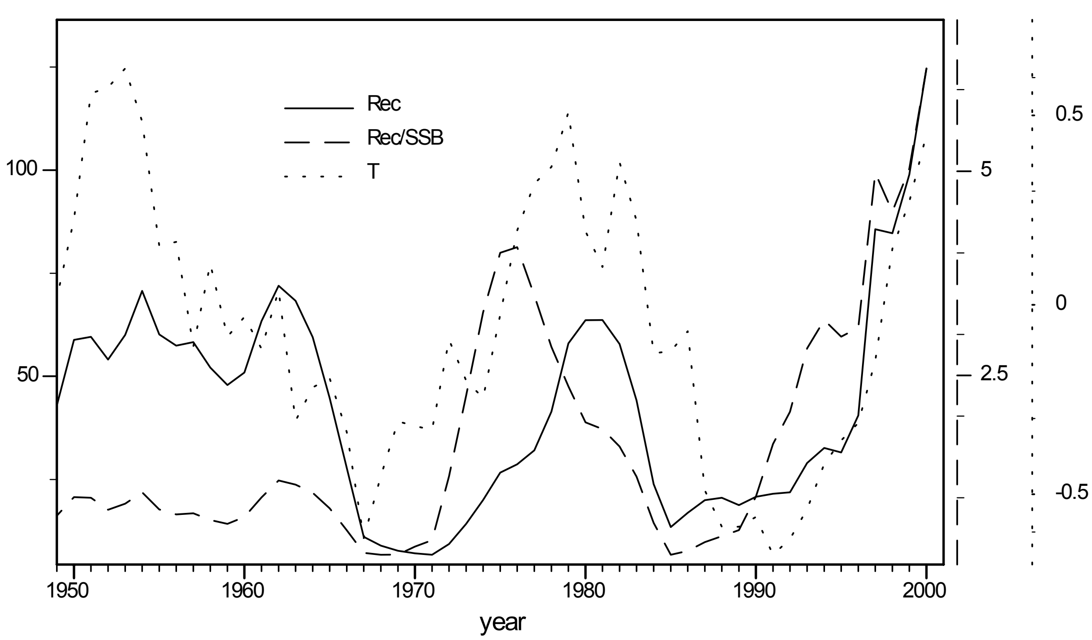

Figure 33. Time series of recruitment, recruits per unit biomass and Misaine tempreature anomoly.

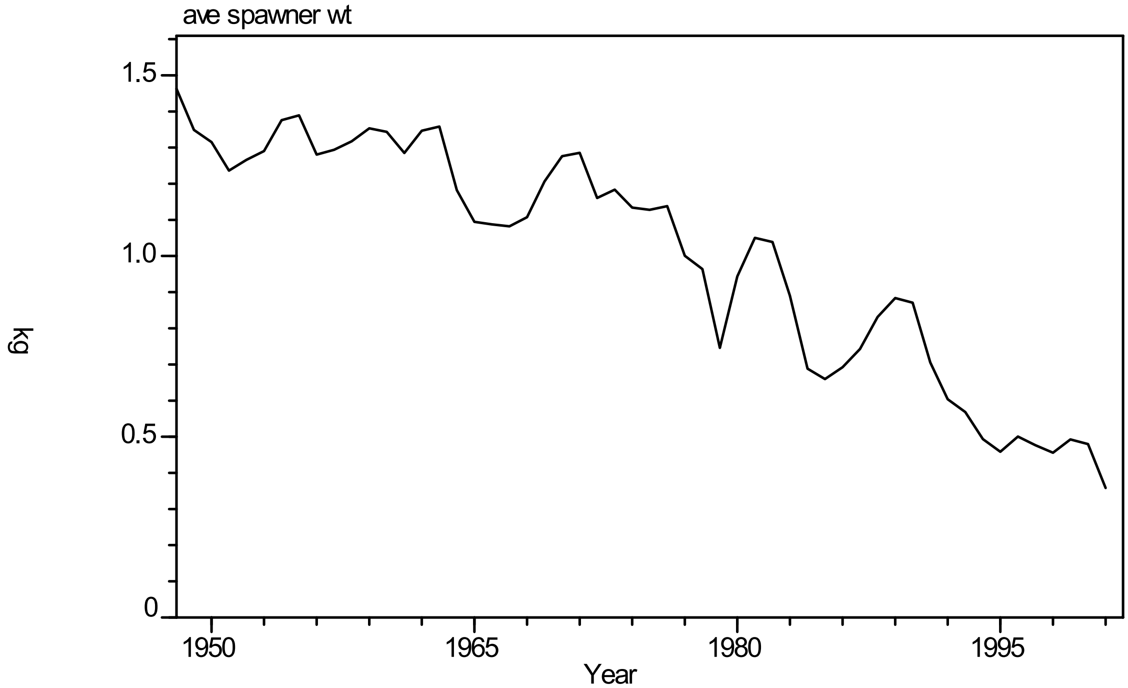

Figure 34. Average weight of a spawning haddock in 4TVW haddock.

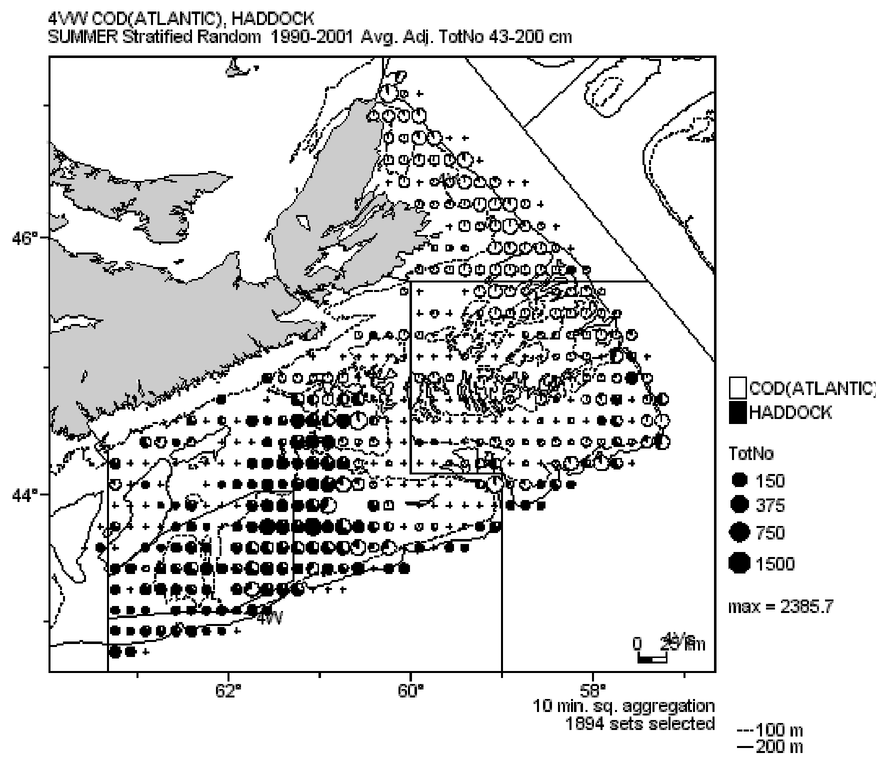

Figure 35. Distribution of cod and haddock > 43cm from the summer RV survey.

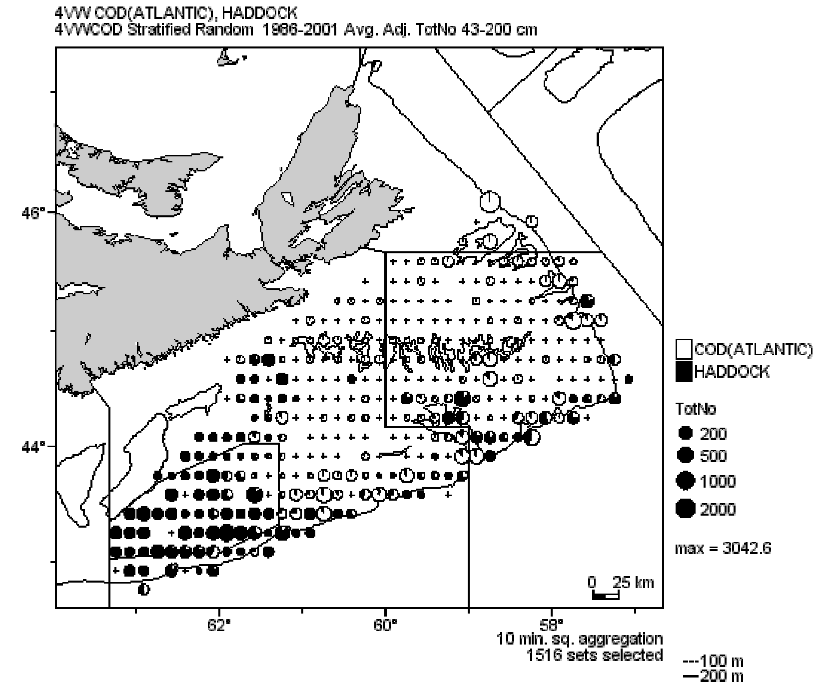

Figure 36. Distribution of cod and haddock > 43 cm from the March RV survey.

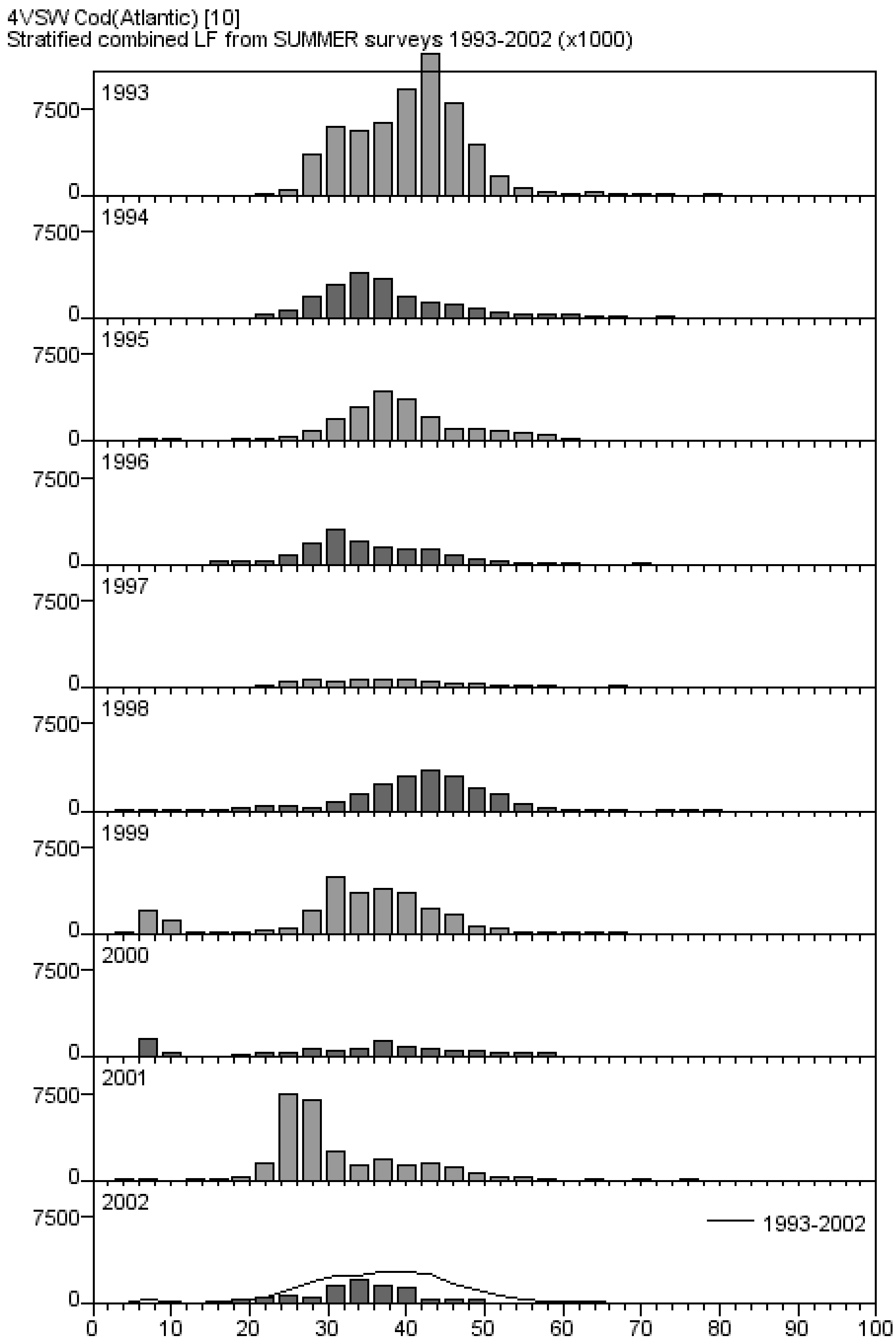

Figure 37. Length frequencies of 4VsW cod from the summer RV survey, 1993-2002.

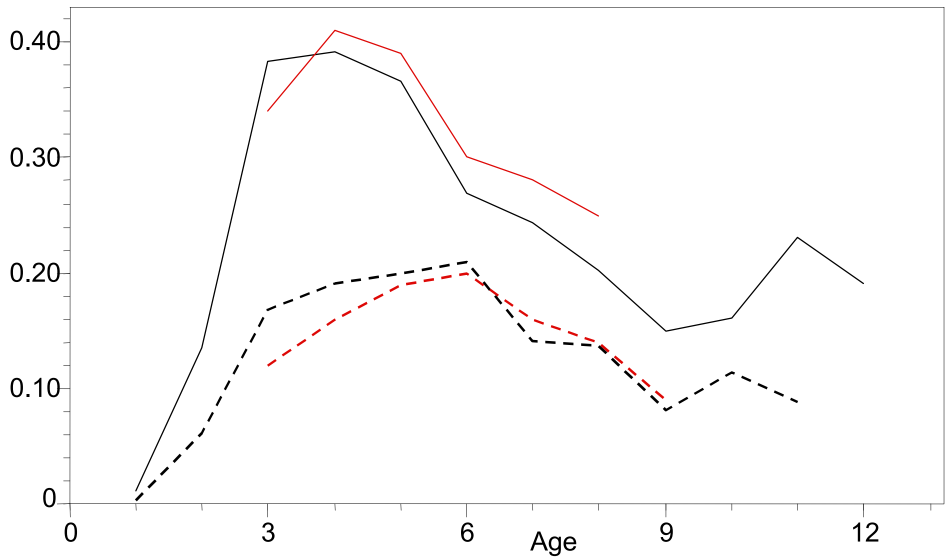

Figure 38. Comparison of q's from Mohn et al. (1998) and a trial SPA for 4VsW cod. Solid lines are summer survey and dashed are March survey. The shorter series are from the published work, ages 3-8 for the summer RV survey and ages 3 to 9 for the March RV survey.

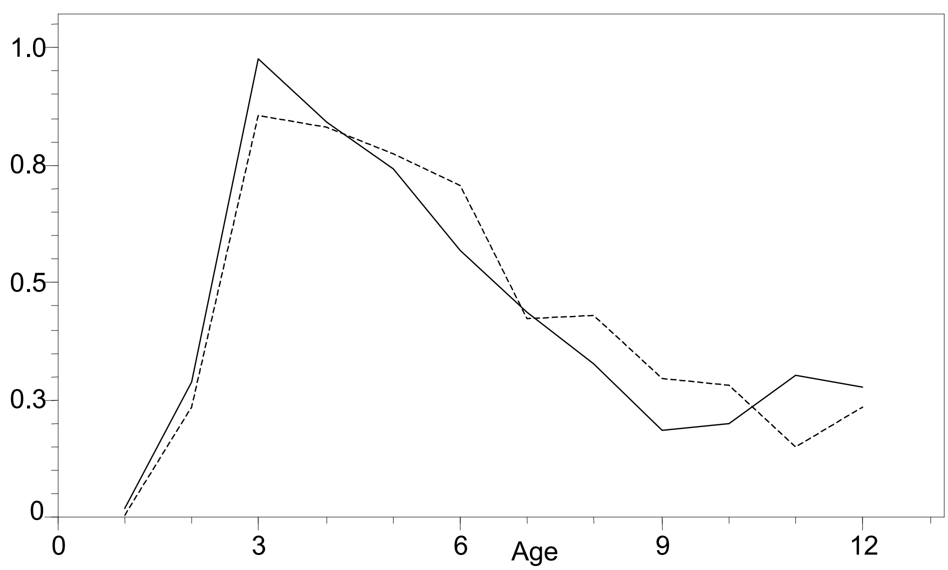

Figure 39. q's for total biomass (areal expansion) for the summer RV survey (solid line) and the March RV surveys (dashed).

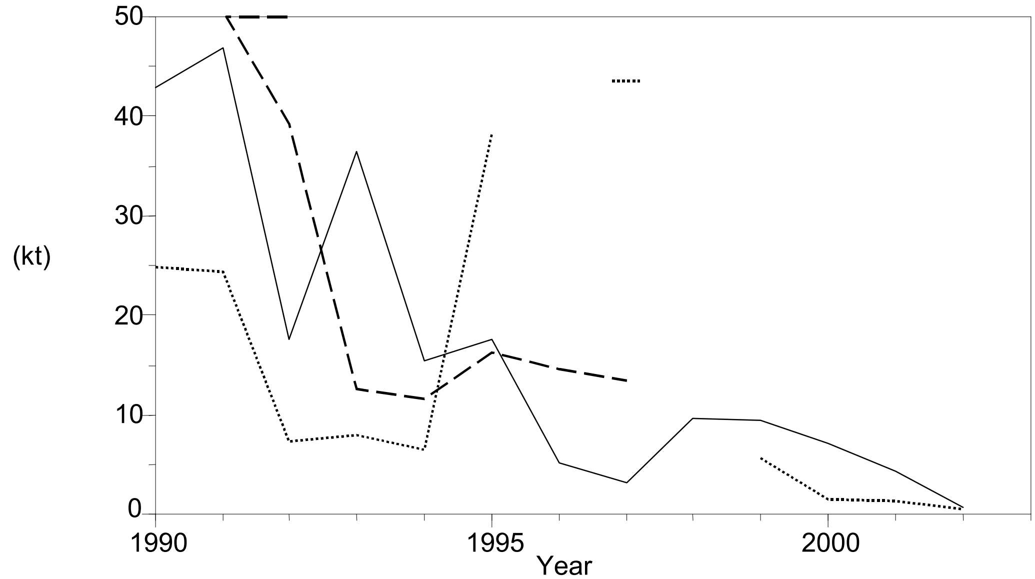

Figure 40. Biomass estimates (5+) from the summer RV(solid line) and March RV(dotted) survey data after scaling by q at age. For comparison the 5+ biomass from Mohn et al (1998) is shown as a dashed line.

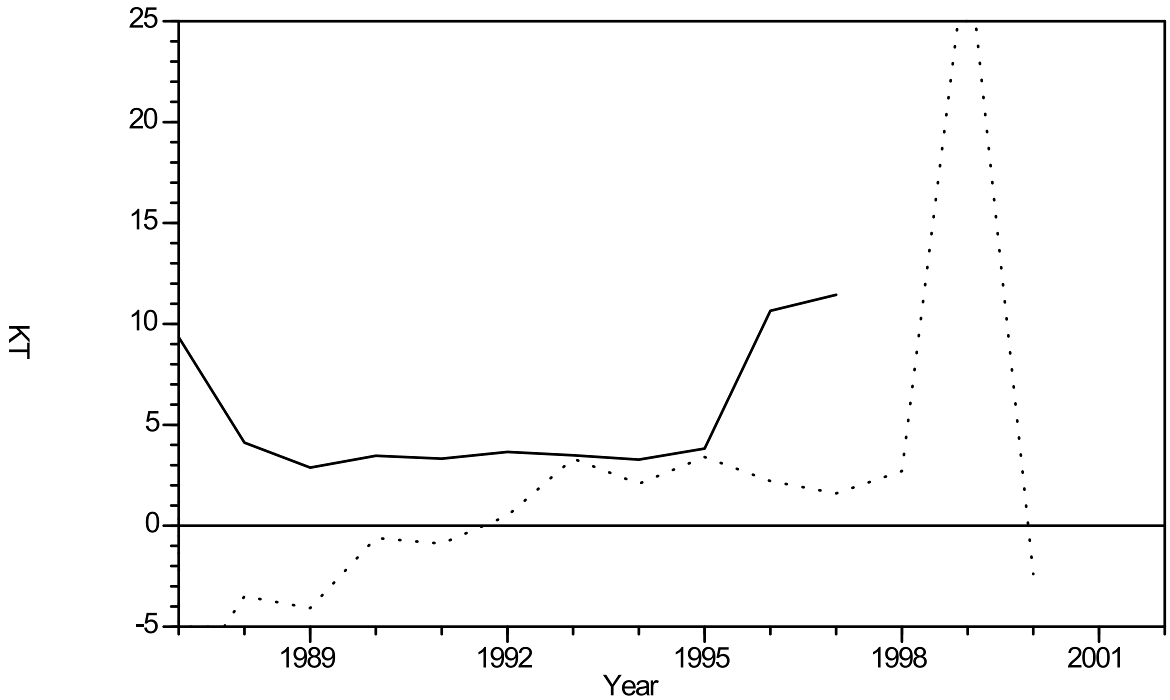

Figure 41. Moving window of productivity (Sissenwine-Shepherd MSY (solid)) and production (dashed) for recent years. Detail from Figure 25.

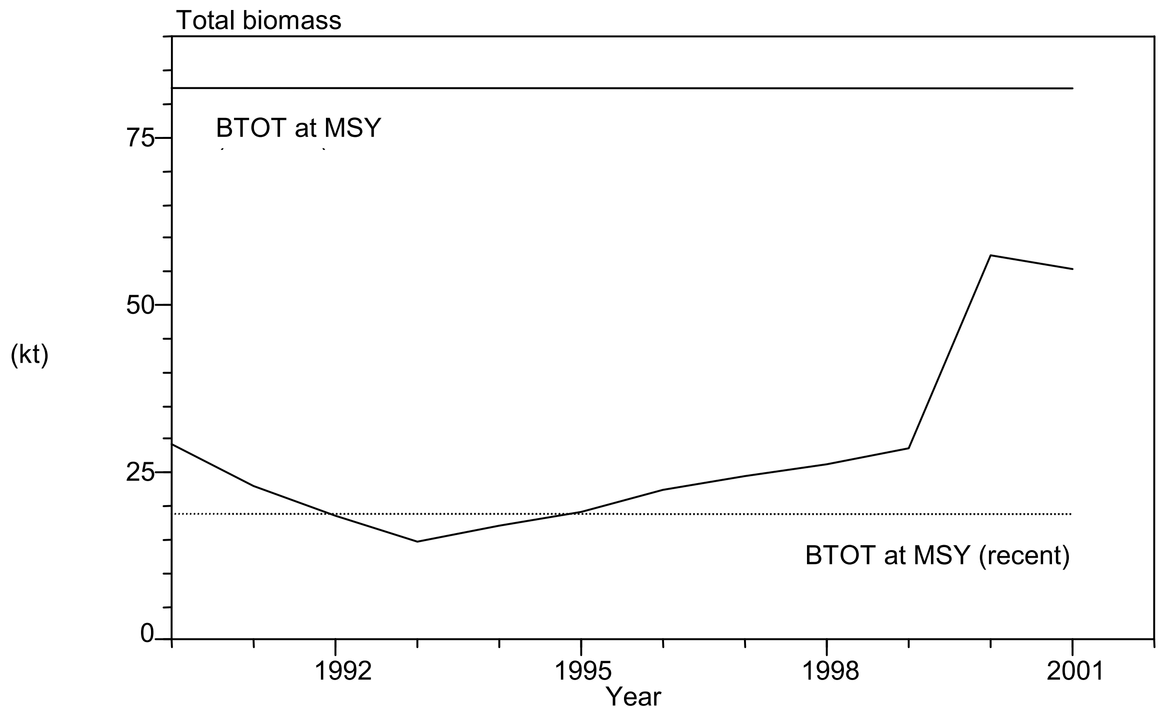

Figure 42. Total biomass and MSY reference points.

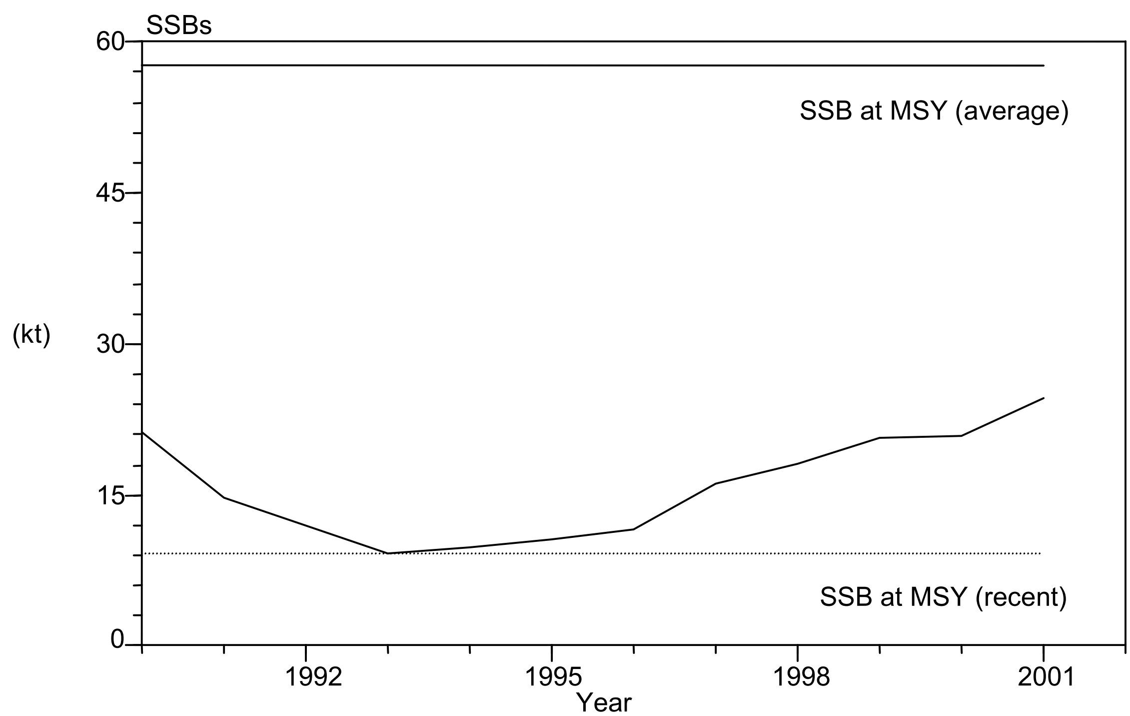

Figure 43. Spawning stock biomass and MSY reference points.

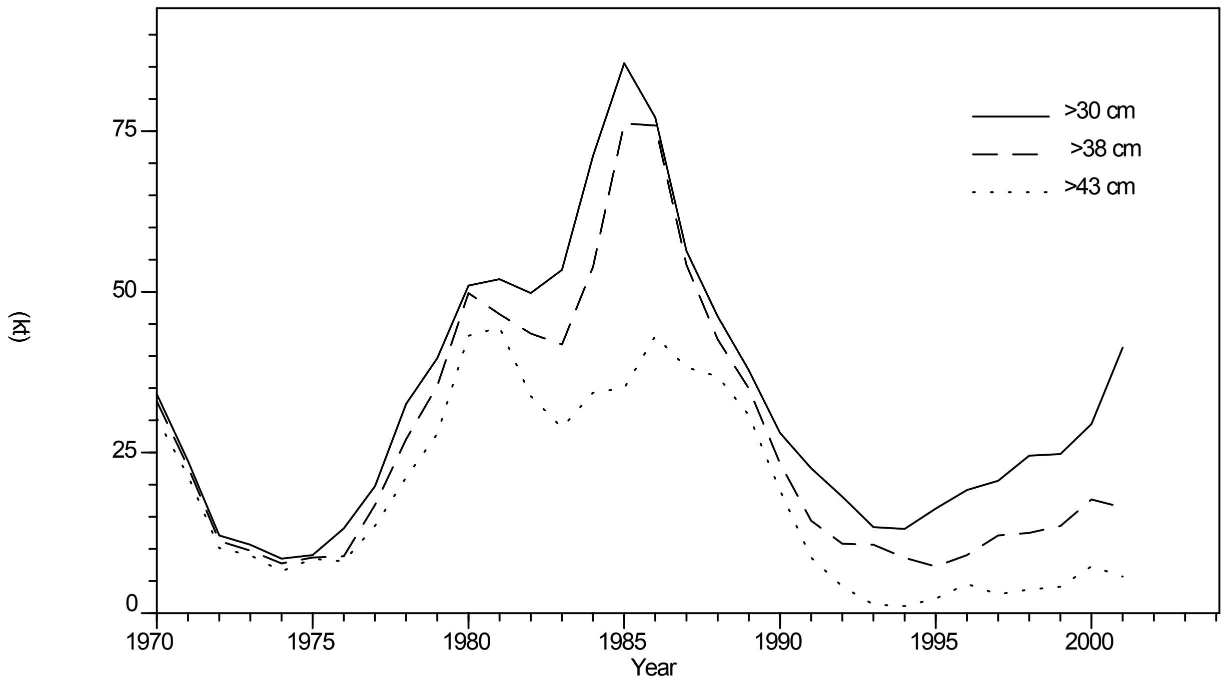

Figure 44. Biomass of 4TVW haddock greater than 30, 38 and 43 cm.