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International Council for the
Exploration of the Sea

REPORT OF THE AD HOC MULTISPECIES ASSESSMENT WORKING GROUP

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*General Secretary
ICES
Palægade 2-4
DK-1261 Copenhagen K
DENMARK

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1 INTRODUCTION

1.1 Participants

B. Brown (part-time)	USA
R. Cook	UK (Scotland)
N. Daan	Netherlands
J. Finn	USA
H. Gislason	Denmark
P. Grotnes	Norway
J.C. Holst	Norway
S. Mehl	Norway
W. Overholtz	USA
J.G. Pope (Chairman)	UK (England)
J. Rice	Canada
H. Sparholt	Denmark
P. Sparre	Denmark
K. Stokes	UK (England)
E. Ursin	Denmark
M. Vinther	Denmark

Dr E.D. Anderson, ICES Statistician, also participated in the meeting.

1.2 Terms of Reference

The term of reference of the Multispecies Assessment Working Group (C.Res.1985/2:3:25) was that:

> "the ad hoc Multispecies Assessment Working Group (Chairman: Mr J.G. Pope) will meet at ICES Headquarters from 12-18 November 1986 to continue the trials with MSVPA models".

1.3 Overview

The Multispecies Working Group previously met in 1984 (Anon., 1984a) and 1985 (Anon., 1986a) to develop the MSVPA model. As with all new assessment techniques, the practice has developed through discussion and through new data becoming available. This year, the MSVPA program and data set underwent minor changes since last year's report. These changes were:

1) Catch data from 1985 are included.

2) O-group numbers in the stock are carried back to 1 July instead of 1 January in order to restrict the analysis to fish of a size relevant to the MSVPA input data. This, of course, reduces estimates of O-group predation mortality.

3) Average stock biomasses for the year are given for comparison with annual yields and predation deaths.

4) The single set of size-at-age arrays is replaced by separate sets for the weight in the sea and the weight in the catch in order to improve the biomass and food consumption estimates.

5) The arrays of food consumption per fish per quarter are replaced by functions of body weight in the sea such that changed assumptions on size at age are automatically reflected in the food consumption. The changes mainly concern cod (less consumption) and mackerel (higher consumption).

6) Input average fishing mortalities for mature age groups are now based upon comparable trends to those in single-species assessment reports.

7) Estimates of other sources of natural mortality were revised in accordance with estimates of the biomass of fish predators not included in the MSVPA model (seals, birds, and other predatory fish).

Some of these changes influenced the results appreciably, but it is anticipated that only modest changes will occur as the technique comes of age.

In 1984, it was only possible to suggest a lay out for long-term yield calculations. In 1985, the Working Group made its first estimates of long-term yield changes that could be achieved by modifying various fisheries, and this year it has been possible to compare two methods and to make some sensitivity analysis of the long-term yield advice to inputs and assumptions. The Working Group thus feels on surer ground in making such predictions.

As regards short-term advice, the 1985 Working Group (Anon., 1986a) noted a discrepancy in TAC estimates when natural mortality changed. This problem was taken up by the Methods Working Group of the same year (Anon., 1986b), which was largely able to explain the discrepancy and also able to give advice on how such discrepancies could be minimized. The ideas developed there have been further developed at the current meeting.

The Working Group would, therefore, suggest that advice on short-term management TACs can, provided due regard is paid to technique, be safely provided by single-species working groups. Advice on long-term management in the North Sea (mesh changes and effort changes) cannot, however, be given in a single-species context even if the current estimates of natural mortality given here were adopted. This is because multispecies interaction causes changes in predation mortality which can only be predicted in a multispecies model. These changes may well invalidate a long-term assessment based upon single-species considerations. ACFM is, therefore, advised that such long-term advice should be provided by this Group in the future with appropriate inputs and advice from single-species working groups.

1.4 Acknowledgement

The Working Group wishes to acknowledge the vital help of the following groups of people:

1) the ICES Secretariat,

2) the 1981 ICES stomach sampling coordinators,

3) the single-species working groups and the individual scientists who provided important data sets, and

4) the authors of the various working papers submitted to the Working Group.

The Working Group noted with pleasure that it was possible to run most analyses on the ICES computer this year and that facilities for linking microcomputers to the NORD were also successful. This greatly facilitated its work.

2 TEST RUNS WITH THE MULTISPECIES VPA (MSVPA)

2.1 FORTRAN Programs

The MSVPA program used in 1986 is an extended version of the program used in 1985. The computational procedure remained the same except for some minor modifications (Sparre and Gislason, 1986):

1) O-group fish in the first and second quarters are excluded; and

2) yield is calculated as SOP applying age/weight data for the catches (which may be different from that in the sea).

The extensions of the MSVPA program are:

1) a "menu" program to facilitate editing and updating of the data base (Vinther, 1986); and

2) a routine to produce and input file for the multispecies forecast program from the VPA results.

The multispecies forecast (MSFOR) program corresponding to the MSVPA was used for the first time in 1986. Disregarding predation, this forecast program is equivalent to the traditional procedure of ICES working groups (Sparre, 1986).

Predation mortalities are calculated using the same routine as is used in the MSVPA program.

The MSFOR program allows for short-term predictions (say, a 3-year forecast), or it may be used to calculate the long-term (*quasi* equilibrium) prediction.

The long-term predictions are made simply by letting the program predict for, say, 50 years or until the system goes into a steady state.

The programs are written in FORTRAN 77.

At the 1985 Working Group meeting, the programs were executed on the VAX 11/750 computer at the Danish Institute for Fisheries and

Marine Research. At this meeting, all the programs were executed on the NORD 500 computer at ICES headquarters.

2.2 Catch-at-Age Data

Assessment working groups were requested, as part of their terms of reference, to supply quarterly age compositions, mean weights at age, and catch data for input to MSVPA for 1985. Data were available as follows:

Mackerel: Appropriate data are given in the Mackerel Working Group report (Anon., 1986c).

Norway pout, sandeel, sprat: Data are given in the Industrial Fisheries Working Group report (Anon., 1986d). It should be noted, however, that in the case of sprat, sampling was poor and the figures given by the Working Group report represent average age compositions of Danish catches for the period 1981-1983 and do not, therefore, reflect year-class strength.

Herring: At the 1985 meeting of the Multispecies Working Group (Anon, 1986a), inconsistencies were noted between the quarterly catch-at-age data and the annual catch-at-age data. The Herring Working Group (Anon., 1986e) considered these problems and revised the data accordingly for the period 1974-1984. This revision was undertaken at the Danish Institute following the meeting of the Herring Working Group and circulated to members of that Working Group. Data for 1985 came from the same source.

Cod, haddock, whiting, saithe: At the 1985 meeting of the Multispecies Working Group, a number of difficulties in the data were noticed and these are summarized in the North Sea Roundfish Working Group report. There was insufficient time at the Roundfish Working Group meeting this year to solve these difficulties. Minor amendments and changes were made to the whole data set for all species at the Scottish Laboratory, where data for 1985 were also worked up. These data were supplied to the Multispecies Working Group.

2.3 Relative Food Composition Data

The nature of the stomach sampling program and the way the data are raised to reflect the average consumption by the total North Sea predator populations by age class leads inherently to the presence of some erratic data points. In general, these can be traced back to small sample sizes, odd weighting factors, or inappropriate age/length keys. Although they hardly affect the global results of MSVPA, they may lead to severe distortions when the results are studied in detail. Therefore, the species coordinators were asked last year to go critically through their data base and make such revisions as were found necessary to reduce erratic results, particularly in the light of more appropriate age/length keys having become available for the various prey species.

Although progress had been made in this field, the final revisions could not all be incorporated at the time of the meeting.

Final revisions will be incorporated in the Cooperative Research Report.

Additional stomach content data were made available from the English groundfish surveys in the third quarter of 1982 (cod and whiting) and 1984 (cod) (Casey et al.,1986). At present, these data do not allow a reliable comparison with the predicted food compositions in those years and quarters from MSVPA, because only unweighted averages are available for all North Sea samples and because of a lack of appropriate age/length keys for the various prey. However, the data might reflect similar global trends as MSVPA and should be worked up further.

As yet no data were available from stomachs collected in the sampling project initiated in 1985.

2.4 Estimates of Rations Used in MSVPA Runs

In the past, rations used for the different species were supplied by the individual species coordinators, who applied different models to achieve the estimated rations by age group and quarter. This has caused some inconsistencies, because, although rations are essentially a function of weight of the fish, body weight matrices of fish in the sea were changed without corresponding changes in the rations. Therefore, it was decided to consider the possibility to replace the input of food consumption matrices in the MSVPA by corresponding functions of body weight, so that revisions of the latter automatically result in adjusted rations.

Three proposals were put forward to the Working Group, which are described in two working papers:

1) Bromley (1986) proposed to regress the relative annual feeding rate in percent of mean body weight per day against age for all species combined and then split the annual consumption in quarterly rations according to the average contributions of each quarter in the estimated rations for all species age groups as provided by the coordinators.

   It was appreciated that this approach in fact indicated that the various consumption models resulted in similar trends and that these could be fitted to a general empirical model. However, it was observed that application of this general model would result in systematic increases or decreases in food consumption by individual species, which might drastically change the output of MSVPA. Also, this general model assumes that a fish is a fish and does not allow species-specific differences. Since various studies indicate that rations differ between species, this approach was not pursued any further.

2) Ursin (1986) proposed to fit a simplified version of Daan's (1973) model to each of the individual species (i) in each quarter (q):

$$C_{iq} = A_{iq} \times W_{iq}^{2/3}$$

where C represents consumption, W represents weight in the sea, and the parameter A takes into account the average feeding level as implied by the stomach content weight and the temperature effect on the digestion rate.

3) As an alternative option, Ursin (1986) proposed to apply an analytical model, in which production and maintenance requirements are taken into account and to fit this model to the available rations. Because detailed information on the appropriate quarterly production values was not available to the Group, it was decided to skip this model for the time being. Still, it was emphasized that ultimately this approach might be extremely useful, especially when annual estimates of weight in the sea are entered in the MSVPA so that annual changes in production can be dynamically evaluated.

In principle, all three proposals allow simple estimation of the rations on the basis of entered weight-at-age arrays in the sea, but for the reasons described, the second model was chosen for further evaluation, particularly since all the essential data appeared to be at hand.

For all species, values for the ambient temperature in each quarter were selected from various bottom temperature charts in order to allow for a modification of the digestion parameter according to

$$\delta = \delta_o \exp [0.096(T_o - T)]$$

where δ_o is the experimentally obtained digestion coefficient at temperature T_o.

The values of the ambient temperature for all species are given in Table 2.4.1.

For cod, whiting, and haddock, the rations given by the species coordinators were based on the associated mean length of the sampled size classes and, therefore, as a first step, the value of A had to be derived from the average feeding level (φ) as given by

$$\varphi = S/L^3$$

where S represents the weight of the stomach contents. The values of the feeding level in each age or size class and the averages are given in Table 2.4.2

Subsequently, the temperature correction on the digestion coefficient was applied to yield the A values given in Table 2.4.3.

For saithe, the A values were directly obtained from the available consumption rates, because in this case, the temperature correction had already been made at an earlier stage.

For mackerel, quarterly consumption rates were first recalculated using the same temperature relation for the digestion coefficient as for the other species in order to improve internal consistency. The actual temperatures used (Table 2.4.1) were unweighted quarterly means of the regional values used in the earlier calcu-

lations (Anon., 1984b). New quarterly consumption rates by age class for the total North Sea were estimated by multiplying the old figures by the ratio of the new and old digestion rates. From these and the unweighted average of the quarterly mean weights at age in 1985 (Table 9.2 in Anon., 1986c), the quarterly As were calculated as unweighted means of the three age groups considered.

Figure 2.4.1a-e shows comparisons of the resulting new estimates of annual ration per age with the estimates used in previous Working Group meetings (Anon., 1984a; Anon., 1986a) for each predator species. The main changes are reduced ration estimates for cod and haddock and increased ration estimates for mackerel.

2.5 M1 Levels Used in Runs

Several new sources of information on predation by "other" predators (i.e., predators not included in the MSVPA model) and on natural mortality have become available during the last year. These are:

1) biomass estimates of "other" fish predators than the MSVPA predators, based on catch rates from the IYFS and the EGFS (Sparholt, 1986a);

2) estimates of seabird predation (Bailey, 1986);

3) estimates of grey seal predation (Prime and Hammond, 1986);

4) estimates of natural mortality rates for Norway pout and sandeel from age composition of unexploited stocks given by the Industrial Fisheries Working Group (Anon., 1986d).

The new information has been compiled in a preliminary way by Sparholt (1986b) and evaluated together with information from older literature.

Predation by "other" fish predators

The estimated biomass of "other" fish predators as an average over the years 1983-1985 is shown by species in Table 2.5.1 (based on Sparholt, 1986a). The estimates are based on a comparison of catch rates of unassessed with assessed species, for which VPA biomass estimates are available from single-species working groups. The catch rates were taken from the IYFS and the EGFS. The species were grouped in order to obtain groups of species with equal catchabilities.

The selection of predator species were made in a preliminary way without a thorough consultation of the literature. Because of doubts about the predatory stocks of grey gurnards and horse mackerel, the present Working Group decided to exclude these two species from the list.

The total biomass estimate of "other" fish predators based on the IYFS was 18% of the biomass of the MSVPA predators and 32% when based on the EGFS. The difference was mainly caused by a large amount of Western stock mackerel in the North Sea in the third

quarter. The IYFS estimates were, therefore, taken as representative for the first, second, and fourth quarters and the EGFS for the third quarter. The annual mean percentage thus becomes equal to 21%.

The amount eaten and the food composition of 1 tonne of "other" fish predators were assumed to be equal to that of the MSVPA predators.

Predation by birds

Bailey (1986) estimated the total amount of fish taken by seabirds in the North Sea in 1981 to be approximately 340,000 t. Bailey did not separate the annual consumption into quarters. The Working Group, therefore, decided to separate the annual consumption equally into quarters which then becomes 85,000 t per quarter. The food composition was given by Bailey in qualitative terms: "With the exception of the largest seabird species (gannet, cormorant), most seabirds take fish in the length range 5-16 cm. North Sea seabirds are assumed to feed entirely on fish. Fish that are assumed to be acceptable as food for seabirds include all age groups of sandeels, sprats, and Norway pout, together with 0- and 1-group herring and gadoids and 0-group mackerel".

As the food composition is needed in quantitative terms, the Working Group decided to assume the food composition to be equal to that of the five MSVPA species. This is not in great conflict with Bailey's qualitative description.

Predation by seals

Prime and Hammond (1986) gave an estimate of the fish consumption by grey seals in the North Sea. The value obtained was 57,283 t in 1982. As for the seabirds, the Working Group decided to separate this consumption equally into quarters giving 14,321 t per quarter.

The food consumption was assumed to be equal to the MSVPA predators. Although the diet according to Prime and Hammond is, to a great extent, sandeels, the food items are generally larger than the food items of the MSVPA predators. The assumption used is, therefore, probably not the optimal one, but time did not allow the Working Group to go further into details about this matter.

According to Sparholt (1986b), the total number of common seals in the North Sea is at least 23,946 in 1985, and their consumption of fish is 13,631 t. As a large proportion of the food of common seals is often flatfish, the common seal is not included as a predator in the present context.

Predation by whales and invertebrates

As no data seem to be available on the biomass of whales in the North Sea, the whales were ignored.

Likewise, no information is available which indicates that invertebrates have any significant predatory effect on fish species (>5 cm) in the North Sea.

Cephalopods, which in many other sea areas have an important impact on fish populations, do not seem to occur in any significant number in the North Sea. Both in the IYFS and EGFS, the catches of cephalopods are very small. Furthermore, according to Bulletin Statistique (Anon., 1984c; Anon., 1985a; Anon., 1986f), the commercial catch of cephalopods in the North Sea is very small.

Total predation by "other" predators

The table below shows the total amount of MSVPA prey eaten by the MSVPA predators in 1981, the seabirds in 1982, the seals in 1982, and the "other" fish predators in 1981 (assuming the biomass in 1981 of "other" fish predators was 21% of the biomass of the MSVPA predators in 1981).

The amount of MSVPA prey eaten in 1981 by the five MSVPA predators and "other" predators (in t).

	First quarter	Second quarter	Third quarter	Fourth quarter
MSVPA predators	454,696	465,428	665,291	593,107
Seabirds	51,000	64,000	64,000	51,000
Seals	14,321	14,321	14,321	14,321
"Other" fish	95,486	97,740	139,711	124,552
Total "other" predators	160,807	176,061	218,032	189,873
"Other" predators/ MSVPA pred.	0.35	0.38	0.33	0.32

As the food consumption of the "other" predators is assumed to be equal to the food consumption of the MSVPA predators, the fraction of M1 which is caused by predation is simply 35% of the calculated M2 values from the MSVPA run.

Total M1 values

To the mortalities caused by "other" predators is added a mortality component representing mortalities due to other causes such as diseases, spawning stress, physiological characteristics, and so on. The latter ones have been estimated for adult herring and mackerel in the North Sea. This mortality is equal to the total natural mortality of these species, as their predation mortality is zero according to the MSVPA, and the estimate made above of the predation by "other" predators. The estimates of natural mortality of herring of ages 4-9 are between 0.08 and 0.26 per year. The data make it difficult to reject the value of 0.10 per year as used by the Herring Assessment Working Group for the Area South of 62° N (Anon., 1986e), though a value of 0.15-0.20 per year seems more likely. With respect to mackerel, the value of 0.15 per year is used as by the Mackerel Working Group, based on estimates from tagging experiments.

For all the gadoids, a value of 0.20 per year was used, as this value is used by the Roundfish Working Group (Anon., 1986g), and as this value is supported by Jones and Johnston (1977) with respect to haddock. The only discussion by the Roundfish Working Group about M was in its report in 1976 (Anon., 1976), where Malkov and Yefremov were said to have estimated M equal to 0.40, using the method of Tjurin (1972) without any description of the area and stock in question.

With respect to sprat, Norway pout, and sandeel, a value of 0.20 per year was used for the sake of consistency and because no further information was available.

The M1 values are then obtained in an iterative way, using as starting values in a new MSVPA run 35% of the MSVPA M2 values from the key run in 1985 (Anon., 1986a) plus the mortality components for mortalities caused by other reasons. The M2 values obtained by this new run are then used in the same way as from the key run in 1985, and this procedure was continued a few times until the new M2 values were approximately equal to the input M2 values.

The M2 values were not used directly to estimate M1 but plotted against age, and a curve fitted by eye for each species. M1 values were then calculated by proportion. The resultant M1 values are shown in Table 2.5.2.

The M2 values from 1981 (Table 2.5.3) were used as these values were assumed to be the most reliable since stomach sampling was carried out in this year.

Based on age composition in unexploited Norway pout and sandeel stocks, the Industrial Fisheries Working Group (Anon., 1986d) estimated M to be 1.5-1.6 per year for Norway pout, 1.1 per year for 1-group sandeel, and 0.5 per year for older sandeels.

Comparing these values with the present estimates gives for Norway pout as mean over all age groups an M equal to 1.46, for sandeel 1-group 1.38, and for older sandeels 0.67. Thus, generally a fairly good agreement exists between the Industrial and Multispecies Working Group estimates.

2.6 Feeding Relationship Used in Runs

As in 1985, the Working Group chose to make runs using the Helgason-Gislason feeding relationship.

2.7 Weights at Age Used

There are now three sets of weights at age:

1) body weight in the sea;

2) body weight in the catch; and

3) body weight in the stomachs in 1981.

Body weights in the stomachs were the same as at the previous meeting except for minor corrections for saithe.

Body weights in the sea were separated from body weights in the catch in order to:

a) avoid overestimating the biomass of juveniles which are usually of large size in the catch; and

b) make possible the calculation of food consumption as a function of body weight.

The body weights in the catch are used exclusively for calculating the biomass of the catch. Whenever possible, the weights were calculated as means for 1974-1984 using assessment working group estimates as the source.

Weights in the sea for young ages are from various literature sources. Weights at older ages are, in some cases, copied from the arrays of weights in the catch. For cod, quarterly length at age from Daan (1973) were used. These were converted to weights using the same condition factors for all four quarters. This is likely to underestimate the seasonal variation of body size.

Details about the sources for weights in the sea and in the catch are in Appendix A.

2.8 The Key Run of the MSVPA

As at the two previous meetings, a "key run" was identified, which was based on a selection of various possible assumptions. The key run adopted was based on:

1) the Helgason-Gislason feeding relationship;

2) revised rations consumed, expressed as functions of body weight instead of by the different models used in the past. A simplified version of Daan's (1973) model was chosen, and a temperature correction on the digestion coefficient was applied (see Section 2.4);

3) revised stomach contents data for saithe;

4) revised residual natural mortalities, based on new information on predation by "other" predators. The mortalities caused by "other" predators were added to the residual natural mortalities (see Section 2.5);

5) three sets of weights at age: body weight in the sea, body weight in the catch, and body weight in the stomach in 1981 (see Section 2.7);

6) revised quarterly catch-at-age data for herring;

7) terminal F values selected mainly the same way as last year (Gislason, 1986).

Input data listings for the key run are available at ICES, on the same basis as the Working Group report.

Mackerel presented a special problem. A large proportion of the Western stock is in the North Sea in the third quarter. The mortalities they cause are included in the mortalities caused by other predators. The Mackerel Working Group decided to make a combined assessment of the North Sea and Western mackerel stocks in its 1986 report. The terminal F values, therefore, had to be taken from work not presented in its report (but available in the Mackerel Working Group file of 1986).

Table 2.8.1a-i presents the MSVPA results for the species included in the model (cod, whiting, saithe, haddock, herring, sprat, Norway pout, and sandeels). This table is the equivalent to the conventional VPA tables, i.e., it gives fishing mortality and population numbers but in addition gives the predation mortality caused by predators (cod, whiting, saithe, mackerel, and haddock) in the model. Mortality of the 0-group is for the third and fourth quarters only. The predation mortalities observed in this year's key run are a little higher for Norway pout and sandeels and a little lower for the other species. This is due to higher rations consumed for mackerel, which preys heavily on Norway pout and sandeels, and lower rations consumed for cod, whiting, and haddock. It should be noted that the mortalities of the 0-groups are not comparable because this year the mortalities in the MSVPA are for the third and fourth quarters only. Table 2.8.2a-c summarizes the 1978-1982 averages for fishing mortality, natural mortality, and population size.

The levels of fishing mortalities for the different species are in agreement with the results of the single-species assessments. Because the single-species working groups have increased their M2 values (predation), there is also better consistency between the numbers at age in the youngest age groups.

As last year, the total herring biomass computed by the single-species working groups was considerably higher than the results from the MSVPA, and there must be something erroneous in the data base for herring. The total stock biomass and spawning stock biomasses computed in the MSVPA and in the single-species working group reports are shown in Figures 2.8.1a-g for all species except mackerel and sprat where no biomass estimates were available.

The differences observed between the MSVPA and the VPA estimates are mainly due to differences in weight at age and in maturity ogive. Differences in natural mortalities do only cause small differences in biomass estimates except for sandeel because sandeels had very variable natural mortalities over years. The single-species working groups use constant natural mortalities over years.

The means of the ratios between numbers at age in the MSVPA key run and in the single-species VPAs for the years 1974-1985 are shown in Table 2.8.3 for cod, whiting, haddock, and herring. This

year, there is better agreement between MSVPA and SSVPA for all age groups.

Differences in total biomass are mostly due to the strange practice used by single-species working groups of forming an SOP of 1 January numbers and mid-year weights at age.

2.9 Sensitivity of MSVPA

Sensitivity of the MSVPA to halving predator ration and M1 was tested by last year's Working Group by performing two runs (one for each condition). It is clear that these two parameter groups may interact with each other and with other model parameters to produce sensitivities different from the ones observed by varying a single parameter. To examine this question more closely, one must vary parameters simultaneously. Designed experiments offer access to statistical techniques that are well described and well known, among them are factorial, Latin, and Greaco-Latin designs (Reed, Rose, and Whitmore, 1984). However, for k parameters varied at two levels each, a factorial design requires 2^k experiments. For even a few parameters, this means a prohibitively large number of experiments. However, fractional factorial designs allow estimation of main effects and some interaction terms by doing only a small fraction of the full factorial design. One type of fractional factorial design requires only $2^{\log(k)+1}$ experiments, where log(k) is the base 2 logarithm of k. This year's Working Group decided to attempt sensitivity analysis of the MSVPA by performing a fractional factorial experiment.

The Working Group chose 7 parameters in the MSVPA program on which to do a sensitivity analysis (in addition to 9 more in the forecast model, Section 4.5). The parameters were varied up and down by 10% of their key run values (Table 2.9.1). The experimental design (Table 2.9.1) was set up by a program described in Finn et al. (1986) and listed in Finn (1986). It describes corners of a 7-dimensional hypercube arranged so that all two-way interactions are independent of all main effects.

The MSVPA runs provided considerable output that has yet to be digested by the VAX.

3 SHORT-TERM PREDICTION PROBLEMS

3.1 Background

At the 1985 meeting of the Working Group, trial short-term single-species predictions were run for North Sea roundfish stocks using the old conventional value of M = 0.2 and also using average age-dependent M as output from MSVPA. It was found that, in some cases, notably haddock and whiting, the catch predictions differed between the two assumptions of M by about 20%. This problem was further investigated by the Working Group on Methods of Fish Stock Assessment in 1985 (Section 2 of its report, Anon., 1986b), and it appeared that the problem was associated with the use of survey indices to tune the F values in the last data year. The problem can be examined by considering the catch ratio:

$$\frac{C(a+1,y+1)}{C(a,y)} = \frac{F(a+1,y+1)\ Z(a,y)\ [1-\exp -Z(1+1,y+1)]\exp -Z(ay)}{F(a,y)\ Z(a+1,y+1)\ [1-\exp -Z(a,y)]}$$

$$= \text{CRATIO} \qquad (3.1)$$

In making a catch prediction from year t (the last year of catch-at-age data), and if C(a,t) is the catch in the last data year, then the predicted catch is simply:

$$C(a+1,t+1) = C(a,t)\ \text{CRATIO} \qquad (3.2)$$

In a typical VPA-based catch prediction, F(a,t) is determined and thus F(a+1,t+1) must be chosen to estimate CRATIO and make the prediction. In making such a prediction, if it can be shown that CRATIO is independent of M, then the catch prediction will be independent of M because C(a,t) cannot change. In general, the methodology adopted by assessment working groups is to choose

$$F(a+1,t+1) \ \underline{\Omega}\ F(a+1,t) \qquad (3.3)$$

so that the right hand side (RHS) of (3.1) becomes:

$$\text{KRATIO} = \frac{F(a+1,t)\ Z(a,t)\ [1-\exp(-Z(a+1,t))]\exp -Z(a,t)}{F(a,t)\ Z(a+1,t)\ [1-\exp -Z(a,t)]} \qquad (3.4)$$

and hence $C(a+1,t+1) = C(a,t)\ \text{KRATIO}$

$$\left(\text{NB: KRATIO} \neq \frac{C(a+1,t)}{C(a,t)}\right)$$

KRATIO is determined by the Fs and Ms in the last data year of a conventional VPA. We wish, therefore, to know if KRATIO is independent of M. Attempts were made to show analytically the conditions under which KRATIO is M independent, but no clear demonstration can be found at present though it is suspected that separability is a sufficient, but not necessary, condition. A practical investigation in the next section indicates that KRATIO is in general unaffected by M, but the use of survey index tuning may violate the rule and lead to problems, i.e., modifying F on the recruiting ages so that the catch and survey population estimates remain unchanged can make TAC estimates sensitive to changes in assumptions about natural mortality.

3.2 Short-Term Catch Prediction for North Sea Haddock

Work by the Methods Working Group indicated that, for North Sea haddock, at least, KRATIO values were insensitive to M in a converged VPA. Trials were made at this meeting to check that KRATIOs were also M independent for tuned values of F in the last data year t. This was done for the North Sea haddock stock using

values of M = 0.2 and variable M (Table 3.2.1). Terminal Fs were tuned using the catchability method (Anon., 1985b) on ages 2-7 and mean F on ages 0-1. Runs were made assuming last data years of 1975, 1980, and 1985. In all cases, the calculated KRATIO values (Table 3.2.2) are largely unaffected by changes in M.

As discussed before, the problem in making short-term catch forecasts when M is changed appears to be associated with tuning using a survey index. The procedure above was, therefore, repeated for the 1985 terminal year but with the IYFS index being used to tune F on ages 0 and 1. Table 3.2.3 shows that, in this case, KRATIOs on young fish are sensitive to M which means that a catch forecast based on the tuned Fs would be affected by changes in M.

In the past, tuning, using the IYFS, has been done using a regression of VPA on IYFS. At its 1986 meeting, the North Sea Roundfish Working Group used a different method. An average of recent values of IYFS/VPA was used to scale the survey index to VPA. This method was also used to tune Fs on ages 0-1 in the trials here. It can be seen that this method also leads to M sensitivity in KRATIOs (Table 3.2.3). It is also noteworthy that the direction of sensitivity is different according to the treatment of the survey.

The sensitivity of the catch prediction to changes in M is an undesirable feature. As an example, Table 3.2.4 shows predicted catches for North Sea haddock using M = 0.2 and the variable M values given in Table 3.2.1. Changing M in the assessment clearly has an effect and is due to the way in which the IYFS survey is used to tune the VPA. It would be desirable to adopt a prediction procedure which is less sensitive to these changes, and the Working Group endorses the recommmendation of the Methods Working Group that F in the prediction procedure be chosen to preserve KRATIOs. In the case of haddock, this can be done by setting aside the catch of 1-year-old fish in the last data year and using the IYFS population size in conjunction with a recent year's average age F for the calculation of forecasts. The same principle should apply to other stocks. Working groups should note this point since TACs which are robust to M change would be desirable at this time due to revisions of advice on M levels being likely.

4 LONG-TERM ASSESSMENTS

4.1 Introduction

The general problems associated with carrying out long-term multispecies assessments were discussed in the 1984 report of the Working Group. That document should be consulted for necessary background material.

At this meeting, two different methods were used to investigate long-term consequences of changes in fishing patterns in the multispecies context: the forecast MSVPA developed by Sparre (1980), and the multispecies multiplicative steady-state model developed by Shepherd (1984). The methods differ in two key ways. The forecast MSVPA method uses the individual suitability values

produced by the key run of MSVPA to compute different M2 values for each individual forecast quarter year, whereas the multispecies multiplicative steady-state model uses parameter estimates smoothed by a model fit to the M2 values from the MSVPA. Also, the MSVPA may change levels of predation mortality on various ages of prey over a run, because the intensity of predation is a function of both suitabilities (which are fixed within a run) and predator and prey abundances (which can vary within a run). In the multiplicative model, predation mortality is assumed to vary with predator abundance but to remain constant under changes in prey abundance.

Neither of these models represent the exact truth. However, they are likely to bracket the true patterns and variation in predation mortality.

Therefore, if the long-term predictions of the two models are similar, we may place greater confidence in the long-term advice provided. The 1985 report documents the differences in long-term harvests expected, when predation mortality is added to fishing mortality. That work was not repeated here.

4.2 Description of Long-Term Models

The forecast MSVPA is an extension of the MSVPA program used in 1985. It is run for 50 years to provide a forecast which is checked for convergence. Section 2.1 contains a description of how the program works. The method is intended primarily to augment traditional methods of projection used by working groups by adding the impacts of predation mortality to the factors commonly used in forecasting.

The multispecies multiplicative steady-state model was described at length in the 1984 report of the Working Group, and modifications were outlined in the 1985 report. Basically, given fixed recruitment and specified levels of natural and fishing mortalities and predation mortality per unit predator biomass, the model finds, for each species, the distribution of numbers at age which produce steady-state conditions. The yields of each population to each fishery can be calculated easily from these results.

4.3 Parameterization of Models

Forecast MSVPA

The input tables of weight at age, M1, and so on were the same ones used in the key run of MSVPA. Recruitment was assumed to be constant at the arithmetic mean (1974-1983) of numbers of 0-group fish of each species in the third quarter from the key run of MSVPA (Table 4.3.1). The recruits entered in the third quarter for each forecast year. The annual fishing mortality on each age of each species was the mean fishing mortality over 1978-1982 as calculated from the key run. This fishing mortality was partitioned among the six fisheries described in the 1985 report of the Working Group (see Appendix B tables).

Multiplicative model

Aside from predation mortalities, all input values to this model were exactly the same as those used in the forecast MSVPA except that they are applied annually rather than quarterly.

Predation mortalities were calculated from the predator relative preference matrix. This matrix was calculated from the parameters estimated in the core M2 smoothing model. This model is described in Section 8.4. It differs notably from the model used in 1985, in that the slope of the size preference function was estimated separately for each predator species. In 1985, a common slope was used for all predators. Difficulties were encountered estimating interaction parameters of the accepted model, due to aliasing by the statistical package used. A separate computer run treating each of the 34 predator-prey combinations as levels of a single factor, and using the same covariates, was used to provide the parameter estimates used in the multiplicative runs. In every case, these estimates were identical to the unaliased estimates from the factorial run.

The parameter estimates in Table 4.3.2 were converted into the relative preference matrix values by the formula

$$\exp(\text{interaction} + \text{correction term})$$

and then scaled to whiting preying on whiting as 1.0. (The same scaling was used last year.) The correction term

$$\frac{\mu^2}{2\sigma^2}$$

was different for each predator, as the mean (μ) of the size preference function was different for each predator, although a common standard deviation (σ) was used. Furthermore, because the actual distribution of log transformed predation mortalities was skewed relative to the normal distribution assumed by the model, the overall predation mortalities were corrected for the deviation using a value toward the geometric mean correction of exp(MSE/2) (see Appendix C for a further description of the estimation).

4.4 Results of Long-Term Forecasts

Predation mortalities

Both the MSVPA and multiplicative models showed substantial levels of predation mortality on harvested species (Table 4.4.1). The multiplicative model, using a parameterized size preference relationship, produced at least small levels of predation mortalities on all ages of each prey species. The MSVPA, using calculated suitabilities, had predation cease on large fish. Otherwise, there were no consistent patterns in the differences between M2s calculated by the two methods. The only large differences were in Norway pout, where the multiplicative model estimated M2s usually at least twice those of the MSVPA forecast, and in haddock.

Equilibrium harvests at status quo fishery levels (average 1978-1982)

The two models differ substantially in the yields they predict from each fishery once equilibrium is (assumed to be) reached (Table 4.4.2). The MSVPA forecasts greater yields of whiting, haddock, sprat, and Norway pout. The multiplicative model predicts larger yields of cod, herring, and sandeel. Both models predict similar yields of saithe and mackerel, the species without predators in the models. This suggests that differences in predicted yields must arise from differences in the predation mortality used as does the different balance of yield of whiting and haddock between the human consumption and industrial fisheries. The investigation of the relationship between differences in age-specific predation mortalities in the two models and yields under the status quo fishery conditions warrants further investigation, but was not possible at this meeting. Certainly, the predicted sandeel harvest of 1.9 million t in the multiplicative model seems unrealistic.

Equilibrium harvests with the human consumption roundfish fishery increased by 10%

In the multiplicative model, a 10% increase in this fishery leads to modest increases in yield to that fishery (Table 4.4.3). There are increases to both of the industrial fisheries and especially to the herring harvests. The increases to the industrial fisheries are small percentages of their total harvest, however, compared to the increases to the roundfish fishery.

In the MSVPA forecast, there are greater absolute increases in yield to the roundfish fishery directly and the herring fishery indirectly. The percentages are generally comparable between the two models, although this model predicts a much larger return from haddock, whiting, and Norway pout to the industrial demersal fishery.

Equilibrium harvests with the industrial demersal fishery increased by 10%

The multiplicative model indicates that a 10% increase in this fishery leads to increases in return from most species harvested by this fishery (Table 4.4.4). There are corresponding declines in yield of cod, whiting, and haddock in the human consumption fishery. Only whiting, haddock, pout, and sandeel in the industrial fishery show increased yields of any percentage at all. Given the large baseline yield of herring, the additional yield is negligible.

The MSVPA forecasts show similar percentage increases in yield to the industrial demersal fishery, where yields of all species increase by from 2 to nearly 10%. The decreases in the roundfish fishery are slightly larger than those indicated by the multiplicative model.

Equilibrium harvests with the industrial pelagic fishery increased by 10%

Both models provide similar predictions for a 10% increase in the industrial pelagic fishery (Table 4.4.5). Yield of whiting in this fishery increases by nearly 10%, whereas yields of herring and sprat are increased by lesser percentages. As much or more yield of herring is lost in the human consumption fishery, however, there is only a slight decrease in the human consumption fishery for whiting, and most other yields show changes of less than 1%. In both models, there is a very small change in the yield to the industrial demersal fishery arising from the increased industrial pelagic fishery, but the models differ in their net effect.

Equilibrium harvests with the human consumption herring fishery increased by 10%

A 10% increase in this fishery produces about a 5% increase in yield from that fishery in both models (Table 4.4.6). Both models also show a decrease in yield of herring to the industrial demersal fishery of about half that size. No other yields are affected.

Equilibrium harvests with the saithe fishery increased by 10%

For both forecasting models, increasing the saithe fishery mortality has a number of consequences (Table 4.4.7). Yield in the saithe fishery actually changes very little, compared to the 10% decline in yield of saithe in the roundfish fishery. Yield of all other roundfish increases, however, and by higher percentages in the MSVPA forecasts than in the multiplicative model predictions. Yield of all species except saithe generally increases in the industrial fisheries, and usually by a slightly higher percentage in the MSVPA model than in the multiplicative model.

Equilibrium harvests with the mackerel fishery increased by 10%

In both models, an increase of 10% in fishing mortality on mackerel leads to much less than a 10% increase in yield from that fishery (Table 4.4.8). Small increases in yield of herring, haddock, and cod are seen in fisheries which harvest those species. Increases in yield of pout and sandeels to the industrial demersal fisheries also occur, but are small. There is likewise a very small increase in yield to the industrial pelagic fishery.

Summary

Both projection methods present quite similar evaluations of percentage changes in the major fisheries in the North Sea. Increasing the saithe fishing mortality appeared to have fairly wide ramifications, as did changing the fisheries which harvest several species. Increasing industrial fisheries generally decreased yield from the roundfish fishery.

The models, although consistent in the patterns they showed, had very different baseline conditions. Given the care taken to make initial conditions as similar as possible, these differences are cause for concern. Additional work is needed to determine whether

we were not successful in matching initial conditions closely enough, or if the dynamics of the two models produce the differences. If the discrepancies in baseline conditions can be cleared up, it seems that both models paint broadly the same pictures of long-term dynamics, and long-term assessment advice may well be improved through use of either method.

4.5 Long-Term Sensitivity

Since the Working Group's management recommendations will rely heavily upon interpretation of the long-term yield forecasts, determination of the sensitivity of long-term yield to the parameters is important both for interpreting results and for quantifying the need for improved estimates of certain parameters.

The sixteen sensitivity runs made on the MSVPA (Table 2.9.1) were doubled to allow addition of nine recruitment parameters to the analysis (Table 4.5.1). Deviations away from the key run parameter values were kept at 10% for recruitment, and no changes were projected in the fishing effort.

The forecast model (Sparre, 1986) was run for 35 years at which point the model was reasonably close to convergence. Yields of each species and the total yield were taken as independent variables (responses) in a multiple linear regression with the 16 parameters as independent variables.

As an indication of the overall sensitivity of yield to this set of parameter manipulations, Figure 4.5.1 shows the coefficient of variation of each species' yield. Herring is by far the most sensitive species (CV = 56%), followed by Norway pout (CV = 25%). The most stable species are cod and whiting (both with CV = 5%).

Table 4.5.2 shows the ranked sensitivities of yield to each parameter. The sign on each rank indicates the direction of the response. Note the sensitivity of each species to its own recruitment. All species, except for haddock and herring, are most sensitive to their own recruitment. Herring is most sensitive to haddock recruitment, and haddock yield is most sensitive to saithe recruitment (a negative relationship). Saithe and mackerel appear to be sensitive only to their own recruitment and to overall M1 (i.e., yield for these two species is independent of the rest of the system). Total yield is sensitive to recruitment and cod ration.

Other food has little effect on the yield of any species, no ration level has an effect, except cod ration, on sandeel yield, and M1 has little effect except on saithe and mackerel yield.

Figure 4.5.2 and Table 4.5.3 show the relative sensitivities of yield to changes in each parameter. The scale on this plot can be read as the % change in the yield that a 1% change in the parameter will produce. Note first that the highest sensitivity (Fv) is for herring to haddock recruitment. A 1% change in haddock recruitment produces almost a 5% change (in the same direction) in herring recruitment.

Figure 4.5.3 shows a plot of herring yield versus haddock re-

cruitment for the 33 runs of the model. There is obviously a strong positive relationship, but there are two outliers for the case with low haddock recruitment. For one of these cases, all 16 parameters were set to -1 (all rations were low and all recruitments were low). The second outlier had all recruitment high, except for haddock, and all other parameters low. Although it is clear that a higher order, non-linear interaction is taking place, there is not enough information in these 33 runs to decipher just which higher order interaction it is.

The analysis of the relative sensitivities of each species' yield to its own recruitment suggests that there are three types of response: fish whose yield changes exactly as much as their own recruitment (saithe, mackerel, and herring); fish whose yield changes less than their own recruitment (cod, whiting, and haddock); and fish whose yield changes more than their own recruitment (sprat, Norway pout, and sandeel).

Herring appears sensitive to most parameters, while saithe and mackerel are sensitive only to their own recruitment and to M1. Ration levels do not seem important, except to herring and Norway pout. Only herring yield is at all sensitive to other food.

Discussion

This sensitivity analysis, although preliminary, demonstrates the compensatory nature of the MSVPA and forecast model. Despite the large variation in some fish yields, overall yield varies little (Table 4.5.3). Even though we already expected that the long-term forecasts are sensitive to recruitment, it is nice to have our suspicions confirmed. The manner in which various species are sensitive to their own recruitment, and to that of other species, is interesting. A species' sensitivity to its own recruitment summarizes all the indirect predator-prey relationships for each species, showing that some tend to damp out oscillations in recruitment, while others tend to amplify changes in recruitment. The relationship between haddock recruitment and herring appears to be important, and the exact nature of this very strong effect should be further considered. It seems likely that herring and haddock are alternative prey for some important predators.

The purpose of making a forecast is to look at the effect of changes in effort on yield. The sensitivity of yield to changes in effort should be examined either by running several sensitivity analyses for different fishing efforts, or by including the effort of various fleets within the sensitivity analysis itself.

An expanded sensitivity analysis should be attempted in the future. Although 16 parameters is five times as many as were examined last year, there are 1,000 times that number of parameters in the model. Of particular interest are the natural mortalities and terminal fishing mortalities (Finn et al., 1986).

Some reworking of the program to produce minimal output (or development of a separate program that digests the output as the runs are done), combined with plans to reduce the number of feeding parameters, makes it conceivable to eventually examine the

sensitivity of all parameters. It may also be possible to use these techniques to help "tune" the terminal Fs and M1s to external data or to data already in the model.

5 FEEDING STUDIES

5.1 Stomach Sampling Programme 1985-1987

The stomach sampling programme for cod and whiting in the first and third quarters during the period 1985-1987 is in full progress, but no data are as yet available.

Experience with the 1981 project has shown that the processing of data for use in MSVPA is slow. It is felt that much gain could be expected if a data base and associated software packages were available for exchange between countries and if this data base could also be accessed by the Working Group during meetings. Development of such a system deserves high priority.

Before the next meeting of the Working Group, the 1985 and, possibly, 1986 data should be evaluated. Therefore, the species coordinators involved should meet early in 1988 in order to produce the output required for input in MSVPA. They should also discuss what steps must be taken to set up the data base.

5.2 Sampling of Herring Stomachs

In response to last year's request for a pilot study of feeding of herring on eggs and larvae, working papers were received from Last (1986) and Stokes (1986), which presented the results of samples taken in February 1984 and 1986 and May 1986. These papers indicate that predation on plaice eggs might account for 10% of the egg production. This appears to be rather higher than the estimate of 1% given by Daan *et al.* (1985), but this difference is almost entirely accounted for by the adjustment of the natural mortality in the herring assessment, which resulted in considerable increases in stock size. The rate of predation by individual herring was of the same order of magnitude.

It remains unclear whether such a mortality rate could be expected to influence recruitment levels of plaice, because different sources of mortality may be largely compensatory. What really counts is whether the presence of large stocks of herring results in lower egg survival, but this question can as yet not be answered.

Clupeoid and *Ammodytes* post-larvae supplied a significant proportion of the food of herring. Also, in this case, it is not clear how such results could be incorporated in the assessments. Obviously, feeding on eggs and post-larvae is related to the recruitment mechanism and, therefore, might affect our conception of long-term yields. Still, it would not seem profitable to extend MSVPA further into the early life phase because 1) the time scale seems highly inappropriate to describe events in rapidly changing phases of life and 2) the specific effects of the few predators considered in the system become imbedded in the effects of a multitude of other factors.

Further research has to be planned at the national level before such problems could be profitably tackled by internationally co-ordinated research programmes. Further samples of herring should, if possible, be forwarded to Mr J. Last of the Lowestoft Laboratory, UK.

5.3 Predation Among O-Group Fish

Macer (1986) describes incidences of predation of O-group fish by O-group fish. The conclusion reached was that, in several instances, O-group gadoids have been found preying upon other fish, including their brothers and sisters. From the point of view of density-dependent mortality, these observations appear to be highly interesting, but only as far as this predation would take place in the second half of the year, data could be used in MSVPA to improve estimated predation rates. More detailed studies of food habits of O-group fish between July and December deserve high priority.

5.4 Other Studies

The method adopted to estimate M1 values among juvenile fish might be considerably improved when more detailed information was available on the food composition of other fish predators than those included in MSVPA. It might be feasible to collect stomach samples of these fish during ongoing research vessel surveys without large extra costs. In fact, in the past, such samples have been collected by various countries, the main problem being that the information is not readily available. This situation could be improved by incorporating the information in the international data base, which has to be developed for the ICES Stomach Sampling Programme.

5.5 Future Stomach Sampling Surveys

The 1981 Stomach Sampling Project involved comprehensive at-sea surveys to obtain the required input data for estimating quarterly sets of suitability indices for running MSVPA. Since then, special sampling programmes (1985-1987) have been designed to test the hypothesis of constant suitability. It is important to realize that the Multispecies Working Group is dependent primarily on a single year of observations. Therefore, it is essential that planning begins now for another intensive stomach sampling effort. The year 1991 would be appropriate for such a large-scale experiment. The ICES Multispecies Symposium in 1989 should contribute significantly to the design of the hypotheses to be examined during the 1991 survey. Evaluations of the 1985-1987 stomach sampling will also contribute to this effort. Results of these evaluations should be presented to the 1989 ICES Multispecies Symposium. It is important that correct planning and further model development begin now so that the maximum increases in scientific information can be obtained from such a large-scale cooperative field research effort.

6 IMPROVEMENT TO THE MSVPA MODEL

6.1 Alternative Forms of MSVPA

At last year's meeting, it was suggested that a simplified MSVPA which uses numbers rather than weights might produce results similar to the current version of the MSVPA. This idea was further explored in Daan (1986) and the results indicate that, both in theory and in practice, the two models are virtually identical.

The main advantage of using an MSVPA based on numbers is that it allows stomach samples to be worked up in numbers instead of weights. At least for species eating large food items, this would ease the analysis of stomach contents considerably.

A disadvantage is that consumption rates are commonly expressed in energetic terms and only empirical functions can link rations in terms of numbers to rations in weight.

Because the two methods can be tuned to give similar results in terms of stock sizes and mortalities, the Working Group did not pursue this concept any further at this meeting. Because of the possible implications for sampling programmes, the idea may have to be picked up again in the future.

6.2 Uniqueness of VPA Runs

The problem of uniqueness was discussed in the 1984 report of this Working Group and has been subjected to considerable analytic investigation (Dekker, 1982; Magnus and Magnusson, 1983). The latter paper develops "sufficient" conditions for uniqueness which are generally met by the North Sea model. Whether these are "necessary" conditions is less clear. At the present meeting, it was anticipated that suitability estimates might possibly change if large-scale changes in abundance and distribution occurred. Thus, it is possible that the stomach samples being analyzed from 1985, 1986, and 1987 may indicate systematic changes in suitability for some species. If this is the case, then there are several possible ways that this problem might be addressed. Ideally, but very expensively, stomach samples might be taken regularly and suitabilities estimated separately for each year.

An alternative approach would be to use survey estimates of areal distribution to monitor changes in overlap (Houghton, 1986); again this might be expensive if new surveys were needed. A third possibility would be to make suitability of some species a function of abundance. The latter would be the cheapest but might affect the uniqueness of the MSVPA. The following tentative analysis of uniqueness in these circumstances suggests that including such a function might not affect uniqueness.

Firstly, we can consider the usual case. Using the multispecies cohort analysis (Pope, 1979), we may write the equation for population of a prey species j of age b of predator species i of age a as

$$N(j,b,y) = C(j,b,y)e^{\frac{M1}{2}} + N(j,b+1,y+1)e^{M1}$$

$$+ e^{\frac{M1}{2}} \sum_{\substack{\text{all}\\ \text{predators}\\ i,a}} \frac{\bar{N}(j,b,y)\bar{N}(i,a,y)Ration(i,a)SUIT(i,a,j,b)}{\sum_{\substack{\text{all}\\ \text{prey}\\ k,c}} \bar{N}(k,c,y)SUIT(i,a,k,c)wt(k,c)} \qquad (1)$$

If we estimate $N(j,b,y) \overset{\Omega}{=} [N(j,b,y) \times N(j,b+1,y+1)]^{1/2}$

and call $N(j,b,y)^{1/2} = V(j,b)$,

we may rewrite equation (1) as

$$V^2(j,b) = K1(j,b) + \sum_{\substack{\text{all}\\ \text{predators}\\ S,A}} \frac{V(j,b)K2(i,a)}{K3(i,a) + K4(i,a)V(j,b)} \qquad (2)$$

where K1, K2, K3, and K4 are a series of positive constants, provided the populations of other species are positive. Dropping the j,b indices, equation (2) may be rewritten as

$$y = -V^2 + K1(j,b) + \sum_{S,A} \frac{K2(i,a)V}{K3(i,a) + K4(i,a)V} \qquad (3)$$

such that the correct value of V is found when y = 0.

It is easy to show that y is +Ve when V = 0 and that $\frac{dy}{dV}$ is a

monotonically decreasing function of V. Thus, there is only one +Ve solution of equation (3) when y = 0. This suggests that the solutions are unique provided that other population sizes are positive, which is a condition of a reasonable solution. Some doubt as to the validity of this argument does, however, exist since it does not clarify whether the values of V appearing in equivalent equations to (3) for other prey populations could lead to multiple solutions. This clearly needs to be investigated further.

If the argument is valid, the argument is also valid if suitability for a species increases as N(s,a), since this gives an equation

$$y = -V^2 + K1 + \sum_{S,A} \frac{K2V^2}{K3 + K4V^2}$$

which also has y > 0 when V = 0 and has $\frac{dy}{dV}$ monotonically decreasing.

Thus, with this particular functional form, the uniqueness argument developed above would still hold. Since it would be difficult to suggest a more extreme response of suitability to abundance, this argument would seem to cover all reasonable cases. Clearly, more work on the uniqueness of the MSVPA model using the multispecies cohort analysis (Pope, 1979) as a simple analogy would be worthwhile. In particular, the validity of the initial uniqueness argument needs to be carefully examined.

6.3 Incorporation of Several Years of Feeding Data

A proposal on how to use several years of stomach content data was put forward in a working document by Gislason and Sparre (1986). It consists of using an average of the suitability indices estimated in years for which stomach content data are available. As usual, the MSVPA calculations are initiated with a guess on the quarterly suitabilities. These suitabilities are then used to estimate predation mortalities and stock sizes back to the start of 1981, the first year for which stomach content data are available. In each quarter for which additional stomach content data exist, a new set of suitabilities is estimated, and a weighted average (with respect to the number of stomachs sampled and convergence of the VPA) of these suitabilities used as a new guess. This procedure is repeated until the average suitability remains constant (Figure 6.3.1).

6.4 Comparison of Suitability

The MSVPA is currently based on the assumption that suitability is constant from year to year.

The MSVPA, like single-species VPA, relies on guessed terminal fishing mortalities and makes no allowance for the variance of the catch-at-age data. It is impossible to estimate the variance of the suitabilities in order to test this assumption.

Given several years of stomach content data, sensitivity analysis may, to some extent, indicate if reasonable changes in other parameters such as residual mortality, ration, stomach content, etc. can produce constant suitabilities.

However, if an average suitability is estimated, as suggested in Section 6.3, it may be equally interesting to study deviations from this average in individual years. These deviations could show whether it would be sensible to make the suitabilities a function of the spatial overlap between predators and prey and/or to incorporate a model of prey/predator switching.

A working document by Houghton (1986) described a simple measure of spatial overlap based on the abundance of cod, haddock, and whiting by age group and roundfish area in the English groundfish survey. The results showed that the distribution of older cod, and hence the overlap with its prey, has changed over the years. Such changes did not occur for whiting. An analysis of variance furthermore showed different age groups of cod of more than 2 years of age to have a similar distribution within any one year,

while the age groups of whiting had different distributions, which, however, were relatively constant from year to year.

With respect to prey/predator switching, it has been shown by Chesson (1984) that if suitabilities vary between individual predators of the same species age group, then switching can occur at the population level even though the suitabilities of each individual remain constant. This implies that if the suitability of e.g., herring as prey for cod in the northern North Sea is different from the suitability of herring in the southern North Sea, then the overall suitability will be a function of the relative overall abundance of herring, even though the spatial distribution does not change. This conclusion, however, depends upon the actual model of food selection used.

6.5 Comparison of Observed and Predicted Prey Fractions

Additional stomach content data were available (Casey et al., 1986) for the third quarter of 1982 and 1984 for the North Sea. The sampling intensity was approximately 25% of the 1981 level and, therefore, is useful for only a coarse analysis. A preliminary comparison of cod from the third quarter of 1982 and 1984 and of whiting from the third quarter of 1982 with predicted fractions from those periods was possible with the available information. Prey ages were not available though, so only a rough table of the observed and predicted fractions was attempted.

Table 6.5.1 shows the prey fractions for cod in 1982 and 1984 and whiting in 1982. The predicted diet does not appear to reflect the observed fractions as well as previous comparisons which more complete data had indicated (Anon., 1986a). The predicted cod fractions are generally higher than the observed data indicated, and small percentages of gadoids were predicted in most of the whiting age groups and not found in the samples. Herring, sprat, and sandeel predictions, however, were in close agreement with the empirical data for whiting. These results may partly reflect the fact that the areal distribution of sampling in the third quarter of 1982 and 1984 was not strictly comparable with the design in 1981. This analysis should only be considered as very preliminary and further work is certainly warranted.

7 MSVPA PERSPECTIVES OF FEEDING RELATIONSHIPS IN THE NORTH SEA

7.1 Who Eats Who?

Table 7.1.1 summarizes the total consumption by individual predators and the estimated stock biomasses in 1974, 1981, and 1985.

Table 7.1.2 shows the total biomass and consumption estimates for all years 1974-1985.

As appears from Table 7.1.2, the total biomass decreased about 50% from 1974 to 1978 and has since then remained approximately constant at 5 million t. The total yield has shown a proportionally similar change from 4.2 million t in 1974 to 2.5 million t in 1977 and has since then stabilized on that level. The amount of MSVPA species eaten has shown a slightly different

change with a more gradual decrease from 1974 to 1981 and has since then remained rather stable. The reduction in the amount eaten from 1974 to 1981 was about 70%.

The amount of fish dying due to the residual mortality has decreased by 50% from 1974 to 1980 and has since then remained stable. The biomass of the MSVPA predators has decreased by 60% from 1974 to 1982.

The "yield/average biomass" has been approximately constant during the period as has the "amount dying due to residual mortalities/average biomass". The "amount eaten/average biomass" has decreased more or less steadily from 1974 to 1985.

The "amount eaten/predator biomass" has been rather constant around 1-1.3 during the period. This means that the five MSVPA predators each year eat an amount of MSVPA species equal to their own biomass. The total amount dying each year due to predation, fishing, and other causes is between 1.13 and 1.49 times the average biomass.

Figures 7.1.1a-g show the biomass and annual yield together with the biomass consumed annually by various predators for each prey species. Saithe and mackerel are not shown because their predation mortality is estimated to be zero. For cod too, the predation is very small compared to its biomass. For herring, it is about 1/10 of the biomass and for whiting, haddock, and sprat, about 1/2 of the biomass. With respect to Norway pout, the predation is about equal to the biomass, and for sandeel too, at the beginning of the period, caused by a high predation by the large mackerel stock in that period. Later on, from about 1977, the predation is only half the biomass of sandeel.

Figures 7.1.2a-e compare the biomass and annual yield of predator with the prey biomass consumed. For cod, whiting, saithe, and mackerel, the total yearly consumption of fish is estimated to be between one and two times the predator biomass. For haddock, it is considerably lower.

The most conspicuous difference between the results depicted in Figures 7.1.1 and 7.1.2 and those given in the 1985 report (Figures 6.2.1 and 6.2.2) is observed in the biomass estimates. This is because:

1) The depicted biomasses are averages for the year, whereas the previous ones were biomasses at the beginning of the year.

2) 0-group fish are supposed to exist only from the beginning of the third quarter. Last year, the standard procedure of most assessment working groups was adopted. This is to back-calculate 0-group numbers to 1 January of the year in which the fish are spawned and to multiply by a body size which is largely derived from the sizes in the catch later in the year.

Levels of consumption are influenced by changes made this year to the calculations of the quarterly consumption rates (see Section 2.4).

8 FOOD FOR THOUGHT

8.1 Alternating Cod Year Classes

A striking feature of North Sea cod is the alternation of strong and weak year classes from year to year when year- class strength is measured as the number of 1-group cod at 1 January from the VPA produced by the Roundfish Working Group (Anon., 1986g). It could, therefore, be interesting to see if the MSVPA model is able to explain this alternation, i.e., if the alternating year-class strength is caused by predation by the MSVPA predators.

If the MSVPA explains the alternating year-class strength of 1-groups at 1 January, the MSVPA numbers of 0-groups at 1 July, which is the starting point of the MSVPA model with respect to cohorts, should not show the same alternations as the 1-groups.

Figure 8.1.1 shows that both the number of 0-group cod at 1 July and of 1-group cod at 1 January from the MSVPA keyrun shows the same alternations.

This means that the MSVPA model does not explain the alternating year-class strength of cod. The factors responsible for the phenomenon must, therefore, act before 1 July or be factors acting after 1 July and not accounted for by the MSVPA model.

Correlation between 0-group number of cod and 0-group survey indices

As the 0-group MSVPA number at 1 July correlates closely with 1-group MSVPA number at 1 January, which again correlates closely with 1-group numbers from VPA (Figure 8.1.2), the correlation between the 0-group survey indices from both the international 0-group survey (1974-1983) and the English groundfish survey (EGFS) (1977-1986) cannot be expected to have a significantly better correlation with 0-group MSVPA than that found for the VPA 1-groups.

As can be seen from Table 8.1.1, this is precisely what comes out of a correlation analysis. The MSVPA 0-group number at 1 October correlates in fact a little less than the VPA 1-group number (at 1 January) with the 0-group indices.

8.2 Testing the Forecast Program to Destruction

Considering that recruitment is not a function of stock size in the forecast program (MSFOR), the program cannot be expected to react realistically to situations much different from those in the MSVPA years (1974-1985). Much work remains to be done before a safe range of fishing patterns can be identified.

At this meeting, it was possible to perform only a few exercises with the extreme situation: F = 0 everywhere. A long-term forecast based on the key run tuned made saithe extinguish Norway pout.

The key run uses the Helgason-Gislason option. The Sparre option was tried (but using the key run output) with a similar result.

However, doubling the biomass of the Sparre option from 40 to 80 million t gave reasonable results. The system became dominated by saithe, cod, and sandeels, whereas haddock (not Norway pout) almost disappeared. The main problem seems to be that the MSVPA has no influence (through predation) upon the saithe population until the saithe are 3 years old. Large predator stocks, therefore, do not reduce recruitment to the adult saithe stock.

What can be learned from these few exercises is perhaps that more attention should be paid to the two elusive parameters: total biomass in the Sparre model and available other food in the Helgason-Gislason model. The values used were adopted because they happened to work well with the MSVPA. Higher values, however, might make little difference to the MSVPA, but increase the robustness of the MSFOR.

8.3 Smoothing of Suitabilities

Background to model

At last year, an attempt was made to fit various models of size selection to the suitabilities estimated by the MSVPA. According to Andersen and Ursin (1977), suitability may be described by assuming that the weight of the predator divided by the weight of the prey is log normally distributed:

$$SUIT(i,a,j,b,q) = Q(i,j,q)\exp-\frac{1}{2}\left\{\frac{\ln[WSEA(i,a)/WSTOM(j,b)]-\mu(i)}{\sigma(i)}\right\}^2 \qquad (1)$$

where i and a are indices of predator species and age, j and b are indices of prey species and age, q is quarter, WSEA(i,a) is weight of predator i at age a in the sea, WSTOM(j,b) is weight at ingestion of prey j at age b, μ and σ are the mean and standard deviation of the log normal distribution, and Q(i,j,q) is a coefficient expressing the general vulnerability of prey j to predation by predator i in quarter q.

The suitabilities are estimated in the MSVPA from relative stomach content, body weights at age of prey at ingestion, and numbers at age of prey in the sea. However, the body weight of prey in the sea and at ingestion often differ. It is hence reasonable to think that the numbers of a certain age are distributed in various size classes, of which some are more suitable than others.

If we assume that the individual weights at age in the sea follow a normal distribution, the number of prey of a suitable size is proportional to:

$$\bar{N}(j,b,q)\exp\{-R(j)[WSEA(j,b)-WSTOM(j,b)]\}^2 \qquad (2)$$

where R(j) is a constant. Hence, after taking logarithms

$$\ln SUIT(i,a,j,b,q) = \ln Q(i,j,q) - \frac{1}{2}\frac{\ln[WSEA(i,a)WSTOM(j,b)]-\mu(i)}{\sigma(i)}^2 - R(j)\left[WSEA(j,b)-WSTOM(j,b)\right]^2 \quad (3)$$

Results of fitting suits

Three models were fit to the ln (suitability) values. All three treated predator and prey main effects and interactions the same, and used the weight ratio covariates in the same way as well. This kernel model in analysis of variance notation was

$$\ln(SUIT) = pred + prey + pred \times prey + \ln(wt\ ratio) + [\ln(wt\ ratio)]^2 + wt\ diff + (wt\ diff)^2$$

The three variants of this kernel tested the level of specificity of the size difference factor. Variant one estimated a common first and second power size difference term for all prey. The seccond tested the first power term under prey species (testing a common second power term). The third nested both first and second power terms under prey species.

From the model fitting, a substantial improvement was gained by estimating separate size difference slopes for each prey, but little more was gained by estimating separate curvature terms (Table 8.3.1). Hence, the second variant was adopted as the core model for smoothing suitabilities.

The estimates of μ and σ for the wt ratio of predator to prey are 5.0924 and 1.893, respectively (Table 8.3.2). These are reasonably close to the mean and standard deviation of the weight ratio function estimated from predation mortalities, although the SD is somewhat larger, implying the distribution of suitabilities is slightly broader than the distribution of resultant M2s.

The parameter estimates of the individual weight difference factors differ greatly among prey (Table 8.3.2). These estimates are difficult to interpret biologically, although they suggest that cod and sandeels eaten by predators are relatively small for their age, whereas pout eaten by predators are often large for their age. Confidence in these patterns should match the confidence placed in the estimates of weights of prey at age in stomachs.

Individual parameter estimates were obtained for all predator/prey combinations (Table 8.3.3). Although these were not expanded into full interaction coefficients (see Section 4), their relative magnitudes are consistent with the patterns explained in some detail in Section 4.3. Note particularly that suitabilities of various prey to whiting differ less than suitabilities to other predators, particularly saithe. Also, Norway pout are a suitable prey to most predators, as are haddock and cod (although in the MSVPA, saithe and haddock are not allowed to feed on cod).

A final model included the entire core plus interactions of quarter of year with predator and with prey. Both of these terms accounted for substantial variation in suitability, and the resi-

dual error was reduced substantially (Table 8.3.4). There are good biological reasons for such interactions, due to changing patterns of distribution of the species over the year.

Time did not allow further exploration of these interactions, but more work is warranted in this area. It was noted in the 1985 report that quarter did not account for much variation in M2s, but the term was used only as a main effect.

Summary

There are theoretical grounds to believe that suitabilities could be represented by mathematical functions. The model fitting supported that point, although the importance of the prey-specific $(\text{weight difference})^2$ term was somewhat less than expected. More work would be useful, particularly looking at quarter effects.

8.4 Smoothing of M2 Values

The rationale for smoothing the M2s and the basis of the estimation procedure were both outlined in the 1985 report of the Working Group. As with last year, attempts to fit ln(M2) without the biomass correction produced results which were not qualitatively different from the results of fitting M2s per unit predator biomass, but the fits had larger mean square errors (MSE = 3.95-2.4). Hence, only the models fit to M2/biomass will be discussed in this section.

Models fitted

The combined slopes model

This model is the same model used in the 1985 smoothing and subsequent long-term projections. It contains terms for predator and prey main effects, their interactions, and the weight ratio terms. It again provided a reasonable fit to the M2s, and the coefficients of the weight ratio terms were of the expected size and with appropriate sign. However, on biological grounds, it was thought that the preferred weight ratio might differ among predators. Therefore, a second model was fit with the weight ratio term nested under the predator effect.

The CORE model (main effects with nested slopes)

This model contains the main effects for each predator and prey species and their interaction. A common weight ratio squared term was included, but the weight ratio covariate had a unique slope for each predator. This model provided a substantially improved fit to the M2 values and was adopted as the standard for long-term projections (Section 4).

From the ANOVA table (Table 8.4.1), it is clear that both the predator interaction terms and the nested weight ratio covariates account for substantial variation in M2 . The individual interaction terms will be discussed in the next section. The estimates of the slopes are biologically reasonable (Table 8.4.2). Cod and

whiting have similar preference ratios of approximately 50:1, whereas mackerel, saithe, and haddock have substantially higher slopes from 175:1 to 270:1. For a given size of predator, these species all prefer much smaller prey than do cod and whiting. This model, summarized as

$$LN(M2/PB) = PRED + PREY + PRED \times PREY + LWTR \text{ within } PRED + LWTR^2$$

may be a useful tool for investigating aspects of feeding strategies and foraging constraints.

The 34 levels model

The SPSS-X package used to fit the models aliased one level of every factor. Because the parameter estimates of the model were vital to other work of the meeting, the model was restructured so that each unique predator-prey combination was a separate level of a single factor. Fitting this model changed details of the ANOVA table (Table 8.4.3), but none of the individual parameter estimates. Only the value of the final level was aliased, and the model was structured so that interaction, between haddock and sprat, was known to be very small. From the parameter estimates of this model (see Table 4.3.2), cod and whiting are clearly different from the other species. Furthermore, when size differences are accounted for by the covariate, cod shows relatively little differentiation among prey species, whereas whiting and saithe show a great deal of differentiation among prey species. This is another ecological point which warrants further investigation.

The fit of individual predicted values to the observed M2 values

Figure 8.4.1 shows the plot of the expected normal values vs. LN(M2/PB) for the core model. If the assumption of log linearity of the data was correct, the line would be straight with a gradient of one. The line, however, is not straight and the complimentary plot labelled "detrended normal plot" shows how the fitted data deviates from normality.

Essentially, the detrended normal plot indicates a mean value of LN(M2/PB) lower than expected with a bunching of the data to the left. On the right of the distribution, the data are more spread out than expected and have an abrupt cutoff.

8.5 Definition of Fisheries and Interactions

The models used for long-term assessments all require some estimate of the technical interactions between fisheries. To date, no considered analysis has been done to define these interactions, and model runs have been done using technical interactions based on informed guesswork. It is desirable, therefore, that these interactions should be defined on a more objective basis. Since the herring and mackerel are "clean" fisheries in the sense that by-catches are small or absent, the most important fisheries in which to consider technical interactions are the demersal human consumption and industrial fisheries. In the case of North Sea roundfish, catch-at-age data and effort data (where extant) are

available disaggregated by fleet, and it should be possible to analyze partial Fs by fleet in order to evaluate technical interactions between fisheries. Similar data should be available for the industrial fisheries. The Working Group would welcome an analysis of these data before the next meeting so that long-term predictions can be established on a sound basis.

8.6 Extending MSVPA Backwards Before 1974

At present, the MSVPA must necessarily be restricted to the years beginning with 1974. This limitation is due to the fact that for some industrial species no catch-at-age data exist for earlier years and also there appears to be little chance that the catch data for some of the other species can be split in quarterly values in a reliable way. Still, it would be extremely valuable if the MSVPA could be run over the 1960s, when large changes in species composition in the North Sea were observed. Particularly, quantitative information on the possible scope for variations in predation mortalities could improve our conception of the range of realistic options for recruitment changes in long-term yield predictions.

Extending the MSVPA further backwards should probably be done on an annual basis, to which end annual suitability indices must be tuned to yield similar results to the quarterly indices for recent years. In addition, the model would have to be adapted to take into account a variable number of species for which catch-at-age data exist. Although the results would necessarily become less refined than those for the later years, such an exercise would seem useful, and it is recommended that this problem is addressed during a future meeting.

8.7 Consistency of Groundfish Survey Data with MSVPA

The English groundfish surveys were conducted from 1977-1985 (Harding et al., 1986). Catch in numbers per hundred hours were compared for cod, haddock, and whiting with the estimated numbers at age from the MSVPA runs for the years 1977-1983. The ratio (qs) of number/100 hrs over numbers in population x 1,000 were calculated. An analysis of variance (ANOVA) was then run on the ln data, using SPSS. The ANOVA was run both with and without age 0 fish. In all these species, age 0 deviations from the mean were large. Age was significant in all of these runs. Years were significant only for whiting. When age 0 values were removed, age ceased to be a significant factor for cod and haddock, indicating the consistency of the survey with the MSVPA data J.G. Pope (pers. comm.) indicated that when M = 0.2 was used in VPA for cod, the qs calculated from the ratio with survey data indicated that the survey was more effective in capturing age 1 fish than older ones. The change with the use of MSVPA is indicative that the larger population numbers resulting from using estimates of predator mortality may be more reasonable.

8.8 Other MSVPA Improvements

The Industrial Fisheries Working Group (Anon., 1986d) drew attention to the fact that the sandeels in the North Sea must be split into two major stocks which may suffer different rates of natural mortality. In principle, such a change can be implemented in the MSVPA. Since catches are given by the Industrial Fisheries Working Group for each component on a half-yearly basis, some revisions are required to get the quarterly catches. Within the MSVPA, it is simply a matter of adding another species to the array. Also, the stomach content data can be easily adapted to take account of two components as long as these are defined by their presence in the different roundfish areas. The largest difficulties, however, may be caused by the appropriate age-length keys for each of the two stocks to analyze the age composition of the prey. The possibility of including plaice and sole in the model might also be considered. It is suggested that this problem is taken up at the next meeting of the Working Group.

The effects of mesh changes might also be considered in long-term forecasts.

9 RECOMMENDATIONS AND ACTIONS

9.1 Recommendations

1) The Chairman will edit a Cooperative Research Report on the findings of this Working Group in accordance with C.Res.1986/1:3.

2) The various North Sea assessment working groups should use the levels of natural mortality given in Table 2.8.2 as a guideline for their calculations.

3) With due care, single-species working groups should be able to provide TAC advice even when estimates of natural mortality change.

4) ACFM should take account of the results of Section 4 of this report, particularly noting that increases in the roundfish fishing mortality may well increase yield for these species. This finding is at variance with single-species advice.

5) This Working Group should provide all long-term advice for the 9 North Sea species included in the MSVPA since this cannot properly be considered by single-species assessments.

6) The species coordinators involved in the Stomach Sampling Programme should meet for 5 days in January 1988 in IJmuiden in order to

   a) evaluate the results obtained so far with a view to providing input for the Multispecies Assessment Working Group;

   b) organize the exchange of stomach content data and define requirements for setting up an international data base.

7) Countries are urged to continue their sampling effort on cod and whiting stomachs during the first and third quarters of 1986 and 1987.

8) Herring stomachs should be sampled where possible in the North in 1987 and samples sent to Mr J. Last of the Fisheries Laboratory, Lowestoft, UK.

9.2 Action Sheet

Sec.	Action to be taken by Working Group members
2.3	English groundfish survey stomach data should be worked up.
2.5.1	Stomach content data from other predatory fish should be looked at to see if they support assumptions made.
2.7	Construct checking program for data to find faulty data.
4.	Compare long-term forecast methods. Investigate reduction in effort. Investigate mesh changes.
4.5	Investigate sources of sensitivity, especially herring. Why is herring sensitive to haddock recruitment?
5.	Collect and make public data on predation by other predators. Investigate ways of incorporating other predators in the model.
5.3	In order to allow for an integrated analysis of additional stomach content data available for cod and whiting in the third quarter of 1980, 1982, and 1984, various institutes should merge their data sets, including survey data on catch rates and age/length compositions, so that improved comparisons can be made between observed and predicted prey fractions.
5.5	Work on the design of an intensive stomach sampling effort in 1991, the "Year of the Stomach".
6.2	Further work on uniqueness of MSVPA is required.
6.3	Investigate sensitivity of suitability to input F in order to give appropriate weighting to estimates from different years.
6.4	Further studies of prey overlap would be welcome. Mathematical investigation of the measure of overlap should be developed.
6.5	English groundfish survey stomach data for 1982 and 1984 should be worked up by age.
8.5	Improve estimates of technical interactions between fisheries.

8.6 Investigate the possibility of extending MSVPA earlier than 1974.

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Table 2.4.1 Ambient temperatures for the five predator species according to charts of bottom temperatures in the North Sea, taking into account the centers of distribution of the stocks.

Quarter	Cod	Whiting	Saithe	Mackerel[1]	Haddock
1	6	6	7.2	5.9	6
2	7	7	7.4	7.6	7
3	9	10	9.8	12.2	8
4	8	8	9.4	9.5	7

[1] Unweighted mean of 10 m and bottom temperatures.

Table 2.4.2 Values of feeding level φ = stomach content weight/L^3 g. cm^{-3} by age or size class by quarter.

Species			Quarter			
			1	2	3	4
Cod	Age class	0	-	-	(0.000177)	(0.000136)
		1	0.000181	0.000114	0.000136	0.000162
		2	0.000221	0.000222	0.000221	0.000178
		3	0.000135	0.000204	0.000264	0.000210
		4	0.000139	0.000204	0.000258	(0.000998)
		5	0.000129	0.000142	0.000238	0.000100
		6+	0.000118	0.000150	0.000311	0.000118
		Average	0.000154	0.000173	0.000238	0.000154
Whiting	Size class	10-15	0.000129	0.000143	0.000216	0.000081
		15-20	0.000086	0.000102	0.000073	0.000075
		20-25	0.000045	0.000113	0.000074	0.000067
		25-30	0.000082	0.000115	0.000127	0.000073
		30-40	0.000105	0.000085	0.000144	0.000124
		40-50	0.000131	0.000116	0.000149	0.000169
		50-70	(0.000140)	-	(0.000030)	(0.000050)
		Average	0.000096	0.000112	0.000131	0.000098
Haddock	Size class	10-15	0.000096	0.000105	0.000145	0.000094
		15-20	0.000052	0.000069	0.000137	0.000071
		20-25	0.000051	0.000121	0.000116	0.000088
		25-30	0.000053	0.000090	0.000113	0.000075
		30-40	0.000045	0.000129	0.000096	0.000077
		40-50	0.000051	0.000103	0.000117	0.000127
		50-70	0.000059	0.000058	0.000148	0.000079
		Average	0.000058	0.000096	0.000125	0.000087

Table 2.4.3 Quarterly A values (consumption kgs per quarter) = A x weight in the sea$^{2/3}$ for the different species.

Quarter	Cod	Whiting	Saithe	Mackerel	Haddock
1	0.57	0.32	1.06	0.92	0.18
2	0.70	0.41	1.07	1.45	0.39
3	1.16	0.64	1.34	1.18	0.67
4	0.69	0.39	1.26	0.67	0.39

Table 2.5.1 Estimated mean biomass of fish predators in the North Sea in 1983-1985. Biomass in '000 t.

Species	Biomass from Working Groups	Biomass estimation based on IYFS	Biomass estimation based on EGFS
MSVPA predators:			
Cod	500		
Whiting	1,069		
Saithe	620		
Mackerel	208		
Haddock	1,217		
Total	3,614		
"Other" predators:			
Squalus acanthias		30	87
Other sharks		2	11
Raja spp.		314	292
Lophius piscatorius		33	31
Pollachius pollachius		83	48
Brosme brosme		3	5
Molva molva		113	41
Merluccius merluccius		6	13
Sebastes spp.		14	76
Scomber scombrus (western)		0	512[1]
Scophthalmus maximus		7	3
Scophthalmus rhombus		5	3
Lepidorhombus whiffiagonis		32	17
Hippoglossus hippoglossus		4	2
Total		646	1,141
"Other" predators/MSVPA pred. x 100		18%	32%

[1] Mackerel Working Group estimate.

Table 2.5.2 M1 values used in the MSVPA key run (mortality per year).

Age	0[1]	1	2	3	4	5	6	7+
Cod	0.69	0.41	0.27	0.21	0.20	0.20	0.20	0.20
Whiting	0.73	0.45	0.27	0.25	0.24	0.22	0.21	0.20
Saithe	0.10	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Mackerel	0.075	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Haddock	0.73	0.52	0.31	0.24	0.21	0.20	0.20	0.20
Herring	0.52	0.35	0.21	0.14	0.12	0.11	0.10	0.10
Sprat	0.73	0.62	0.52	0.45	0.38	-	-	-
Norway pout	0.56	0.52	0.48	0.45	-	-	-	-
Sandeel	0.41	0.39	0.38	0.36	0.35	0.33	0.33	-

[1] 0-group M1 levels refer only to the second half year, i.e., 3/4 + 4/4.

Table 2.5.3 M2 (for 1981) values from the MSVPA key run using M1 values from Table 2.5.2 (mortality rates per year).

Age	0[1]	1	2	3	4	5	6	7+
Cod	0.96	0.47	0.11	0.019	-	-	-	-
Whiting	1.68	0.71	0.16	0.09	0.06	0.03	0.02	-
Saithe	-	-	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-
Haddock	1.59	1.25	0.13	0.03	0.02	-	-	-
Herring	0.57	0.91	0.05	0.16	0.01	0.02	0.02	-
Sprat	0.03	0.58	1.37	0.45	0.56	-	-	-
Norway pout	0.46	1.81	0.90	0.65	-	-	-	-
Sandeel	0.33	0.99	0.41	0.17	0.47	0.34	0.23	-

[1] 0-group M2 levels are from the second half year only, i.e., 3/4 + 4/4 mortalities.

Table 2.8.1a Annual fishing mortalities, stock numbers in '000, and annual predation mortality for the MSVPA key run. Mortalities are summed over the four quarters, except for the 0-group for which the third and fourth quarters were summed. Last age group is a plus group.

FISHING MORTALITY COD

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0913	.1490	.0607	.2556	.1218	.1949	.1589	.1716	.2569	.1810	.2485	.2271
2	.8620	.7849	1.0090	.8896	1.0983	.8666	.9436	1.0550	1.0042	1.1355	1.1244	1.0578
3	.7529	.8194	.8775	.7409	.9806	.9469	.9601	1.0067	1.2817	1.2368	1.0718	1.2896
4	.7107	.6646	.8015	.5827	.8108	.5451	.7351	.7252	.8014	.9050	.8341	1.0138
5	.7115	.7950	.6126	.5721	.9613	.7340	.5818	.6862	.7842	.8184	.8066	.9495
6	.7046	.6791	.9241	.4545	.7526	.5455	.6004	.6641	.8622	.7915	.8459	.9107
7	.6553	.7514	.8626	.5695	.7540	.6659	.7186	.7282	.7360	.7509	.7777	.9593
8	.7221	.5414	.5019	.6078	.9197	.5074	.7230	.6312	.7219	.8520	.9073	.8991
9	1.1237	.9462	.4603	.5435	.9897	.8736	.6263	.7157	.6859	.5934	1.1665	.8398
10	.6956	.9259	.9466	.5930	.8264	.7085	.9372	.6926	.6295	.5163	.9263	.9014
11	.6000	.6002	.6002	.6002	.8003	.8001	.8000	.8000	.9000	.9000	.9000	.9000

MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 3)

.7262	.7817	.8450	.6886	.9085	.8810	.8695	.8965	1.1724	1.0560	1.0090	1.1567

STOCK NUMBERS COD

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	258703.	388617.	184540.	710956.	409566.	424973.	854056.	325077.	565250.	257016.	495856.	55212.
2	113242.	108165.	165229.	88748.	285083.	174563.	170306.	349023.	113888.	211448.	102452.	207419.
3	22568.	53778.	34682.	45461.	25742.	66724.	51735.	46755.	83634.	28588.	46795.	23677.
4	31975.	8406.	11878.	11536.	17522.	7716.	20694.	15814.	13591.	18490.	6612.	12845.
5	9440.	12862.	3541.	4363.	5274.	6304.	3670.	8123.	6282.	4995.	6136.	2351.
6	1990.	5795.	4755.	1571.	2016.	1651.	2477.	1679.	3549.	2348.	1905.	2243.
7	949.	805.	1575.	1545.	816.	776.	785.	1113.	708.	1158.	871.	634.
8	795.	405.	511.	544.	716.	521.	327.	315.	440.	278.	447.	528.
9	514.	516.	192.	154.	245.	234.	158.	130.	136.	175.	99.	148.
10	164.	156.	100.	99.	73.	74.	79.	69.	52.	56.	79.	25.
11	435.	121.	80.	58.	87.	42.	47.	40.	45.	34.	41.	38.

TOTAL STOCK BIOMASS ON 1. JANUARY

319810.	279782.	280661.	254565.	346195.	310907.	342344.	414502.	340421.	301562.	240220.	242653.

SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 3)

258276.	177511.	170149.	166548.	160759.	188303.	199922.	196594.	245435.	166429.	155473.	120514.

PREDATION MORTALITY COD

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.4768	.6244	.5618	.7654	.8279	.6990	1.0565	.9553	.8024	.6112	.7185	.5745
1	.3708	.2375	.2616	.2682	.3206	.3096	.3261	.4672	.3164	.3287	.2150	.2617
2	.1209	.0826	.0702	.0779	.0839	.0776	.0792	.1057	.1080	.1047	.0705	.0506
3	.0247	.0157	.0152	.0140	.0143	.0138	.0152	.0188	.0175	.0173	.0111	.0092
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Table 2.8.1b Annual fishing mortalities, stock numbers in '000, and annual predation mortality for the MSVPA key run. Mortalities are summed over the four quarters, except for the 0-group for which the third and fourth quarter were summed. Last age group is a plus group.

FISHING MORTALITY WHITING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.0526	.0608	.0709	.0848	.0423	.0357	.0493	.0786	.0304	.0872	.0200	.0112
1	.4646	.2609	.2391	.5088	.1920	.3070	.1345	.2077	.2695	.3265	.1763	.0977
2	.9381	.8118	1.0345	.5748	.4419	.5511	.4554	.5417	.3445	.5162	.5714	.1409
3	1.0874	1.0816	1.2727	.9308	.7255	.8283	.8211	.7616	.5170	.7290	.9636	.2658
4	.9652	1.0665	1.1203	1.0211	.8775	.7424	1.0196	.9816	.7090	.7419	1.0426	1.2290
5	1.0581	1.0510	.8203	.8610	.7505	.9511	1.1785	1.0495	.9074	.9093	1.0079	.9455
6	1.9916	.9688	1.2669	1.0450	1.1787	1.0240	1.4490	1.4055	1.1920	.9492	1.2018	1.0050
7	1.1648	1.0816	.7462	.8350	1.6051	.9040	1.1594	1.3729	.9561	1.2196	1.0021	.9219
8	.8891	1.2307	.6522	2.2279	1.7435	1.0059	1.9788	1.0660	1.3319	1.5773	1.1892	1.0399
9	2.3451	1.4816	.7125	.3875	.7200	.5298	.7625	.7520	.7679	1.2567	2.1840	1.2015
10	1.2000	1.2015	1.2000	1.2000	1.2000	1.2000	1.2000	1.2000	1.2000	1.2000	1.2000	1.2000
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 2)	.9655	.9256	1.0616	.6904	.5734	.6382	.6181	.5139	.4992	.6506	.7828	.2651

STOCK NUMBERS WHITING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	3044045.	5933800.	3826817.	3870625.	4177611.	4515160.	4217336.	2064734.	1806454.	1577548.	3728886.	4550864.
2	1991672.	880858.	2163547.	1330390.	1026771.	1389390.	1331502.	1509254.	524989.	527652.	445349.	1444[illegible].
3	412641.	514915.	269462.	524872.	511431.	445978.	543276.	573819.	699171.	245308.	209235.	175062.
4	59997.	97641.	126481.	54723.	149460.	178997.	141114.	172883.	190943.	295147.	94391.	58009.
5	8422.	16974.	25431.	31200.	14857.	46860.	64031.	38271.	48148.	69710.	105181.	22624.
6	1576.	2280.	4669.	8795.	10330.	5498.	14160.	15429.	10430.	15962.	21901.	30202.
7	9253.	170.	683.	1044.	2455.	2530.	1568.	2643.	3002.	2498.	4624.	5251.
8	654.	2364.	47.	267.	371.	404.	839.	95.	548.	945.	604.	1390.
9	63.	220.	565.	20.	24.	53.	121.	114.	114.	116.	195.	151.
10	29.	7.	54.	301.	15.	12.	34.	61.	49.	57.	37.	24.
TOTAL STOCK BIOMASS ON 1. JANUARY	481606.	488693.	527190.	460843.	455848.	519691.	519973.	465365.	365879.	303905.	523556.	458249.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 2)	362888.	256975.	378061.	309889.	292921.	343600.	355496.	384841.	295427.	242381.	177930.	200765.

PREDATION MORTALITY WHITING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	1.7239	1.8158	1.5881	1.7378	1.7816	1.6689	2.4805	1.6813	1.5793	1.0092	1.7232	2.0498
1	.5235	.4981	.3668	.3683	.4590	.4645	.4434	.7117	.5112	.4885	.3221	.3651
2	.1446	.1027	.1119	.1112	.1220	.1130	.1164	.1578	.1464	.1367	.0925	.0859
3	.1039	.0725	.0715	.0754	.0744	.0724	.0740	.0888	.0954	.0881	.0591	.0469
4	.0574	.0369	.0389	.0427	.0424	.0457	.0455	.0567	.0587	.0499	.0359	.0279
5	.0285	.0197	.0235	.0244	.0237	.0257	.0247	.0306	.0347	.0286	.0199	.0161
6	.0246	.0208	.0208	.0212	.0179	.0203	.0196	.0235	.0271	.0216	.0165	.0116
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Table 2.8.1c Annual fishing mortalities, stock numbers in '000, and annual predation mortality for the MSVPA key run. Mortalities are summed over the four quarters, except for the 0-group for which the third and fourth quarters were summed. Last age group is a plus group.

FISHING MORTALITY

SAITHE

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0084	.0004	.0026	.0869	.0041	.0046	.0105	.0299	.0044	.0004	.0005	.0020
2	.0650	.1570	.1846	.1572	.1490	.2585	.1344	.1657	.1923	.1211	.1185	.0230
3	.4496	.3857	.2573	.1816	.2675	.2099	.2925	.1506	.3690	.3006	.4772	.2184
4	.5102	.7743	.8113	.5541	.5414	.4109	.3010	.3514	.4586	.5164	.8070	.7102
5	.3652	.7008	.9184	.9765	.5685	.4767	.5846	.3355	.8097	.7195	.7130	.7717
6	.5952	.5334	.7028	.7014	.4488	.3765	.5819	.5897	.5922	1.0318	.9250	.6816
7	.6702	.5296	.5761	.5727	.4888	.4784	.5300	.5658	.5529	1.0986	.9868	.4495
8	.4865	.5242	.5898	.4643	.2826	.3985	.4140	.8206	.5217	.9297	.8804	1.0921
9	.4200	.2725	.3878	.3431	.2666	.2303	.4627	.5206	.6686	.7666	.4921	.4516
10	.3754	.2658	.3919	.2699	.2496	.1797	.3552	.4606	.4810	.4241	.3550	.2708
11	.3416	.2102	.4302	.1960	.2572	.2334	.3497	.5707	.3339	.6491	.2447	.2282
12	.3604	.3651	.5212	.4758	.2323	.2518	.2320	.7036	.4011	.3681	.5148	.2421
13	.6320	.4149	.4488	.3911	.5434	.1309	.2694	.5050	.4588	.5160	.2517	.3005
14	.3096	.4015	.5969	.5892	.4290	.2648	.1887	.6009	.5248	.3308	.5017	.2994
15	.2825	.3001	.3000	.3001	.3000	.3000	.3004	.2999	.3001	.2999	.3001	.3001

MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 5)

	.5201	.5644	.7109	.7346	.4811	.4120	.5338	.4859	.6658	.7841	.8057	.6829

STOCK NUMBERS

SAITHE

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	480205.	190487.	120198.	127488.	113508.	261450.	160776.	198635.	393825.	417695.	259785.	184975.
2	265214.	389859.	155392.	98159.	95692.	92552.	213073.	130257.	157856.	321011.	341825.	212611.
3	183946.	203877.	272823.	106124.	68678.	67504.	58516.	152515.	90357.	106622.	232857.	248651.
4	87355.	96069.	113728.	106856.	72461.	43033.	44804.	35760.	107415.	51148.	64630.	118293.
5	44607.	42941.	56261.	41370.	50266.	34525.	23362.	27148.	21020.	55597.	24986.	23610.
6	50395.	25549.	17444.	11850.	12756.	23309.	17543.	10660.	15892.	7658.	22168.	9977.
7	32590.	22754.	12174.	7073.	4811.	5667.	13097.	8029.	4840.	7196.	2254.	7197.
8	14326.	13651.	10969.	5602.	3989.	2951.	3383.	6311.	3733.	2279.	1984.	692.
9	4568.	7211.	6617.	4980.	2883.	2462.	1622.	1831.	2274.	1814.	757.	667.
10	2850.	2457.	4495.	3676.	2395.	1808.	1601.	836.	891.	954.	690.	369.
11	1563.	1606.	1542.	2487.	2298.	1845.	1237.	919.	432.	491.	511.	396.
12	805.	909.	1066.	821.	1674.	1455.	1196.	714.	425.	253.	193.	328.
13	295.	460.	517.	518.	418.	1086.	926.	777.	289.	233.	143.	94.
14	124.	121.	249.	270.	287.	199.	780.	579.	385.	150.	114.	93.
15	121.	189.	169.	258.	312.	389.	317.	1345.	661.	473.	224.	143.

TOTAL STOCK BIOMASS ON 1. JANUARY

	799595.	748078.	764232.	495447.	412135.	367256.	362987.	389844.	411702.	421491.	490094.	519372.

SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 5)

	470940.	374746.	501184.	245157.	238486.	230755.	209752.	189765.	154307.	193358.	145751.	116364.

No predation mortality on saithe.

Table 2.8.1d Annual fishing mortalities, stock numbers in '000, and annual predation mortality for the MSVPA key run. Mortalities are summed over the four quarters, except for the 0-group for which the third and fourth quarters were summed. Last age group is a plus group.

MACKEREL

FISHING MORTALITY

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000
1	.7437	.0251	.0104	.0080	.0000	.0244	.0200	.0204	.0130	.0077	.0061	.0180
2	.8085	.0295	.1992	.0901	.0687	.0261	.0730	.0527	.0925	.0900	.1689	.2702
3	.8558	.1372	.2694	.2281	.2185	.1212	.1453	.1965	.1783	.2559	.5168	.7113
4	.7939	.2111	.1569	.1475	.2301	.1907	.2124	.0881	.2408	.2795	.5794	.9838
5	.8966	.1784	.2429	.3264	.2610	.2819	.3194	.2703	.2114	.2516	.5988	.7708
6	.9050	.2870	.1715	.2878	.1210	.1958	.3530	.3845	.2528	.1565	.6456	.9652
7	.8898	.1759	.2677	.4314	.0367	.1108	.3171	.4082	.2734	.2739	.7110	1.0011
8	1.0768	.4229	.3134	.4726	.3851	.1759	.3216	.3473	.3189	.3781	.4595	1.7599
9	.9197	.2713	.5571	.2931	.1699	.2668	.4212	.3279	.2809	.2994	.5452	1.4342
10	.5962	.3785	.4699	.5174	.2668	.3302	.1614	.3875	.2897	.3665	.5639	1.1165
11	.1767	.1914	.3890	.6721	.0867	.2380	.2967	.1346	.3083	.2672	.4684	1.0092
12	.3403	.0595	.2143	.3752	.1358	.4075	.4097	.5412	.1839	.4693	.4503	1.3878
13	.3158	.0620	.0724	.1536	.4120	.2897	.2347	.3196	.4367	.1318	.5346	1.7469
14	.0758	.1005	.0895	.0337	.1582	.6391	.7945	.4108	.5504	.8826	.1255	2.0625
15	.6684	.3602	.2535	.4059	.5713	.2927	1.4402		.4108	.7472	.6811	2.0661

MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 3)

	.8658	.2499	.2519	.3577	.2445	.2083	.3037	.3429	.2582	.3052	.5434	.8988

MACKEREL

STOCK NUMBERS

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	955589.	536541.	289514.	158546.	87230.	104986.	151609.	211340.	255297.	24956.	4661.	410973.
2	567626.	390161.	450375.	246427.	135374.	23437.	88188.	127915.	178232.	216897.	21299.	3987.
3	666083.	140972.	326115.	317638.	193832.	108781.	19653.	70559.	104441.	139859.	170619.	15434.
4	487928.	248554.	105778.	214409.	217641.	134091.	82943.	14628.	49894.	75213.	93387.	87594.
5	2459814.	189865.	173215.	77822.	133156.	148825.	95372.	57731.	11529.	33755.	48963.	45051.
6	508598.	863747.	136722.	116941.	57678.	98284.	96625.	59645.	37920.	8033.	22591.	23390.
7	186619.	177094.	557940.	99131.	75477.	43984.	62472.	58428.	34951.	25346.	5913.	10195.
8	190686.	65976.	127838.	367441.	55427.	62621.	33888.	39158.	33436.	22886.	16589.	2500.
9	93809.	55917.	57202.	80265.	24411.	32525.	45206.	21146.	25534.	20920.	13524.	9020.
10	21393.	32186.	32961.	24411.	19814.	126584.	26103.	83439.	19119.	15478.	13347.	6761.
11	10219.	10143.	22876.	8226.	15892.	39576.	20505.	12561.	53380.	13112.	9234.	6536.
12	9504.	7371.	8226.	6561.	9599.	13133.	10365.	7032.	7178.	14917.	8447.	4975.
13	10329.	5786.	5962.	4963.	4843.	8708.	6557.	3755.	4786.	14383.	9435.	3565.
14	39099.	6496.	4503.	4968.	8045.	6557.	5358.	9672.	2142.	10300.	5078.	3053.
15	181761.	78215.	15406.	8312.		9948.	9672.		4336.	14873.	7770.	2561.
TOTAL STOCK BIOMASS ON 1. JANUARY										9383.	9383.	6621.
	1951831.	869265.	1265429.	589873.	425552.	554941.	280173.	230144.	209929.	193996.	153519.	118805.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 3)												
	1796504.	742457.	1005455.	524207.	394048.	321503.	249084.	185736.	151185.	145300.	148567.	85070.

No predation mortality on mackerel.

Table 2.8.1e Annual fishing mortalities, stock numbers in '000, and annual predation mortality for the MSVPA key run. Mortalities are summed over the four quarters, except for the 0-group for which the third and fourth quarters were summed. Last age group is a plus group.

FISHING MORTALITY HADDOCK

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.0182	.0210	.0247	.0199	.0281	.0443	.0595	.0625	.0405	.0540	.0115	.0126
1	.3967	.3777	.3572	.3402	.5525	.1766	.2351	.2055	.2575	.2398	.2208	.3142
2	.9124	1.0213	.8382	.9905	.8270	1.0022	.7988	.4603	.4521	.6719	.7566	.8750
3	.9345	1.2856	1.4145	1.0407	1.0980	1.4732	1.2178	.9242	.8211	1.0565	.9901	1.3593
4	.9867	1.1256	.7986	1.2792	1.1133	1.1142	1.1964	1.0098	.8812	1.1442	1.1322	1.3065
5	.7045	1.0274	1.3817	1.0587	1.1186	.9770	.9478	.7855	.6319	1.2594	1.1650	1.1272
6	.9452	.6705	1.1575	1.0559	1.0422	1.0524	.9545	.5121	.7437	.8759	1.0886	1.0080
7	1.1363	1.3376	.3553	.9249	1.1366	.5694	1.0119	.8914	.9092	.7505	.8581	.9900
8	.7418	1.1602	1.2176	.4773	.6688	1.0226	.6231	.6707	.9317	.5311	.5056	.8604
9	.2758	.8873	.4773	.9881	.2402	.5595	1.5078	.9121	.2540	.5363	.5444	.8274
10	1.1548	2.5651	5.0570	.9000	.9000	.3795	.8792	.9101	.5825	.9687	.6908	.9000
11	.9000	.9000	.9000	.9000	.9000	.9000	.9000	.9000	.9000	.9000	.9300	.9000
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 2)	.9340	1.0435	.9159	1.0442	.9497	1.0715	.8548	.5386	.7093	.8551	.8798	.9352

STOCK NUMBERS HADDOCK

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	9371676.	16404568.	1485310.	2223358.	4446688.	5075810.	8335878.	2183152.	3571759.	1931730.	5864784.	2924902.
2	353875.	1286649.	2246165.	200663.	310516.	456981.	845839.	1423944.	302185.	599814.	370522.	1233135.
3	603821.	91684.	308695.	645473.	49020.	89659.	110503.	252034.	579478.	124636.	202446.	118569.
4	93198.	178674.	19270.	57150.	172949.	12445.	15675.	24890.	75987.	193315.	52095.	57770.
5	5944.	27572.	46159.	6899.	12651.	45304.	3256.	3775.	7233.	25031.	49033.	8487.
6	2344.	1586.	8035.	9436.	1948.	3368.	13898.	1028.	1403.	3132.	5787.	12477.
7	16916.	746.	664.	2067.	2687.	562.	963.	4381.	504.	546.	1070.	1595.
8	491.	4446.	160.	381.	671.	706.	261.	286.	1471.	166.	210.	371.
9	99.	192.	1141.	69.	210.	277.	208.	114.	120.	474.	80.	104.
10	51.	62.	65.	276.	55.	88.	130.	38.	58.	76.	227.	38.
11	15.	20.	6.	4.	126.	34.	74.	66.	19.	26.	55.	155.
TOTAL STOCK BIOMASS ON 1. JANUARY	882121.	1309779.	640371.	446900.	432983.	446056.	687481.	508088.	518369.	396351.	530518.	495169.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 2)	366678.	407528.	598679.	324615.	188415.	166886.	229008.	388015.	321922.	290106.	207955.	332299.

PREDATION MORTALITY HADDOCK

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.9360	1.2357	1.2531	1.2348	1.2537	1.0997	1.5236	1.5917	1.4480	1.0204	1.0991	1.4296
1	1.0692	1.0908	1.1247	1.1085	1.2030	1.0958	1.0129	1.2520	1.0267	.8915	.8186	1.0391
2	.1282	.0962	.0988	.1089	.1052	.1074	.1020	.1287	.1235	.1043	.0728	.0592
3	.0432	.0342	.0342	.0363	.0339	.0307	.0328	.0348	.0367	.0352	.0259	.0193
4	.0212	.0179	.0186	.0187	.0164	.0166	.0173	.0161	.0193	.0176	.0129	.0100
5	.0066	.0059	.0061	.0058	.0050	.0047	.0055	.0044	.0050	.0050	.0036	.0050
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Table 2.8.1f Annual fishing mortalities, stock numbers in '000, and annual predation mortality for the MSVPA key run. Mortalities are summed over the four quarters, except for the 0-group for which the third and fourth quarters were summed. Last age group is a plus group.

FISHING MORTALITY HERRING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.0855	.0860	.1353	.1005	.0346	.0558	.0512	.3099	.2556	.3930	.0945	.0365
1	.4699	.7646	.2687	.1837	.1815	.3504	.0746	.1732	.2304	.1536	.0805	.1848
2	1.0520	1.2513	1.3301	.1537	.0184	.0791	.2648	.2897	.1832	.2364	.2041	.3169
3	.8114	1.5688	1.3542	1.1371	.0331	.0552	.4704	.2191	.4341	.2705	.3095	.4301
4	.8935	1.5266	1.1908	.3814	.0411	.0597	.3804	.2005	.5234	.3575	.4139	.4150
5	.7846	2.0950	1.4927	.5942	.0142	.0185	.4360	.3265	.1682	.2348	.4263	.4150
6	1.0589	1.8805	1.8967	.5801	.0078	.0000	.0397	.3520	.1614	.2783	.2915	.4117
7	.7084	2.1436	2.1100	1.4756	.0000	.0093	.8088	.6010	.2223	.3247	.4577	.4100
8	.9796	1.9685	2.4310	.8847	.0000	.0000	1.6698	2.2448	.2575	.3875	.4334	.4102
9	1.0005	1.0004	1.0004	.8003	.0004	.0002	.0000	.3000	.3001	.3002	.3201	.4101
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 3)	.8441	1.5815	1.3809	.9954	.0518	.0477	.4183	.2820	.3594	.2909	.3450	.4244

STOCK NUMBERS HERRING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	3796879.	6254210.	1254369.	926189.	1787253.	2244697.	3775430.	7133948.	10240670.	17028216.	11652352.	10043894.
2	1950765.	830809.	1366341.	362582.	326048.	574850.	588836.	1346568.	1697114.	3127421.	5804872.	8318590.
3	794565.	421820.	186718.	285035.	242831.	249651.	412769.	353126.	775405.	1095741.	1939945.	3738271.
4	429232.	271017.	85015.	37772.	69656.	182247.	179868.	199107.	209262.	380166.	588391.	1143882.
5	176859.	153852.	51775.	22646.	22595.	58598.	150735.	107857.	142676.	132964.	233858.	369366.
6	56751.	46685.	16654.	10198.	13366.	19532.	50573.	85517.	68056.	105941.	92647.	135554.
7	15869.	18050.	6362.	2225.	5076.	11809.	17441.	43167.	53330.	51455.	71415.	82346.
8	5525.	6130.	1915.	698.	460.	4595.	10587.	7029.	21415.	38658.	33547.	40676.
9	3342.	1795.	1170.	190.	2729.	4366.	43657.	5471.	2044.	45416.	6915.	49397.
TOTAL STOCK BIOMASS ON 1. JANUARY	547598.	262108.	163905.	82621.	91543.	141517.	210126.	297760.	418807.	686204.	982454.	1511455.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 3)	185728.	124747.	46611.	44313.	45643.	71467.	120658.	111160.	166635.	247309.	407240.	714[illegible].

PREDATION MORTALITY HERRING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.3490	.4275	.4758	.4755	.5033	.4819	.7008	.5654	.4840	.3554	.4726	.4569
1	.6997	.4066	.6069	.5104	.6030	.6380	.6071	.9127	.6058	.5726	.5558	.5777
2	.0400	.0315	.0342	.0372	.0388	.0421	.0365	.0522	.0443	.0352	.0265	.0231
3	.1220	.0929	.1059	.1249	.1139	.1347	.1187	.1642	.1387	.0958	.0744	.0541
4	.0125	.0109	.0121	.0125	.0118	.0102	.0110	.0128	.0102	.0085	.0059	.0046
5	.0229	.0196	.0220	.0231	.0215	.0188	.0208	.0240	.0195	.0161	.0104	.0088
6	.0215	.0127	.0150	.0177	.0160	.0133	.0187	.0202	.0183	.0162	.0092	.0084
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Table 2.8.1g Annual fishing mortalities, stock numbers in '000, and annual predation mortality for the MSVPA key run. Mortalities are summed over the four quarters, except for the 0-group for which the third and fourth quarters were summed. Last age group is a plus group.

FISHING MORTALITY SPRAT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.0068	.0020	.0156	.0063	.0022	.0031	.0063	.0072	.0018	.0028	.0045	.0010
1	.1071	.2663	.2953	.1829	.5447	.3966	.4101	.4775	.7118	.5929	.4289	.2664
2	.5095	.6554	.7594	.6627	.6093	.8359	.8674	1.3718	1.1994	1.1779	.5290	.9102
3	1.0725	1.3466	2.4966	.7534	2.6695	2.3196	2.5053	1.0937	2.0735	1.9609	2.6077	1.1249
4	3.0416	2.0047	2.7246	4.6002	1.4933	1.9141	2.0789	.5099	.6374	2.1943	2.2235	1.0457

MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 2)

	.5553	.7328	1.2666	.6757	.9314	1.0217	.9285	1.3410	1.2320	1.2785	.7225	.9185

STOCK NUMBERS SPRAT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	368640896.	197078656.	286565584.	151288512.	147396192.	249979944.	115863008.	69490112.	34415840.	23108800.	41526024.	30470260.
2	45007848.	103070576.	44844704.	60142912.	38798456.	25815608.	50666216.	20392028.	12932436.	5713669.	4644158.	8035628.
3	2357889.	6669402.	9841790.	3732090.	6887196.	3533541.	1836448.	2257339.	779267.	777014.	430505.	304677.
4	337977.	423487.	547147.	141698.	941627.	234964.	167448.	83917.	393717.	48400.	55350.	16822.

TOTAL STOCK BIOMASS ON 1. JANUARY

	1405574.	1479034.	1300454.	996699.	838827.	943567.	755158.	589391.	218259.	121696.	157574.	152417.

SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 2)

	408245.	946921.	526732.	588220.	440858.	268645.	442328.	201768.	125336.	59302.	45454.	70147.

PREDATION MORTALITY SPRAT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.0207	.0321	.0296	.0289	.0326	.0322	.0469	.0289	.0293	.0198	.0471	.0590
1	.5474	.5942	.5662	.5580	.5775	.5795	.7075	.5840	.4639	.3917	.5935	.8256
2	.8799	1.1757	1.2070	1.0644	1.2671	1.2874	1.7242	1.3728	1.0926	.8877	1.6745	2.3138
3	.2454	.2521	.2986	.2692	.3187	.3207	.3794	.4479	.3089	.2717	.2764	.4375
4	.2553	.3487	.4127	.3721	.4531	.4755	.6893	.5605	.4381	.3095	.5411	.9374

Table 2.8.1h Annual fishing mortalities, stock numbers in '000, and annual predation mortality for the MSVPA key run. Mortalities are summed over the four quarters, except for the 0-group for which the third and fourth quarters were summed. Last age group is a plus group.

FISHING MORTALITY NORWAY POUT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.0394	.0550	.0382	.0199	.0125	.0125	.0121	.2184	.0097	.0296	.0166	.0101
1	.9660	.6525	.5941	.5437	.4146	.4796	.6308	.4819	.5309	.5266	.6459	.2685
2	3.0609	1.4580	1.7496	1.0175	1.5021	1.6104	2.1142	1.2693	1.7559	1.4775	1.3642	1.0876
3	2.3164	1.0879	.9497	.9980	2.0475	2.1374	.7288	2.0639	.8423	.7168	1.3918	.5261
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 1)												
	.9997	.6953	.6369	.5710	.5452	.5460	.7564	.6359	.5592	.6178	.7936	.5134

STOCK NUMBERS NORWAY POUT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	188980224.	124352368.	147182304.	126324560.	68630080.	92032352.	98669904.	43953128.	118575360.	96797184.	77606430.	106726480.
2	2769621.	6963509.	5530287.	7459011.	8148806.	5020298.	9138618.	9816040.	2652667.	10251026.	10377652.	5986986.
3	509375.	372220.	484841.	293090.	779046.	480819.	360483.	583687.	823205.	175129.	851840.	746520.
TOTAL STOCK BIOMASS ON 1. JANUARY												
	1523561.	1112573.	1270569.	1149901.	748250.	839123.	982531.	583780.	998881.	986988.	872575.	984965.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 1)												
	1523561.	1112573.	1270569.	1149901.	748250.	839123.	982531.	583780.	998881.	986988.	872575.	984965.

PREDATION MORTALITY NORWAY POUT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.6756	.6350	.5885	.5108	.4387	.3566	.4221	.4567	.3866	.3142	.4556	.4576
1	1.8155	1.9409	1.8686	1.6777	1.6811	1.3105	1.1580	1.8056	1.5972	1.1864	1.3981	1.5505
2	.8846	.8617	.8414	.8019	.8904	.7595	.6191	.8984	.7125	.6581	.5507	.5837
3	.6456	.6464	.6402	.6034	.7068	.5691	.4306	.6498	.5385	.4734	.4086	.4585

Table 2.8.1i Annual mortalities, stock numbers in '000, and annual predation mortality for the MSVPA key run. Mortalities are summed over the four quarters, except for the 0-group for which the third and fourth quarters were summed. Last age group is a plus group.

FISHING MORTALITY SANDEEL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.0135	.0187	.0201	.0373	.0386	.1089	.0694	.1195	.1612	.0367	.0930	.1188
1	.2522	.1736	.2995	.4025	.5280	.2789	.5339	.4042	.3987	.2431	.4930	.5606
2	.1868	.3858	.5742	.5316	.8047	.9976	.8426	.9161	.8956	.8655	.2688	1.1342
3	.1224	.5792	.4344	.9031	.4526	.7922	1.0610	.5747	1.2464	.6597	1.9705	1.0208
4	.6005	.3050	.6211	.5350	.5784	.7305	.6167	.9432	1.3566	.5711	.4900	1.0512
5	.5409	.7521	.2110	.9951	.2785	.9697	.5643	1.1322	.9565	.5285	.4616	1.0065
6	.8768	.6903	.7194	.9699	.8962	.8506	1.0164	.8086	.8183	.8152	.6310	.4745
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 2)												
	.2233	.4320	.5511	.6472	.7354	.9521	.8638	.8554	1.0262	.8469	.9451	1.1166

STOCK NUMBERS SANDEEL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	428137024.	394567872.	255458400.	297739648.	345027264.	242938176.	268846272.	127640352.	537263232.	99671984.	378515200.	276507840.
2	54976192.	37886424.	64033104.	52566748.	49768528.	55577176.	51128272.	42653312.	21527652.	89425008.	27915236.	86871056.
3	10012530.	12243716.	10296264.	13924722.	8624812.	10788554.	10453706.	10647224.	7782836.	4531842.	19390892.	11755598.
4	6470305.	5261514.	4165999.	3918982.	3458498.	5418555.	5072987.	4208625.	3519150.	1389750.	1471304.	1707583.
5	1131565.	1699659.	1922676.	1356033.	1126271.	994720.	858781.	800939.	579996.	456516.	510847.	495145.
6	276050.	262509.	489677.	882154.	258596.	622606.	270428.	370070.	179519.	115380.	234026.	313269.
TOTAL STOCK BIOMASS ON 1. JANUARY												
	2517565.	2247664.	1843155.	1911629.	2059707.	1762741.	1797847.	1149377.	1728702.	1382580.	2088287.	1195690.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 2)												
	847629.	708849.	924867.	650445.	721901.	815282.	749346.	651579.	413375.	993859.	612858.	1087931.

PREDATION MORTALITY SANDEEL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	.8716	.8415	.0862	.4855	.4781	.3967	.5350	.3284	.5654	.2918	.5159	.5085
1	1.7837	1.2550	1.2892	.9967	.9024	.8902	.9174	.9857	.5388	.6596	.5885	1.1874
2	.9155	.5365	.5716	.4172	.3443	.2954	.3466	.4051	.2826	.2851	.2160	.3245
3	.1611	.1427	.1716	.1356	.1128	.1057	.1317	.1724	.1164	.1055	.0992	.1504
4	.3864	.3517	.4201	.3620	.3120	.3012	.3781	.4667	.3558	.2797	.2590	.3964
5	.9129	.4738	.4858	.3411	.2753	.2485	.2407	.3378	.2244	.2257	.1959	.2699
6	.5284	.2677	.2690	.2246	.1889	.1962	.1785	.2318	.1891	.1527	.1209	.1306

Table 2.8.2a Mean values of fishing mortality, natural mortality (total), and stock size ('000 t) at age from the "Key run" for 1978-1982. The last entry for each species is a + group. Stock numbers on 1 January (0-group 1 July).

Age	Fishing mortality	Natural mortality	Numbers	Fishing mortality	Natural mortality	Numbers
		Cod			Whiting	
0	0.00	1.558	2,044,968	0.47	2.568	35,838,184
1	0.18	0.758	515,745	0.22	0.968	3,356,259
2	0.99	0.361	218,572	0.43	0.402	1,156,381
3	1.04	0.226	54,918	0.73	0.331	554,735
4	0.72	0.200	15,027	0.87	0.290	166,679
5	0.75	0.200	5,931	0.97	0.248	42,433
6	0.68	0.200	2,234	1.25	0.332	11,169
7	0.72	0.200	840	1.20	0.200	2,440
8	0.70	0.200	423	1.43	0.200	513
9	0.78	0.200	180	0.71	0.200	81
10	0.76	0.200	70	1.20	0.200	34
11	0.82	0.200	52	-	-	-
		Haddock			Herring	
0	0.05	2.113	30,909,124	0.14	1.067	27,418,988
1	0.28	1.638	4,722,657	0.20	1.023	5,036,395
2	0.71	0.423	667,893	0.17	0.253	906,683
3	1.11	0.274	216,139	0.24	0.274	406,757
4	1.06	0.227	60,389	0.20	0.131	168,028
5	0.89	0.205	14,444	0.19	0.131	96,492
6	0.86	0.200	4,329	0.11	0.117	47,409
7	0.90	0.200	1,219	0.33	0.100	26,164
8	0.79	0.200	679	0.83	0.100	8,817
9	0.78	0.200	186	0.12	0.100	11,653
10	0.60	0.200	66	-	-	-
11	0.90	0.200	64	-	-	-

Table 2.8.2b Mean values of fishing mortality, natural mortality (total), and stock size ('000 t) at age from the "Key run" for 1978-1982. The last entry for each species is a + group. Stock numbers on 1 January (0-group 1 July).

Age	Fishing mortality	Natural mortality	Numbers	Fishing mortality	Natural mortality	Numbers
		Saithe			Mackerel	
0	0.00	0.100	316,605	0.00	0.075	161,288
1	0.11	0.200	225,639	0.16	0.150	150,092
2	0.18	0.200	137,882	0.63	0.150	110,629
3	0.26	0.200	87,514	0.17	0.150	99,453
4	0.41	0.200	60,694	0.19	0.150	99,6
5	0.56	0.200	31,264	0.27	0.150	89,32
6	0.52	0.200	16,033	0.26	0.150	68,030
7	0.48	0.200	7,489	0.23	0.150	55,063
8	0.49	0.200	4,073	0.31	0.150	44,906
9	0.43	0.200	2,214	0.28	0.150	63,969
10	0.35	0.200	1,606	0.32	0.150	46,182
11	0.35	0.200	1,346	0.23	0.150	20,183
12	0.36	0.200	1,093	0.30	0.150	19,880
13	0.38	0.200	699	0.36	0.150	11,381
14	0.40	0.200	446	0.49	0.150	4,646
15	0.30	0.200	605	0.60	0.150	6,829

Table 2.8.2c Mean values of fishing mortality, natural mortality (total), and stock size ('000 t) at age from the "Key run" for 1978-1982. The last entry for each species is a + group. Stock numbers on 1 January (0-group 1 July).

Age	Fishing mortality	Natural mortality	Numbers	Fishing mortality	Natural mortality	Numbers
		Sprat			Norway pout	
0	0.004	0.764	192,137,632	0.05	0.972	231,859,
1	0.51	1.202	123,427,216	0.51	1.991	84,372,
2	0.98	1.869	29,720,952	1.65	1.256	6,955,284
3	2.13	0.805	3,058,758	1.56	1.029	565,448
4	1.33	0.903	364,335	-	-	-
		Sandeel				
0	0.10	0.831	486,235,648			
1	0.43	1.237	263,943,040			
2	0.89	0.715	44,130,976			
3	0.83	0.487	9,655,426			
4	0.85	0.709	3,131,559			
5	0.78	0.595	832,142			
6	0.88	0.527	340,244			

Table 2.8.3 The mean of the ratio between numbers in the MSVPA and the single-species VPAs for the years 1974-1985 for cod, haddock, whiting, and herring.

Age	Cod	Haddock	Whiting	Herring
1	1.01	1.40	1.04	1.49
2	1.04	1.12	0.98	1.33
3	0.99	1.06	1.00	1.24
4	0.99	1.00	1.01	1.21
5	0.98	0.99	0.97	1.25
6	0.96	0.97	1.01	1.44
7	0.96	0.96	1.09	1.51
8	0.95	0.94	1.19	1.21

Table 2.9.1 Parameter sets used for MSVPA sensitivity analysis.

Parameter	Other food	All M1	Cod ration	Whiting ration	Saithe ration	Mackerel ration	Haddock ration
Parameter deviations	3,000,000	0.1	0.1	0.1	0.1	0.1	0.1
MSVPA no.							
1	1	1	-1	1	-1	-1	1
2	1	-1	1	-1	1	-1	1
3	-1	1	1	1	1	-1	-1
4	-1	1	1	-1	-1	1	1
5	1	-1	1	1	-1	1	-1
6	1	1	-1	-1	1	1	-1
7	-1	-1	-1	1	1	1	1
8	-1	-1	-1	-1	-1	-1	-1
9	1	1	1	1	1	1	1
10	-1	-1	1	-1	1	1	-1
11	-1	1	-1	1	-1	1	-1
12	1	-1	-1	-1	-1	1	1
13	1	-1	-1	1	1	-1	-1
14	-1	1	-1	-1	1	-1	1
15	-1	-1	1	1	-1	-1	1
16	1	1	1	-1	-1	-1	-1

Table 3.2.1 Values of natural mortality used in North Sea haddock assessments for variable M at age. Value for age 0 for half year.

Age	M(a)	M(b)
0	2.05	2.64
1	1.45	1.64
2	0.35	0.42
3	0.25	0.27
4	0.25	0.23
5	0.20	0.20
6	0.20	0.20
7	0.20	0.20
8	0.20	0.20
9	0.20	0.20
10	0.20	0.20
11	0.20	0.20

M(a) = values used by North Sea Roundfish Working Group.

M(b) = values from this meeting used in Table 3.2.4.

Table 3.2.2 Values of KRATIO in North Sea haddock for two assumptions on M (constant and variable) for the three last data years (1975, 1980, and 1985).

Age	1975		1980		1985	
	Constant	Variable	Constant	Variable	Constant	Variable
0	2.3306	2.2295	2.4536	2.5043	0.5472	0.5388
1	0.5501	0.5257	0.5256	0.5254	0.8387	0.847
2	0.4646	0.4653	0.3318	0.3324	0.5892	0.590
3	0.2113	0.2124	0.2050	0.2058	0.2191	0.2205
4	0.2287	0.2290	0.1884	0.1890	0.2111	0.2114
5	0.3576	0.3576	0.1911	0.1911	0.2469	0.2469
6	0.1969	0.1969	0.2733	0.2433	0.3028	0.3028
7	0.1668	0.1668	0.3234	0.3234	0.2832	0.2832

0.8428
0.5900
0.2205

Table 3.2.3 Values of KRATIO in North Sea haddock for two assumptions on M(constant and variable) for 1985 and ages 0 and 1. The IYFS was used to tune the VPA.

Age	Regression		Mean IYFS/VPA	
	Constant	Variable	Constant	Variable
0	3.3450	3.3673	3.0237	3.0441
1	0.8460	0.4741	0.4828	0.5622

Table 3.2.4 Catch predictions for North Sea haddock under three assumptions about M. Prediction in '000 t. Values of M are given in Table 3.2.1.

Choice of M	Fishery	Prediction year	
		1986	1987
M = 0.2	Human consumption	117	149
	Discards	80	131
	Industrial by-catch	6	8
M (a)	Human consumption	116	135
	Discards	74	118
	Industrial by-catch	8	10
M (b)	Human consumption	119	134
	Discards	76	121
	Industrial by-catch	8	10

Table 4.3.1 Table of recruitment values used in the forecast runs.

Species	Assumed recruitment x 10^9
Cod	1.742
Whiting	36.900
Saithe	0.248
Mackerel	0.190
Haddock	32.380
Herring	49.700
Sprat	256.400
Norway pout	276.100
Sandeel	680.000

Table 4.3.2 Parameter estimates from model fit to Ln(M2 per unit biomass).

Prey	Predator				
	Cod	Whiting	Saithe	Mackerel	Haddock
	Multiplicative model parameter estimate				
Cod	2.414	3.009	-	-0.012	-
Whiting	1.905	3.974	-2.133	-2.994	-1.947
Haddock	2.191	4.028	-0.308	-0.337	-1.594
Herring	1.265	3.192	-2.317	-1.380	-2.935
Sprat	1.276	2.506	-3.034	-1.935	-4.500
Norway pout	1.051	2.570	0.860	-0.131	-1.398
Sandeel	1.374	1.946	-3.340	-1.277	-2.150
	Relative values for preference				
Cod	0.2255982	0.3809832	0.4704419	0.1849581	0.2256763
Whiting	0.1356063	1.0000000	0.0557386	0.0093758	0.0322044
Haddock	0.1805045	1.0554850	0.3457350	0.1336373	0.0458375
Herring	0.0715042	0.4574901	0.0463709	0.0470932	0.0119903
Sprat	0.0722950	0.2303858	0.0226390	0.0270349	0.0025070
Norway pout	0.0577288	0.2456125	1.1117300	0.1642073	0.0557625
Sandeel	0.0797387	0.1315985	0.0166710	0.0522025	0.0262877

Overall predation mortality (uncorrected) = 2.0 per megatonne

Wt. ratio estimates

Multiplicative model parameters:

LWRSQ = 0.198
LWR(COD) = 1.555
LWR(WHI) = 1.537
LWR(SAI) = 2.217
LWR(MAC) = 2.045
LWR(HAD) = 2.081

Conversions to size-preference function:

MU(COD) = 3.923
MU(WHI) = 3.877
MU(SAI) = 5.593
MU(MAC) = 5.161
MU(HAD) = 5.251
S.D. = 1.589

Table 4.4.1 COMPARISON OF PREDATION MORTALITIES FORM THE MSVPA AND MULTIPLICATIVE FORECAST MODELS

SPECIES	AGE	0	1	2	3	4	5	6	7	8	9	10	11	Total
COD	MULT	.654	.278	.084	.028	.011	.006	.004	.003	.002	.002	.002	.002	1.036
	MSVPA	.868	.348	.091	.016	0	0	0	0	0	0	0	0	1.323
WHITING	MULT	1.301	.631	.326	.222	.164	.132	.119	.102	.092	.074	.003	0	3.166
	MSVPA	1.836	.518	.132	.081	.05	.028	.022	0	0	0	0	0	2.669
HADDOCK	MULT	1.569	.714	.321	.192	.13	.094	.072	.057	.044	.035	.031	.025	3.284
	MSVPA	1.383	1.118	.113	.034	.017	.005	0	0	0	0	0	0	2.670
HERRING	MULT	.635	.392	.269	.152	.136	.129	.128	.113	.104	.099	0	0	2.097
	MSVPA	.547	.673	.043	.134	.011	.021	.017	0	0	0	0	0	1.446
SPRAT	MULT	.343	.657	.548	.47	.39	0	0	0	0	0	0	0	2.408
	MSVPA	.034	.582	1.349	.355	.523	0	0	0	0	0	0	0	2.843
N.POUT	MULT	1.533	2.198	1.708	1.441	0	0	0	0	0	0	0	0	6.880
	MSVPA	.412	1.47	.776	.579	0	0	0	0	0	0	0	0	3.237
S.EEL	MULT	.253	.441	.371	.335	.323	.297	.288	0	0	0	0	0	2.308
	MSVPA	.421	.847	.335	.127	.359	.265	.197	0	0	0	0	0	2.551

Table 4.4.2 Status quo Baseline yield ('000 t) forecasts for the MSVPA Forecast model (top) and the multiplicative steady state model (bottom).

FLEET[1]	COD	WHI	SAI	MAC	HAD	HER	SPR	N.P	AMM
1	235.681	167.56	22.471	0	192.348	0	0	0	0
2	11.142	43.498	2.664	0	48.889	0	0	484.786	1032.475
3	0	7.517	0	0	0	116.427	310.024	0	0
4	0	0	0	0	0	107.206	0	0	0
5	0	0	138.69	0	0	0	0	0	0
6	0	0	0	35.546	0	0	0	0	0
TOTAL	246.823	218.575	163.825	35.546	241.237	223.633	310.024	484.786	1032.475

FLEET	COD	WHI	SAI	MAC	HAD	HER	SPR	N.P	AMM
1	278.76	81.61	25.8	0	85.39	0	0	0	0
2	13.71	51.53	2.2	0	55.16	0	0	172.92	1899.54
3	0	9.56	0	0	0	294.42	273.03	0	0
4	0	0	0	0	0	250.21	0	0	0
5	0	0	144.65	0	0	0	0	0	0
6	0	0	0	37.27	0	0	0	0	0
TOTAL	292.47	142.7	172.65	37.27	140.55	544.63	273.03	172.92	1899.54

[1] 1 = roundfish human consumption, 2 = industrial demersal, 3 = industrial pelagic, 4 = herring, 5 = saithe, and 6 = mackerel.

Table 4.4.3 Percentage changes in yield for each species in each fleet consequent upon a 10% increase in the roundfish human consumption fishery.

- MSVPA FORECAST

FLEET	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1		.67	6.36	6.11	.00	9.32	.00	.00	.00	.00
2		2.16	-.21	-1.01	.00	3.72	.00	.00	4.30	-.02
3		.00	.28	.00	.00	.00	3.18	.21	.00	.00
4		.00	.00	.00	.00	.00	4.12	.00	.00	.00
5		.00	.00	-1.31	.00	.00	.00	.00	.00	.00
6		.00	.00	.00	.00	.00	.00	.00	.00	.00
TOTAL		.74	4.84	-.18	.00	8.18	5.63	.21	4.30	-.02

- MULTIPLICATIVE MODEL FORECAST

FLEET[1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1		.37	5.15	7.95	.00	5.15	.00	.00	.00	.00
2		.44	-.14	-.91	.00	-.50	.00	.00	2.37	.49
3		.00	.21	.00	.00	.00	2.75	.36	.00	.00
4		.00	.00	.00	.00	.00	4.04	.00	.00	.00
5		.00	.00	-1.74	.00	.00	.00	.00	.00	.00
6		.00	.00	.00	.00	.00	.00	.00	.00	.00
TOTAL		.37	2.91	-.28	.00	2.90	3.34	.36	2.37	.49

[1] 1 = roundfish human consumption, 2 = industrial demersal, 3 = industrial pelagic, 4 = herring, 5 = saithe, and 6 = mackerel.

Table 4.4.4 Percentage changes in yield for each species in each fleet consequent upon a 10% increase in the industrial demersal fishery.

- MSVPA FORECAST

FLEET [1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1		-.82	-1.86	-.20	.00	-3.60	.00	.00	.00	.00
2		9.50	8.97	9.83	.00	8.01	.00	.00	2.06	2.13
3		.00	-.44	.00	.00	.00	.12	.00	.00	.00
4		.00	.00	.00	.00	.00	.10	.00	.00	.00
5		.00	.00	-.19	.00	.00	.00	.00	.00	.00
6		.00	.00	.00	.00	.00	.00	.00	.00	.00
TOTAL		-.36	.34	-.03	.00	-1.25	.11	.00	2.06	2.13

- MULTIPLICATIVE MODEL FORECAST

FLEET[1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1		-.37	-1.34	-.19	.00	-1.79	.00	.00	.00	.00
2		9.92	9.61	10.00	.00	9.25	.00	.00	7.59	3.16
3		.00	-.10	.00	.00	.00	.47	.22	.00	.00
4		.00	.00	.00	.00	.00	.60	.00	.00	.00
5		.00	.00	-.18	.00	.00	.00	.00	.00	.00
6		.00	.00	.00	.00	.00	.00	.00	.00	.00
TOTAL		.11	2.70	-.05	.00	2.54	.53	.22	7.59	3.16

[1] 1 = roundfish human consumption, 2 = industrial demersal, 3 = industrial pelagic, 4 = herring, 5 = saithe, and 6 = mackerel.

Table 4.4.5 Percentage changes in yield for each species in each fleet consequent upon a 10% increase in the industrial pelagic fishery.

- MSVPA FORECAST

FLEET[1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1		-.28	-.50	.00	.00	-.73	.00	.00	.00	.00
2		-.26	-.41	.00	.00	-.49	.00	.00	-.27	-.06
3		.00	9.71	.00	.00	.00	4.56	3.73	.00	.00
4		.00	.00	.00	.00	.00	-6.53	.00	.00	.00
5		.00	.00	.00	.00	.00	.00	.00	.00	.00
6		.00	.00	.00	.00	.00	.00	.00	.00	.00
TOTAL		-.28	-.21	.00	.00	-.68	-.76	3.73	-.27	-.06

- MULTIPLICATIVE MODEL FORECAST

FLEET[1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1		.03	-.20	.00	.00	.13	.00	.00	.00	.00
2		.00	-.08	.00	.00	.09	.00	.00	.02	.02
3		.00	9.94	.00	.00	.00	5.92	3.98	.00	.00
4		.00	.00	.00	.00	.00	-5.01	.00	.00	.00
5		.00	.00	.00	.00	.00	.00	.00	.00	.00
6		.00	.00	.00	.00	.00	.00	.00	.00	.00
TOTAL		.03	.53	.00	.00	.11	.90	3.98	.02	.02

[1] 1 = roundfish human consumption, 2 = industrial demersal, 3 = industrial pelagic, 4 = herring, 5 = saithe, and 6 = mackerel.

Table 4.4.6 Percentage changes in yield for each species in each fleet consequent upon a 10% increase in the herring fishery.

- MSVPA FORECAST

FLEET [1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1	-.02	-.01	.00	.00	-.04	.00	.00	.00	.00	
2	-.02	.00	.00	.00	-.02	.00	.00	-.01	.00	
3	.00	.00	.00	.00	.00	-2.86	.00	.00	.00	
4	.00	.00	.00	.00	.00	5.22	.00	.00	.00	
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	
6	.00	.00	.00	.00	.00	.00	.00	.00	.00	
TOTAL	.02	.01	.00	.00	.03	-1.02	.00	.01	.00	

- MULTIFLICATIVE MODEL FORECAST

FLEET [1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1	.00	.00	.00	.00	.13	.00	.00	.00	.00	
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	
3	.00	.00	.00	.00	.00	-2.20	.00	.00	.00	
4	.00	.00	.00	.00	.00	6.16	.00	.00	.00	
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	
6	.00	.00	.00	.00	.00	.00	.00	.00	.00	
TOTAL	.00	.00	.00	.00	.08	1.64	.00	.00	.00	

[1] 1 = roundfish human consumption, 2 = industrial demersal, 3 = industrial pelagic, 4 = herring, 5 = saithe, and 6 = mackerel.

Table 4.4.7 Percentage changes in yield for each species in each fleet consequent upon a 10% increase in the Saithe fishery.

- MSVPA FORECAST

FLEET[1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1		.58	.68	-10.52	.00	12.06	.00	.00	.00	.00
2		.48	.38	6.98	.00	7.91	.00	.00	13.85	-.11
3		.00	.13	.00	.00	.00	1.31	.23	.00	.00
4		.00	.00	.00	.00	.00	1.70	.00	.00	.00
5		.00	.00	.36	.00	.00	.00	.00	.00	.00
6		.00	.00	.00	.00	.00	.00	.00	.00	.00
TOTAL		.57	.60	1.86	.00	11.22	1.49	.23	13.85	-.11

- MULTIPLICATIVE MODEL FORECAST

FLEET [1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1		-.10	.59	-9.69	.00	5.26	.00	.00	.00	.00
2		-.07	.25	-4.09	.00	2.96	.00	.00	11.10	-.05
3		.00	.10	.00	.00	.00	.67	.15	.00	.00
4		.00	.00	.00	.00	.00	.92	.00	.00	.00
5		.00	.00	-.14	.00	.00	.00	.00	.00	.00
6		.00	.00	.00	.00	.00	.00	.00	.00	.00
TOTAL		-.10	.43	-4.62	.00	4.35	.78	.15	11.10	-.05

[1] 1 = roundfish human consumption, 2 = industrial demersal, 3 = industrial pelagic, 4 = herring, 5 = saithe, and 6 = mackerel.

Table 4.4.8 Percentage changes in yield for each species in each fleet consequent upon a 10% increase in the mackerel fishery.

- MSVPA FORECAST

FLEET[1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1		.10	.13	.00	.00	.48	.00	.00	.00	.00
2		.09	.10	.00	.00	.32	.00	.00	.77	.79
3		.00	.07	.00	.00	.00	.26	.20	.00	.00
4		.00	.00	.00	.00	.00	.30	.00	.00	.00
5		.00	.00	.00	.00	.00	.00	.00	.00	.00
6		.00	.00	.00	2.31	.00	.00	.00	.00	.00
TOTAL		.10	.12	.00	2.31	.45	.28	.20	.77	.79

- MULTIPLICATIVE MODEL FORECAST

FLEET[1]	COD	WHI	SAI	MAC	HAD	HER	SPR	NP	AMM	
1		.25	-.05	.00	.00	.16	.00	.00	.00	.00
2		.29	-.02	.00	.00	.15	.00	.00	.33	.16
3		.00	.00	.00	.00	.00	.07	.09	.00	.00
4		.00	.00	.00	.00	.00	.08	.00	.00	.00
5		.00	.00	.00	.00	.00	.00	.00	.00	.00
6		.00	.00	.00	2.20	.00	.00	.00	.00	.00
TOTAL		.25	-.04	.00	2.20	.16	.07	.09	.33	.16

[1] 1 = roundfish human consumption, 2 = industrial demersal, 3 = industrial pelagic, 4 = herring, 5 = saithe, and 6 = mackerel.

Table 4.5.1 Parameter sets used for MSVPA sensitivity analysis.

Parameter		Cod ration	Whiting ration	Saithe ration	Mackerel ration	Haddock ration	Herring ration	Sprat ration	Norway pout ration	Sandeel ration	Other food	All M1	Cod ration	Whiting ration	Saithe ration	Mackerel ration	Haddock ration
Parameter deviations		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	3000000	0.1	0.1	0.1	0.1	0.1	0.1
Exp no.	MSVPA no.																
1	1	1	-1	-1	-1	-1	1	1	1	-1	1	1	-1	1	-1	-1	1
2	2	-1	1	-1	-1	-1	1	1	-1	1	1	-1	1	-1	1	-1	1
3	3	1	1	-1	-1	-1	-1	-1	1	1	-1	1	1	1	1	-1	-1
4	4	-1	-1	1	-1	-1	1	-1	1	1	-1	1	1	-1	-1	1	1
5	5	1	-1	1	-1	-1	-1	1	-1	1	1	-1	1	1	-1	1	-1
6	6	-1	1	1	-1	-1	-1	1	1	-1	1	1	-1	-1	1	1	-1
7	7	1	1	1	-1	-1	1	-1	-1	-1	-1	-1	-1	1	1	1	1
8	7	-1	-1	-1	1	-1	-1	1	1	1	-1	-1	-1	1	1	1	1
9	6	1	-1	-1	1	-1	1	-1	-1	1	1	1	-1	-1	1	1	-1
10	5	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	1	-1	1	-1
11	4	1	1	-1	1	-1	-1	1	-1	-1	-1	1	1	-1	-1	1	1
12	3	-1	-1	1	1	-1	1	1	-1	-1	-1	1	1	1	1	-1	-1
13	2	1	-1	1	1	-1	-1	-1	1	-1	1	-1	1	-1	1	-1	1
14	1	-1	1	1	1	-1	-1	-1	-1	1	1	1	-1	1	-1	-1	1
15	8	1	1	1	1	-1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1
16	9	-1	-1	-1	-1	1	-1	-1	-1	-1	1	1	1	1	1	1	1
17	10	1	-1	-1	-1	1	1	1	1	-1	-1	-1	1	-1	1	1	-1
18	11	-1	1	-1	-1	1	1	1	-1	1	-1	1	-1	1	-1	1	-1
19	12	1	1	-1	-1	1	-1	-1	1	1	1	-1	-1	-1	-1	1	1
20	13	-1	-1	1	-1	1	1	-1	1	1	1	-1	-1	1	1	-1	-1
21	14	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	-1	1	-1	1
22	15	-1	1	1	-1	1	-1	1	1	-1	-1	-1	1	1	-1	-1	1
23	16	1	1	1	-1	1	1	-1	-1	-1	1	1	1	-1	-1	-1	-1
24	16	-1	-1	-1	1	1	-1	1	1	1	1	1	1	-1	-1	-1	-1
25	15	1	-1	-1	1	1	1	-1	-1	1	-1	-1	1	1	-1	-1	1
26	14	-1	1	-1	1	1	1	-1	1	-1	-1	1	-1	-1	1	-1	1
27	13	1	1	-1	1	1	-1	1	-1	-1	1	-1	-1	1	1	-1	-1
28	12	-1	-1	1	1	1	1	1	-1	-1	1	-1	-1	-1	-1	1	1
29	11	1	-1	1	1	1	-1	-1	1	-1	-1	1	-1	1	-1	1	-1
30	10	-1	1	1	1	1	-1	-1	-1	1	-1	-1	1	-1	1	1	-1
31	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
32	8	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Table 4.5.2 Ranked sensitivity of long-term yield to 16 parameters and R^2 of regressions. Minus signs before the ranks indicate that the relationship between the variables is inverse. A (-) in the table indicates that the parameter explains less variance than the lack of fit in the regression.

		Species yield									
Parameter		Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	N.pout	Sandeel	Total
Recruitment											
Cod	R 1	1	-5	-	-	-	-	-	-	-	-
Whiting	R 2	-7	1	-	-	-4	-	-2	-	-3	-7
Saithe	R 3	-4	-6	1	-	-1	-	-7	-2	-	-4
Mackerel	R 4	-8	-9	-	1	-	-	-8	-	-2	-5
Haddock	R 5	-5	-8	-	-	3	1	3	-	4	3
Herring	R 6	-	7	-	-	-	-	-	-	-	-
Sprat	R 7	6	4	-	-	7	-	1	-	-	6
N.Pout	R 8	2	3	-	-	2	-	5	1	-	2
Sandeel	R 9	3	2	-	-	6	-	6	-	1	1
Other Food	10	-	-	-	-	-	-	-	-	-	-
All M1	11	-	-	-2	-2	5	-	4	-	-	-
Rations											
Cod Rat.	12	-	-	-	-	-	-	-	-	-5	-8
Whiting Rat.	13	-	-	-	-	-	-	-	-	-	-
Saithe Rat.	14	-	-	-	-	-	-	-	-	-	-
Mackerel Rat.	15	-	-	-	-	-	-	-	-	-	-
Haddock Rat.	16	-	-	-	-	-	-	-	-	-	-
Regression R^2		0.995	0.992	0.9997	0.9996	0.983	0.866	0.996	0.913	0.995	0.959

Table 4.5.3 Relative sensitivities of species yield to 16 parameters.

Parameter	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway p.	Sandeel	Total
1	0.50	-0.11	-	-	-0.06	0.12	0.01	0.21	0.07	0.06
2	-0.02	0.40	-	-	-0.57	-0.38	-0.28	-0.02	-0.27	-0.15
3	-0.07	-0.10	1.00	-	-1.22	0.08	-0.04	-1.46	-0.02	3
4	-0.03	-0.04	-	1.00	-0.11	0.02	-0.04	-0.33	-0.29	-0.18
5	-0.06	-0.04	-	-	0.73	4.77	0.14	-0.07	0.15	0.38
6	0.02	0.06	-	-	0.06	1.00	-	0.21	-0.02	0.11
7	0.05	0.11	-	-	0.16	0.18	1.12	-0.14	0.02	0.16
8	0.10	0.11	-	-	0.81	0.28	0.06	1.89	0.04	0.42
9	0.06	0.20	-	-	0.18	0.06	0.05	-0.05	1.25	0.49
10	0.02	0.02	-	-	0.06	-0.71	-0.02	-0.21	-0.03	-0.09
11	-	-0.02	-0.20	-0.20	0.31	-0.86	0.08	-0.05	-0.02	-0.02
12	0.02	0.01	-	-	0.05	-0.74	-0.01	-0.23	-0.06	-0.11
13	0.02	0.02	-	-	0.05	-0.66	-0.01	0.19	-0.03	-
14	0.02	0.02	-	-	0.05	-0.69	-0.02	0.19	-0.02	-0.02
15	0.02	0.02	-	-	0.05	-0.65	-0.02	0.19	-0.02	0.01
16	0.02	0.02	-	-	0.05	-0.71	-0.02	0.19	-0.03	0.03

-0,33
-0,18
0,38
0,11

Table 6.5.1 Prey composition in the food of cod and whiting by percent weight for the third quarter of 1982 and 1984 (O-observed, P-predicted).

Year/Prey	Age											
	1		2		3		4		5		6+	
	O	P	O	P	O	P	O	P	O	P	O	P
1982	Predator (cod)											
Cod	-	2.45	-	2.07	1.71	0.66	5.93	1.44	5.32	3.70	0.78	0.40
Haddock	-	0.42	2.95	4.30	5.91	8.83	3.97	10.18	3.52	8.23	0.91	28.42
Whiting	1.50	8.35	2.17	8.28	4.34	2.13	7.10	2.35	7.71	1.67	11.35	1.32
Norway pout	1.67	0.37	7.74	18.98	9.81	44.41	3.87	30.37	3.37	26.89	0.69	7.29
Herring	11.40	0.74	7.42	6.54	8.07	11.90	3.54	20.75	3.62	15.95	4.75	3.88
Sprat	-	1.52	-	1.11	0.05	0.05	0.18	0.01	0.16	0.01	0.02	-
Sandeel	-	0.91	-	4.19	5.71	1.80	19.87	0.21	20.06	0.13	19.52	0.03
N	563		108		125		27		23		21	
1984	Predator (cod)											
Cod	-	0.50	3.11	0.70	6.56	0.47	1.73	0.94	-	2.62	-	0.37
Haddock	3.90	0.57	16.46	6.51	16.00	13.57	32.81	13.04	37.46	10.41	29.21	17.19
Whiting	1.18	17.87	8.18	17.80	16.62	3.51	10.84	2.66	9.48	1.49	18.51	1.29
Norway pout	11.13	0.33	20.11	13.53	23.74	29.00	6.27	15.86	-	14.93	-	5.90
Herring	0.06	0.57	0.04	8.64	1.62	25.33	5.18	40.56	7.44	33.91	2.61	10.52
Sprat	0.06	3.51	0.04	2.48	-	0.11	-	0.01	-	-	-	-
Sandeel	6.54	0.59	5.25	3.30	0.36	1.39	0.10	0.13	-	0.07	-	0.02
N	902		160		75		20		12		11	
1982	Predator (whiting)											
Cod	-	0.01	-	-	-	-	-	-	-	-	-	-
Haddock	-	1.11	-	9.16	-	12.58	-	10.77	-	10.99	-	12.55
Whiting	-	7.84	-	5.61	-	4.28	-	3.88	-	4.88	-	4.15
Norway pout	-	4.57	-	5.75	-	10.05	-	7.43	-	5.34	-	5.43
Herring	1.74	3.64	10.85	46.18	19.78	48.23	22.11	39.03	19.69	33.46	16.47	27.96
Sprat	6.48	2.30	21.63	4.15	26.70	5.30	33.83	18.88	43.24	30.18	48.31	20.78
Sandeel	84.07	19.72	19.75	13.65	14.97	10.99	10.84	5.69	7.64	2.59	6.45	5.46
N	236		18		217		91		39		22	

Table 7.1.1 Comparison of total consumption in tonnes by individual predators with estimated biomass of prey in 1974, 1981, and 1985.

Prey	Predators					Total	Ave.stock biomass	% consumed
	Cod	Whiting	Saithe	Mackerel	Haddock			
				1974				
Cod	9,655	245	-	470	-	10,371	267,220	3.9
Whiting	61,814	45,898	6,295	634	326	114,966	416,550	27.6
Saithe	-	-	-	-	-	-	725,087	-
Mackerel	-	-	-	-	-	-	1,776,210	-
Haddock	95,995	107,152	14,774	30,828	2,256	451,068	828,575	54.4
Herring	20,592	28,752	5,131	20,518	84	75,077	377,641	19.9
Sprat	48,301	323,267	27,484	314,909	5,832	719,344	1,615,810	44.5
Norway pout	74,398	102,217	1,054,399	563,125	102,134	1,896,274	1,473,450	128.7
Sandeel	47,051	285,221	32,378	2,103,673	100,379	2,568,701	2,041,032	125.4
Total	357,804	892,757	1,340,461	3,034,159	210,560	5,835,740	9,521,576	
				1981				
Cod	25,212	762	-	83	-	26,057	313,452	8.3
Whiting	64,153	36,543	3,110	28	121	103,955	373,104	27.9
Saithe	-	-	-	-	-	-	375,760	-
Mackerel	-	-	-	-	-	-	243,595	-
Haddock	61,425	81,749	63,499	1,055	798	208,527	469,318	44.4
Herring	29,043	116,508	6,030	4,137	80	155,798	465,499	33.5
Sprat	30,390	124,374	7,129	6,794	1,764	170,450	305,056	55.9
Norway pout	60,366	129,054	396,275	94,421	50,436	730,552	949,270	76.9
Sandeel	62,177	238,172	25,736	155,020	79,850	560,954	1,297,828	43.2
Total	332,766	727,161	501,779	261,538	133,049	1,956,293	4,792,844	
				1985				
Cod	2,653	126	-	10	-	2,789	171,303	1.6
Whiting	70,433	236,401	7,688	155	438	315,115	560,562	56.2
Saithe	-	-	-	-	-	-	467,540	-
Mackerel	-	-	-	-	-	-	142,693	-
Haddock	34,565	96,296	83,772	1,441	923	216,997	476,265	45.6
Herring	49,648	146,673	8,417	4,598	67	209,403	1,678,491	12.5
Sprat	6,582	98,685	4,170	2,467	527	112,430	368,216	30.5
Norway pout	39,424	103,244	553,693	18,788	53,032	768,181	910,659	84.4
Sandeel	19,772	161,131	13,859	30,227	18,626	243,615	883,230	27.6
Total	223,078	842,556	671,598	57,685	73,613	1,868,531	5,658,959	

Table 7.1.2 Total biomasses consumed by all predators, compared to total stock biomass, total predator biomass, total yield, and residual natural mortality in terms of biomass.

Year	Biomass 1 Jan	Average biomass	Total yield	Total eaten	Res.n. mort.	Ave.pred. biomass	Yield / Ave.biom.	Tot.eaten / Ave.biom.	Res.n.mort. / Ave.biom.	Tot.eaten / Ave.pred.biom.
1974	10,226,856	9,521,330	4,186,319	5,835,740	4,459,042	4,013,642	0.44	0.61	0.47	1.45
1975	8,796,476	8,233,902	3,165,377	4,235,522	3,963,585	3,118,753	0.38	0.51	0.48	1.36
1976	7,495,967	6,963,542	3,157,496	3,575,275	3,293,479	2,534,528	0.45	0.51	0.47	1.41
1977	6,288,477	5,932,575	2,504,390	2,883,177	2,824,286	2,075,665	0.42	0.49	0.48	1.39
1978	5,810,818	5,615,912	2,415,318	2,480,244	2,861,082	1,856,946	0.43	0.44	0.51	1.33
1979	5,665,800	5,726,110	2,419,094	2,375,140	2,910,597	1,869,815	0.42	0.41	0.51	1.27
1980	5,938,620	5,177,848	2,610,169	2,235,715	2,322,781	1,909,750	0.50	0.43	0.45	1.17
1981	4,428,252	4,792,884	2,410,804	1,956,293	2,317,778	1,775,229	0.50	0.41	0.48	1.18
1982	5,210,949	5,209,360	2,378,075	1,913,177	2,271,213	1,588,610	0.46	0.37	0.44	1.20
1983	4,794,774	5,356,313	2,341,485	1,677,676	2,383,191	1,504,008	0.44	0.31	0.44	1.16
1984	5,838,578	6,077,116	2,585,893	1,677,718	2,581,312	1,595,689	0.43	0.28	0.42	1.05
1985	5,456,758	5,658,959	2,428,323	1,868,531	2,508,880	1,818,363	0.43	0.33	0.44	1.03

Table 8.1.1 COD. Year-class strength estimates and their correlations.

Year	MSVPA		VPA	IOGS June		EGFS Aug-Sep		DGFS Nov	
	0-group 1 Oct	1-group 1 Oct	1-group 1 Jan	AM	GM	0-group	1-group	0-group	1-group
1973	-	124	234	-	-	-	-	-	-
1974	553	216	426	71.6	6.9	-	-	-	-
1975	277	104	207	7.4	1.3	-	-	-	-
1976	1,060	379	709	57.8	14.6	-	6,818	-	-
1977	609	214	426	21.4	5.9	1,559	2,372	-	-
1978	650	221	451	13.5	3.6	1,679	2,264	-	-
1979	1,310	441	786	208.0	5.0	1,856	5,149	-	-
1980	531	147	259	19.5	3.6	1,006	1,232	43.2	-
1981	864	286	533	250.3	23.8	7,963	3,234	176.8	-
1982	402	133	265	52.6	18.0	254	1,541	26.9	-
1983	738	274	527	490.0	44.7	9,595	6,122	121.5	-
1984	88	30	57	-	-	45	419	1.3	-
1985	128	-	-	-	-	798	3,500	143.6	-
1986	-	-	-	-	-	200	-	-	-
	VPA 1-group Regression against indices								
	R			0.43	0.22	0.46	0.87	-	
	a			395	419	329	163	-	
	b			0.53	3.17	0.028	0.087	-	
	n			10	10	8	9	-	
	MSVPA 0-group Regression against indices								
	R			0.40	0.15	0.39	-	0.93	
	a			604	654	536	-	238	
	b			0.80	3.55	0.038	-	3.87	
	n			10	10	8	-	5	
	MSVPA 1-group								
	R			-	-	-	0.86	-	
	a			-	-	-	81	-	
	b			-	-	-	0.047	-	
	n			-	-	-	9	-	

Table 8.3.1 ANOVA tables from fitting the three variants of the kernel model to suitabilities.

Source of variation	SS	df	MS	F
A: Common first & second power difference terms in covariate term.				
Error	7,900.13	3,070	2.57	-
Covariates	769.88	4	192.47	74.79
Constant	1,475.73	1	1,475.73	573.47
Pred	511.87	4	127.97	49.73
Prey	818.94	6	136.49	53.04
Pred by Prey	1,778.50	22	80.84	31.41
B: Common second power difference term in covariate.				
Error	7,484.96	3,064	2.44	-
Covariates	571.27	3	190.42	77.95
Constant	1,448.66	1	1,448.66	593.01
Pred	496.95	4	124.24	50.86
Prey	733.00	6	122.17	50.01
Prey by Pred	1,748.59	22	79.48	32.54
Wt diff. by Prey	680.55	7	97.22	33.80
C: Both weight difference terms nested by prey species. Only covariates are weight ratios.				
Error	7,342.24	3,058	2.40	-
Covariate	450.03	2	225.01	93.72
Constant	1,336.95	1	1,336.95	556.83
Pred	427.62	4	106.90	44.52
Prey	692.80	6	115.47	48.09
Prey by Pred	1,722.11	22	78.28	32.60
Wt diff. within Prey	803.15	7	114.74	47.79
WT diff. within Pred	182.64	7	26.09	10.87

Table 8.3.2 Parameter estimates for covariate coefficients, and the weight difference terms nested by prey, from core model of suitabilities.

Term	Parameter estimate	
ln Wt ratio	1.4218	$= \mu/\sigma^2$
ln Wt ratio^2	-0.1396	$= 1/2\sigma^2$
Wt difference^2	-1.9548	
wt diff. by cod	21.2833	
wt diff. by whiting	3.1376	
wt diff. by haddock	-6.1786	
wt diff. by herring	-8.2830	
wt diff. by sandeel	24.4827	
wt diff. by pout	-15.2108	
wt diff. by sprat	2.6212	

μ = 5.092

σ = 1.893

Table 8.3.3 Parameters estimated from a fitting of the core model (restructed as described in Section 8.4) to the suitabilities.

Predator	Prey						
	Cod	Whiting	Haddock	Herring	Sandeel	Pout	Sprat
Cod	0.178	0.244	0.793	-0.675	-1.071	-1.568	-1.419
Whiting	0.139	1.232	1.429	0.780	-0.450	0.253	0.016
Saithe	-	-2.155	0.753	-1.476	-2.469	1.792	-2.278
Mackerel	0.936	-2.061	0.536	0.192	0.269	1.858	-0.199
Haddock	-	1.550	1.079	-0.683	1.526	1.907	-

Grand mean = 7.176.

Table 8.3.4 ANOVA table from core model plus quarter interactions fit to suitabilities.

Source of variation	SS	df	MS	F
Error	6,519.28	3,034	2.15	-
Covariates	548.14	3	182.71	85.03
Constant	1,347.78	1	1,347.78	627.24
Pred	624.27	4	156.07	72.63
Prey	584.50	6	97.04	45.34
Pred by Prey	1528.93	22	69.50	32.35
Q by Pred	427.60	18	35.66	16.60
Q by Prey	503.04	18	27.95	13.07
Wt diff. within Prey	588.92	7	84.13	39.15

Table 8.4.1 The analysis of variance table for the core model.

Source of variation	SS	df	MS	F	Signif.
Within + Residual	7,659	3,068	2.5	-	-
Regression (LWTRSQ)	913	1	913	366	*
Constant	11,682	1	11,682	4,679	*
Pred	345	4	86	35	*
Prey	682	6	114	46	*
Pred x Prey	1,385	22	63	25	*
LWTR within Pred	1,158	5	232	93	*

Table 8.4.2 LWTR coefficients from the core model.

Predator species	Slope by species	STD-Error	Calculated size preference ratios[1]
Cod	1.5548	0.0956	50.62
Whiting	1.5366	0.0848	48.34
Saithe	2.2165	0.1179	268.92
Mackerel	2.0451	0.1212	174.48
Haddock	2.0810	0.1375	191.02

[1] Calculated as exp (slope/2 x β) where β is the LWTRSQ coefficient (= 0.1981).

Table 8.4.3 The analysis of variance table for the 34 levels model.

Source of variation	SS	df	MS	F	Signif.
Within + Residual	7,659	3,068	2.5	-	-
Regression (LWTRSQ)	914	1	914	366	*
Constant	25,612	1	25,612	10,260	*
UF	3,683	32	115	46	*
LWTR within Pred	1,158	5	232	93	*

Figure 2.4.1a Comparisc f new estimates of annual ration per age for cod, ing, saithe, mackerel, and haddock with the estimates used in previous Working Group meetings.

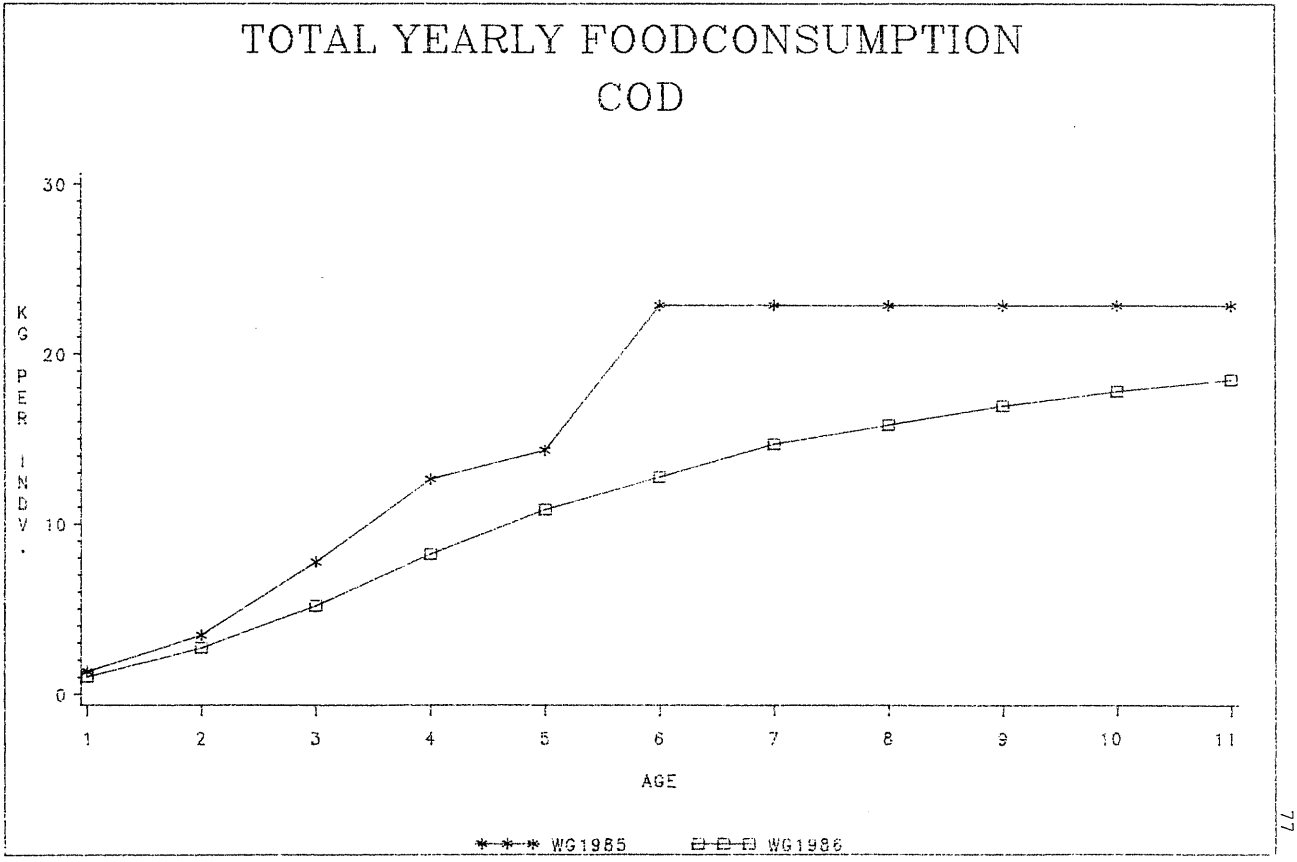
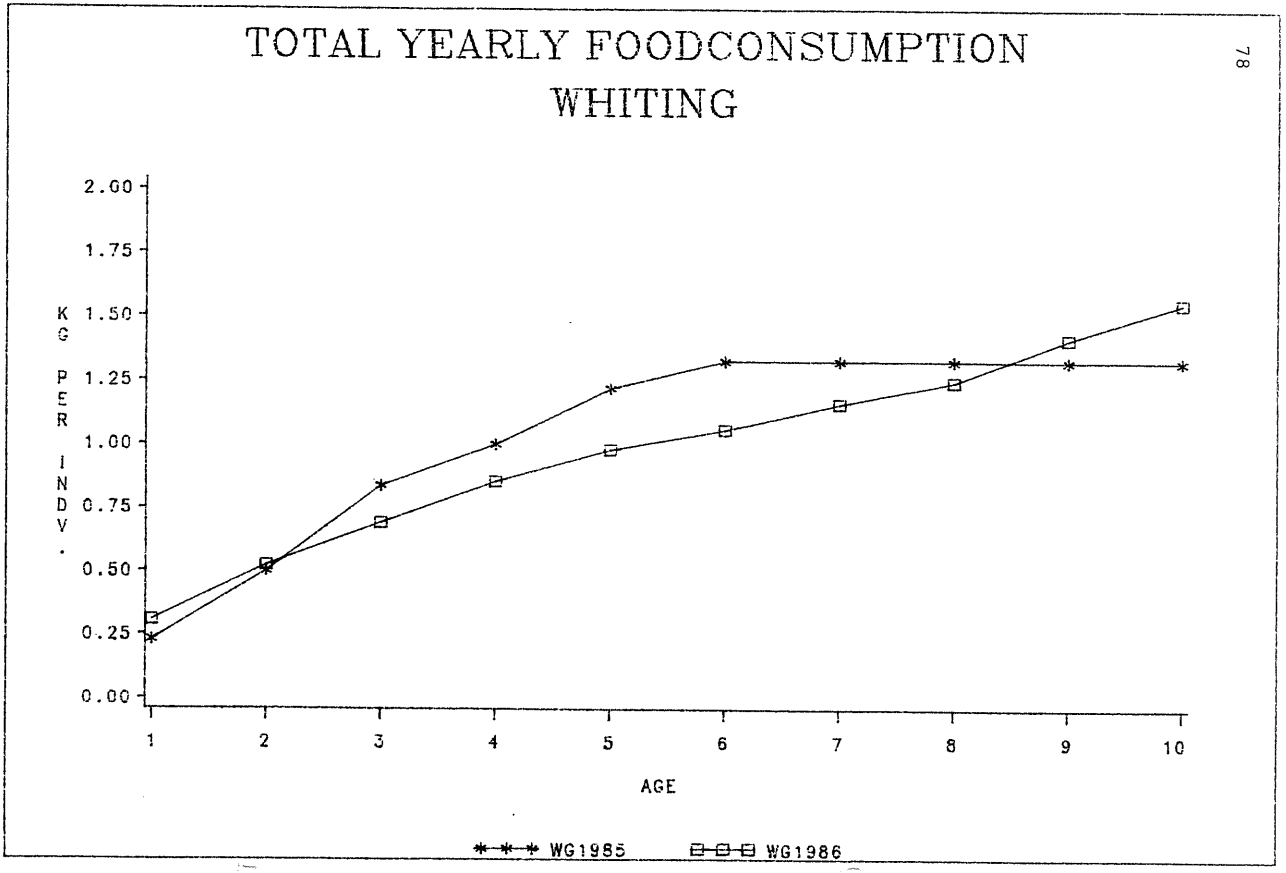


Figure 2.4.1b Comparison of new estimates of annual ration per age for cod, whiting, saithe, mackerel, and haddock with the estimates used in previous Working Group meetings.



whiting

Figure 2.4.1c Comparison of new estimates of annual ration per age for cod, whiting, saithe, mackerel, and haddock with the estimates used in previous Working Group meetings.

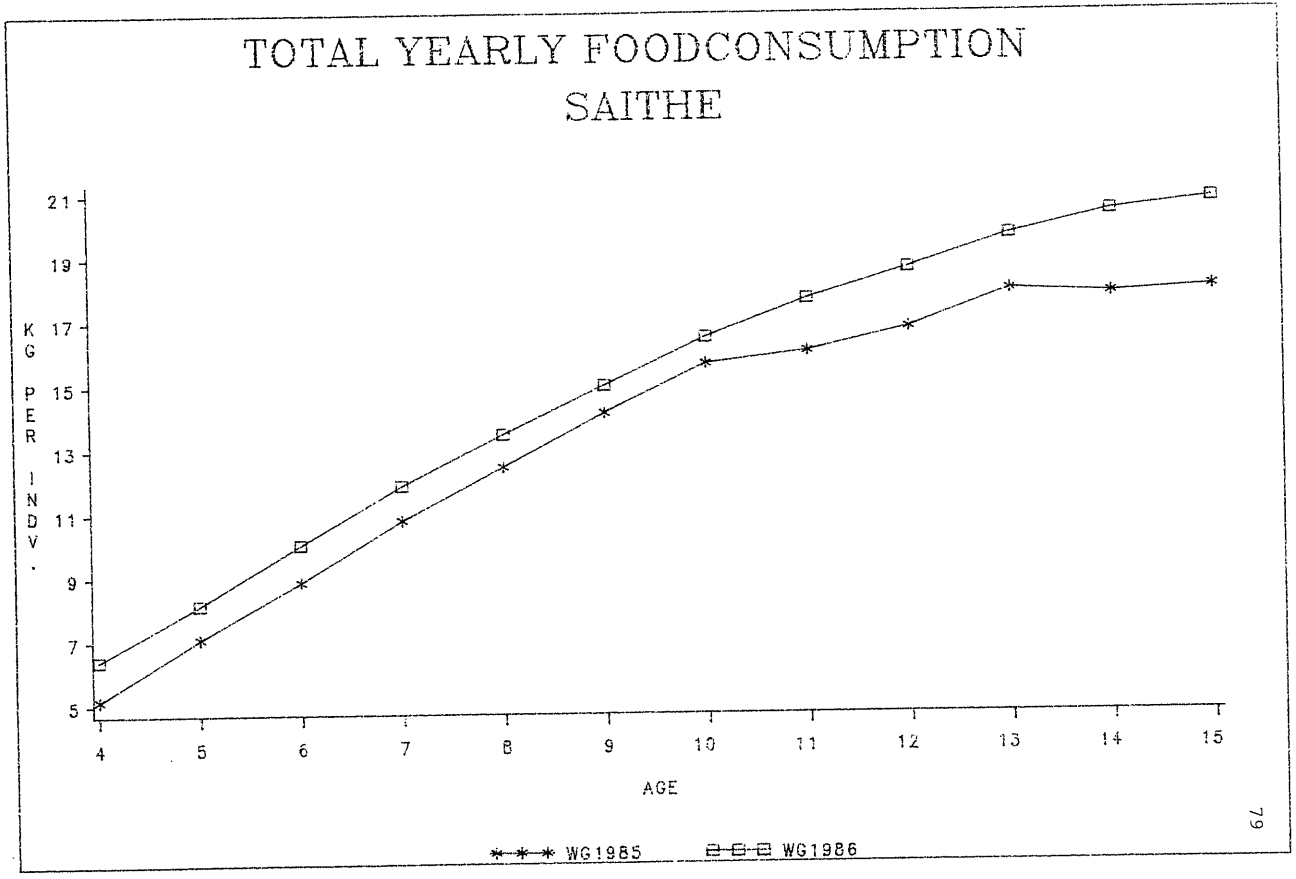


Figure 2.4.1d Comparison of new estimates of annual ration per age for cod, whiting, saithe, mackerel, and haddock with the estimates used in previous Working Group meetings.

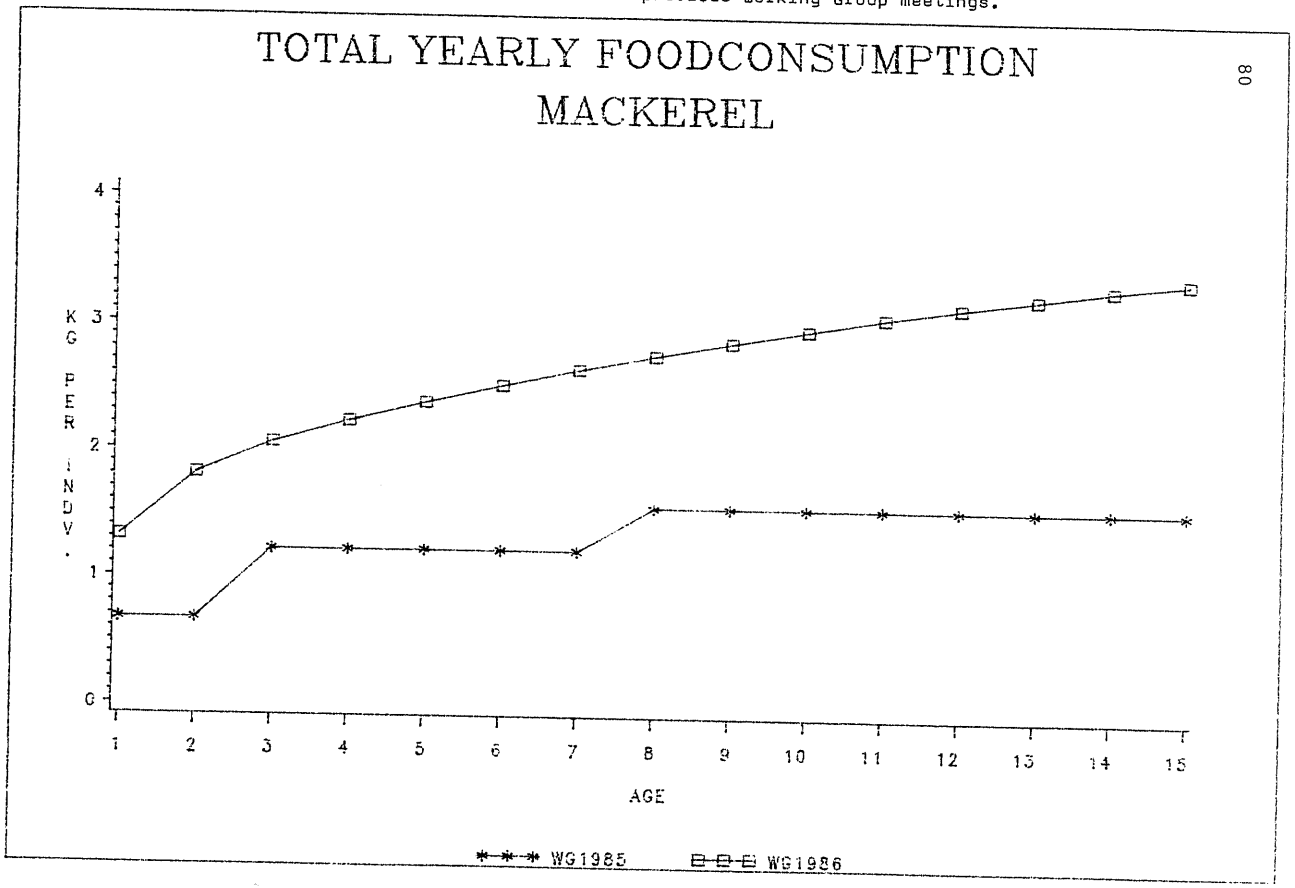


Figure 2.4.1e Comparison of new estimates of annual ration per age for cod, whiting, saithe, mackerel, and haddock with the estimates used in previous Working Group meetings.

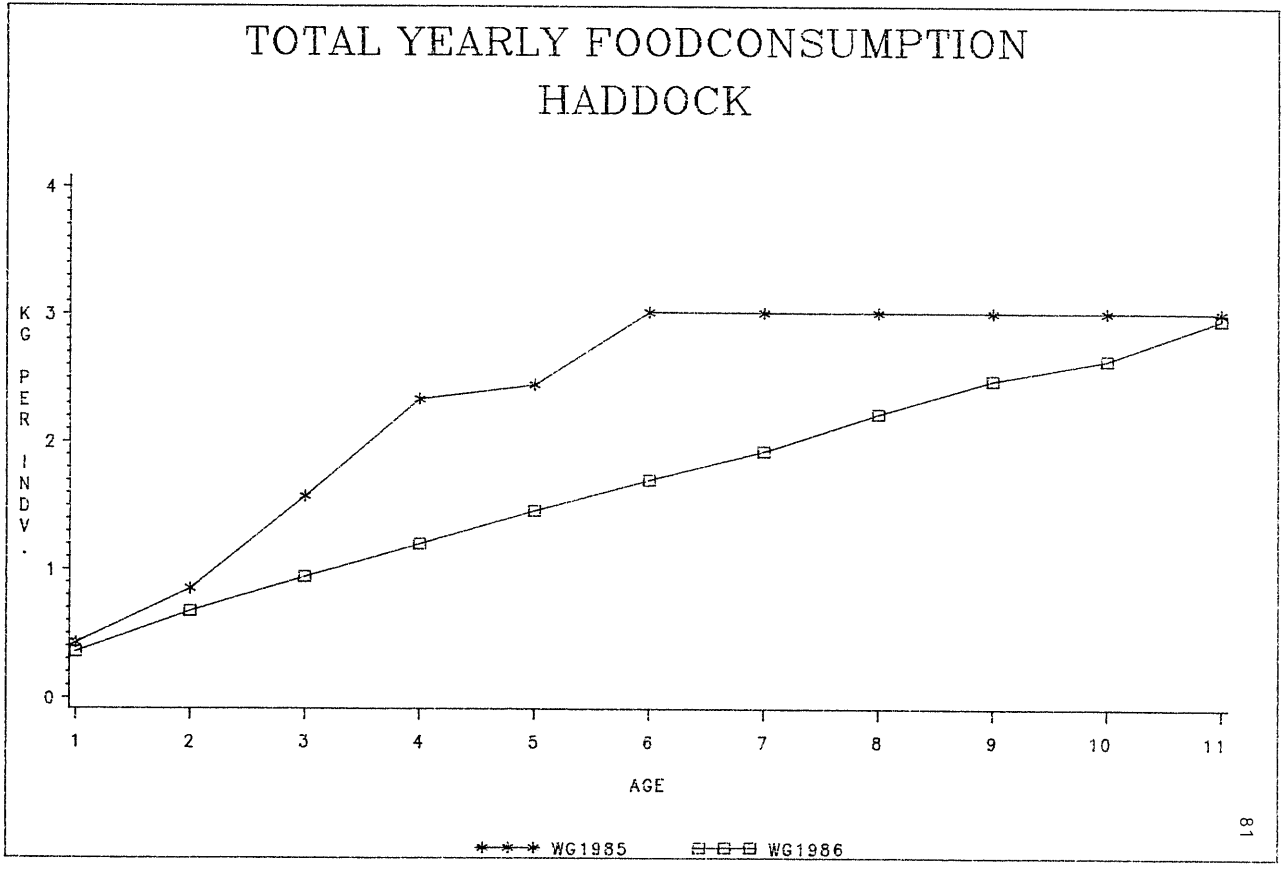


Figure 2.8.1a The total stock biomass (TSB) and spawning stock biomass (SSB) from the MSVPA and the single-species VPA.

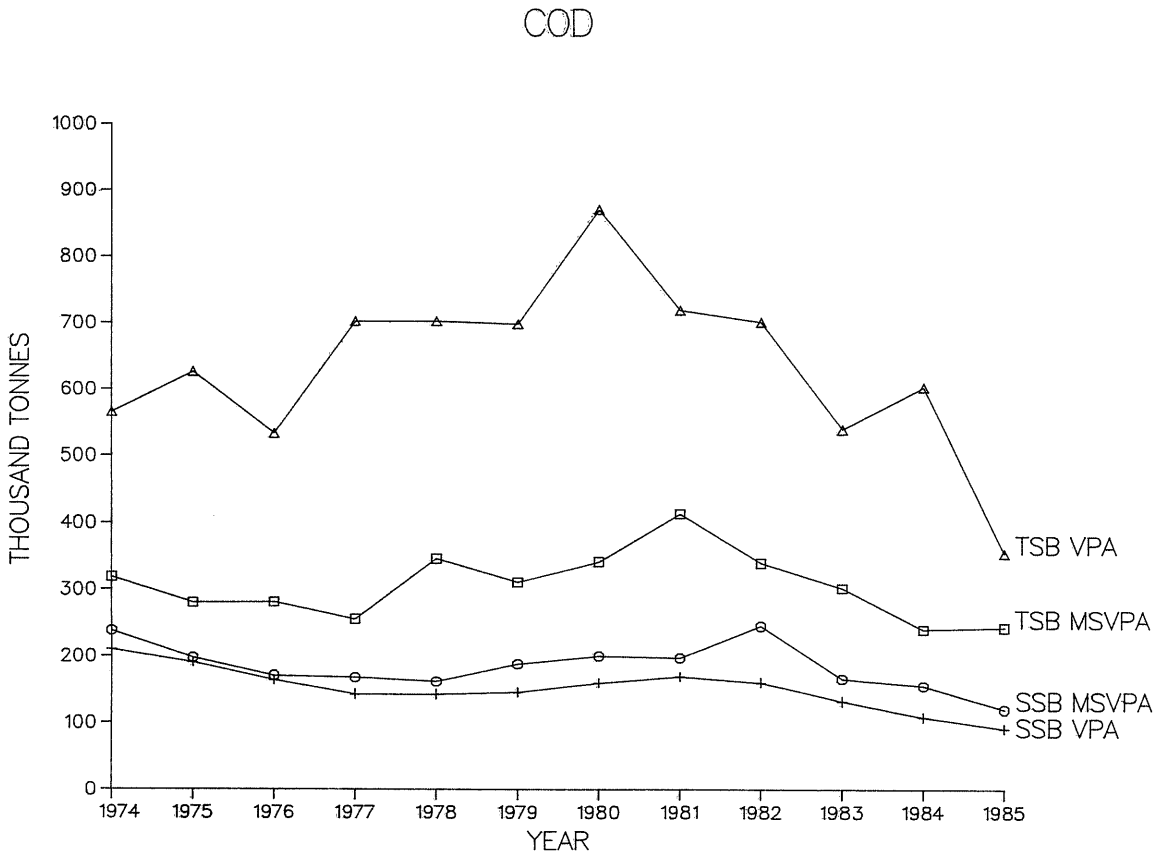


Figure 2.8.1b The total stock biomass (TSB) and spawning stock biomass (SSB) from the MSVPA and the single-species VPA.

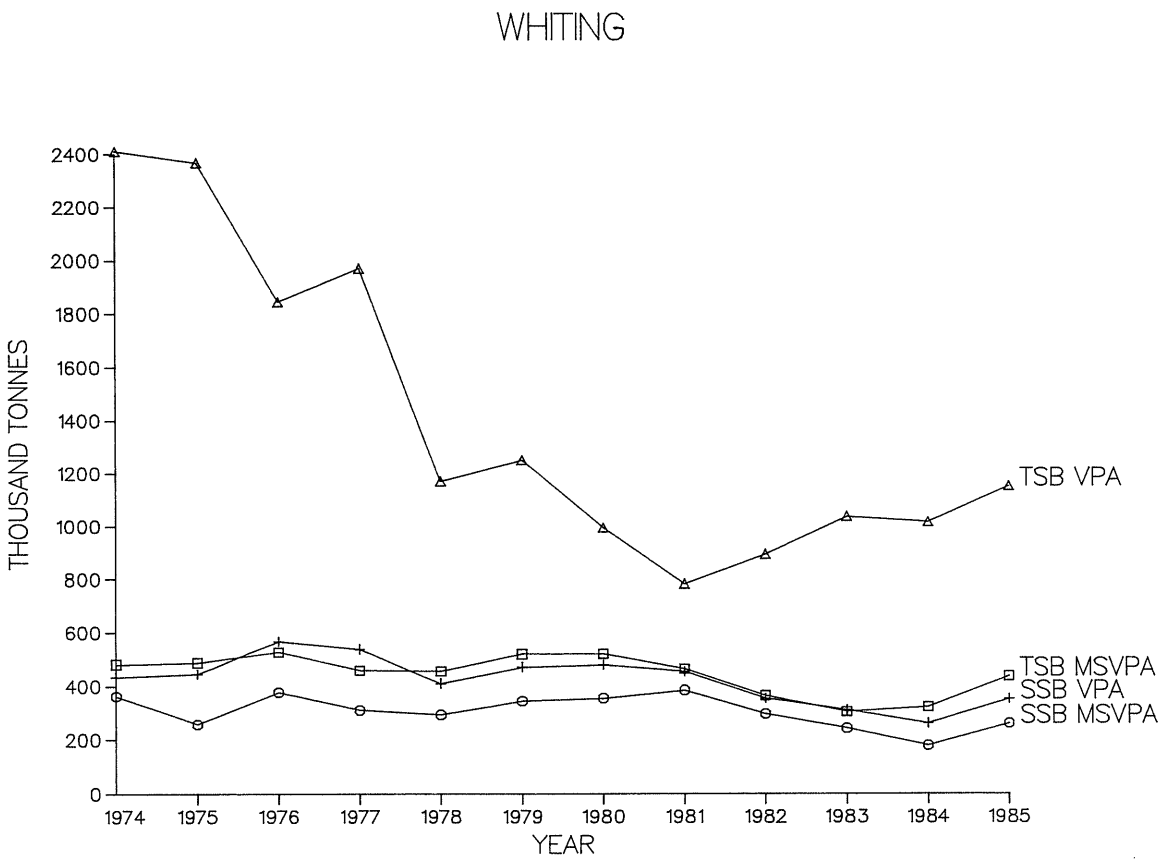


Figure 2.8.1c The total stock biomass (TSB) and spawning stock biomass (SSB) from the MSVPA and the single-species VPA.

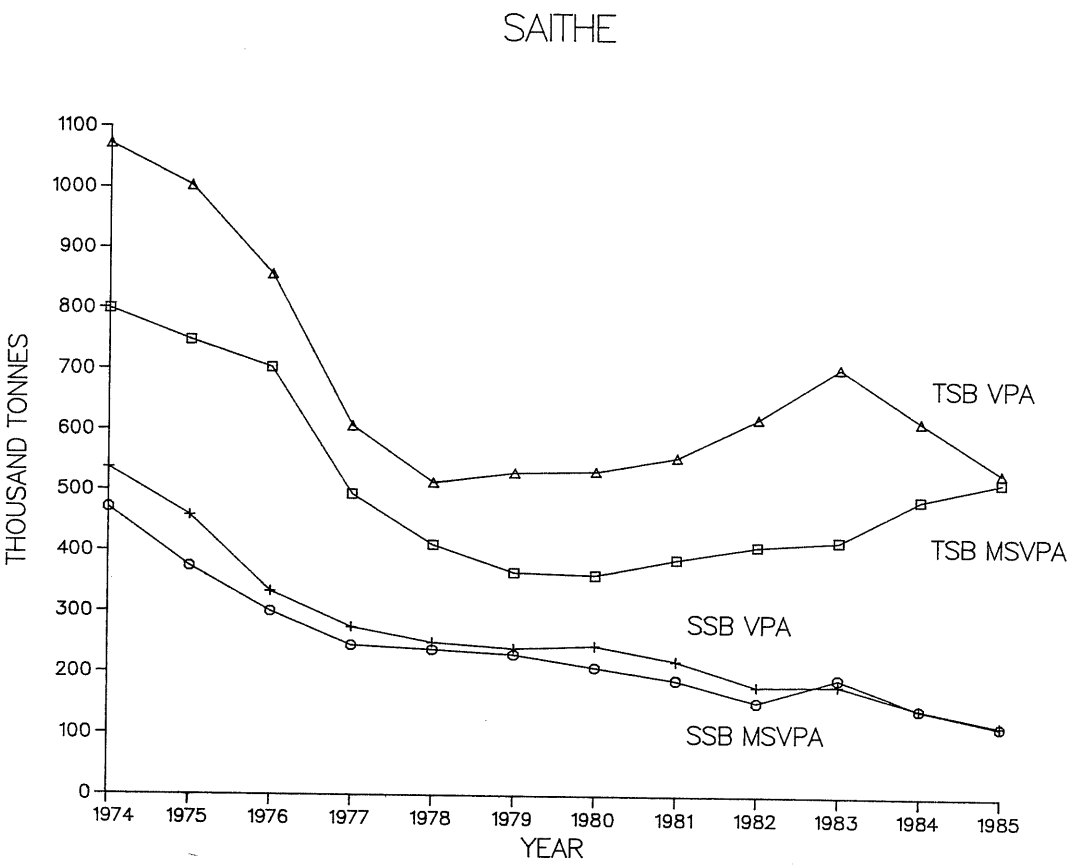


Figure 2.8.1d The total stock biomass (TSB) and spawning stock biomass (SSB) from the MSVPA and the single-species VPA.

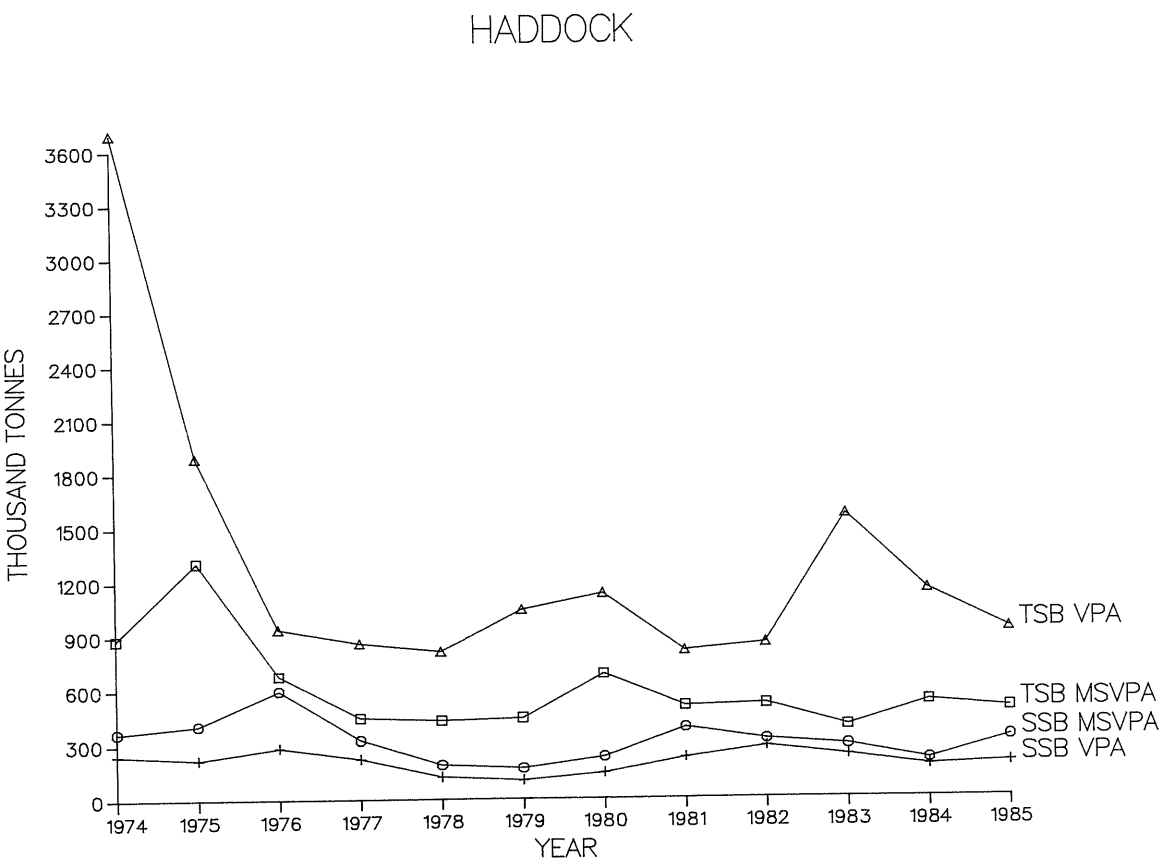


Figure 2.8.1e The total stock biomass (TSB) and spawning stock biomass (SSB) from the MSVPA and the single-species VPA.

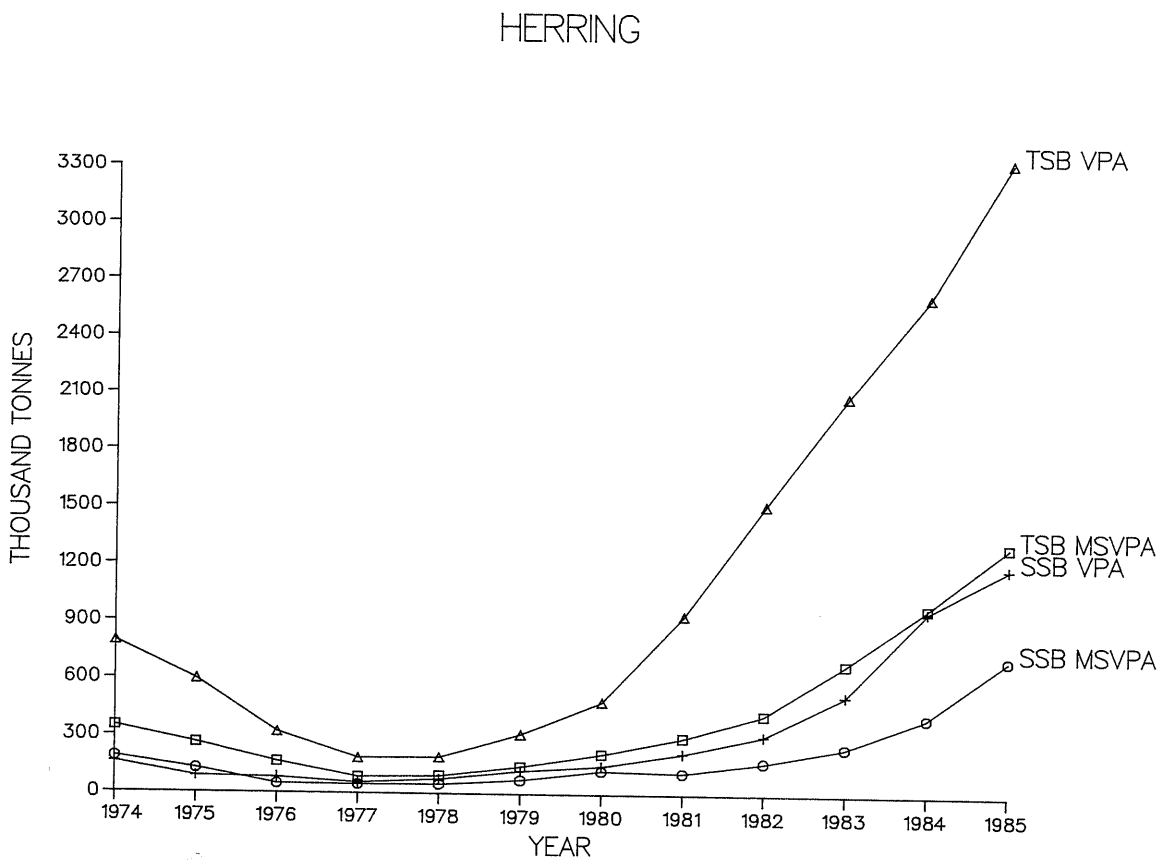


Figure 2.8.1f The total stock biomass (TSB) and spawning stock biomass (SSB) from the MSVPA and the single-species VPA.

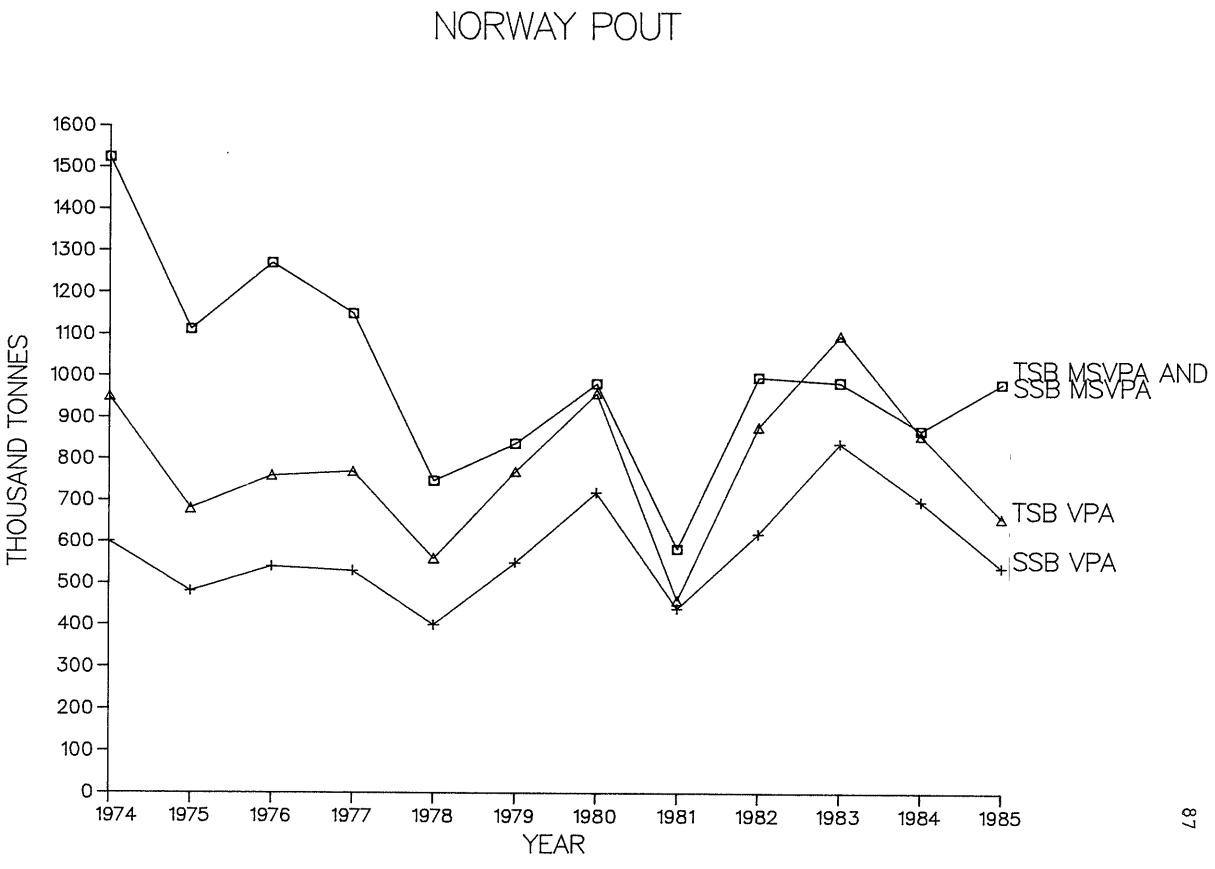


Figure 2.8.1g The total stock biomass (TSB) and spawning stock biomass (SSB) from the MSVPA and the single-species VPA.

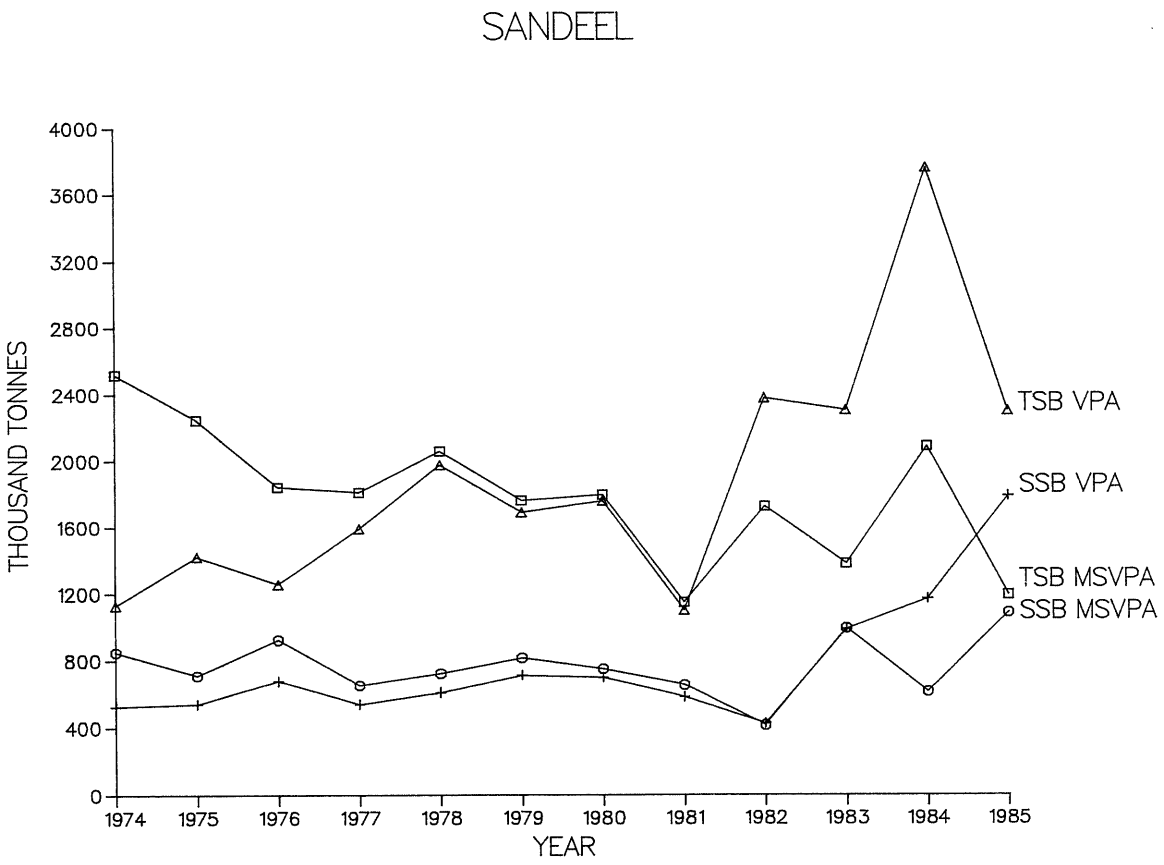


Figure 4.5.1 Results of sensitivity analysis expressed as yield coefficient of variation.

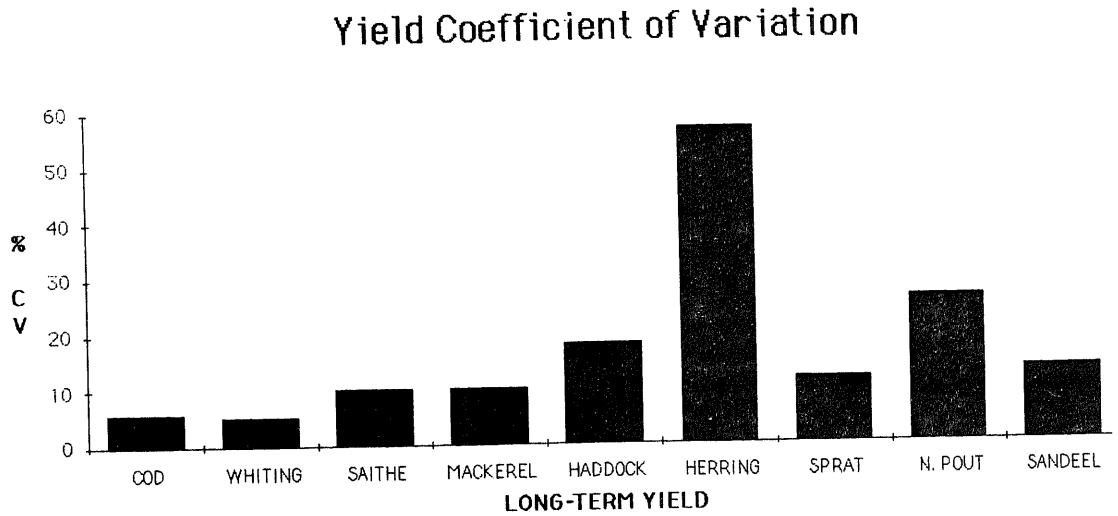
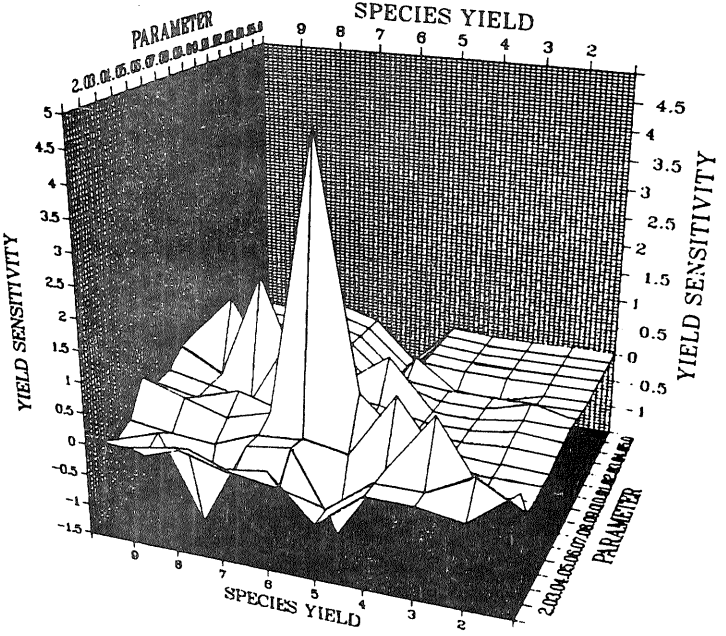


Figure 4.5.2 3-D plot of yield sensitivity of each species yield to the parameters investigated.



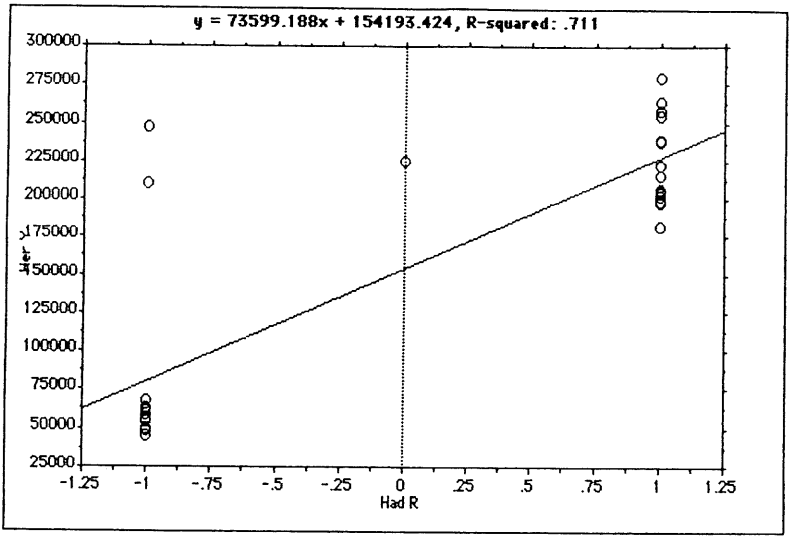


Figure 4.5.3 Herring yield against haddock recruitment for the 33 sensitivity analysis runs.

Figure 6.3.1 Algorithm for estimating an average suitability based on a time series of stomach contents data (e.g., 1981-1984).

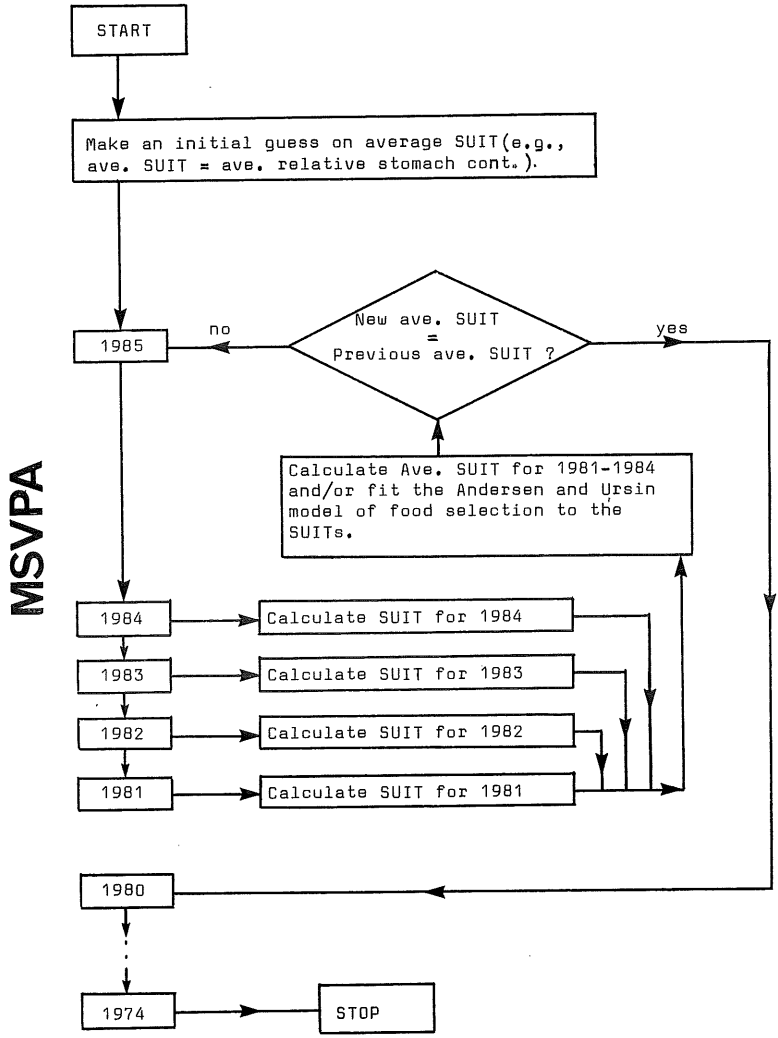


Figure 7.1.1a Prey biomass consumed by predator species.

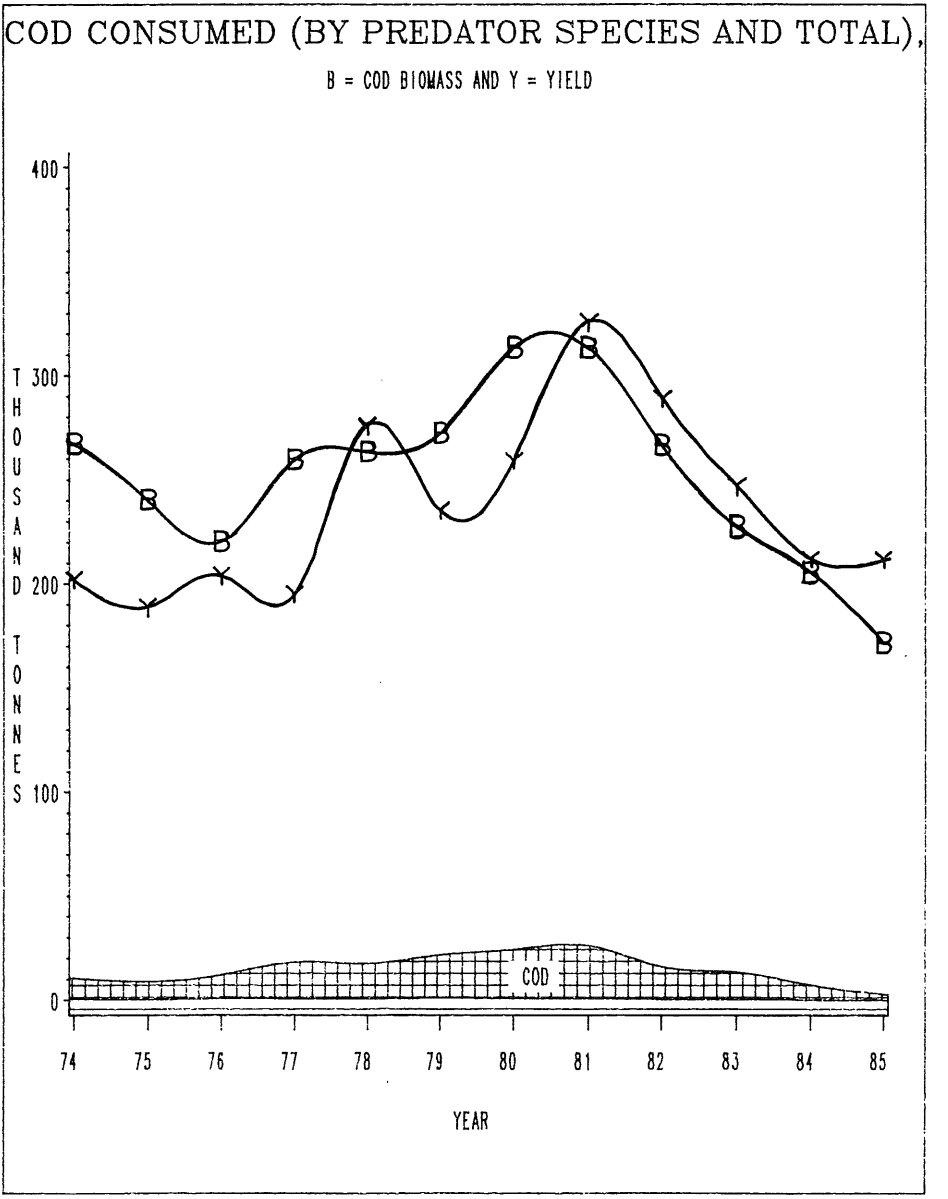


Figure 7.1.1b Prey biomass consumed by predator species.

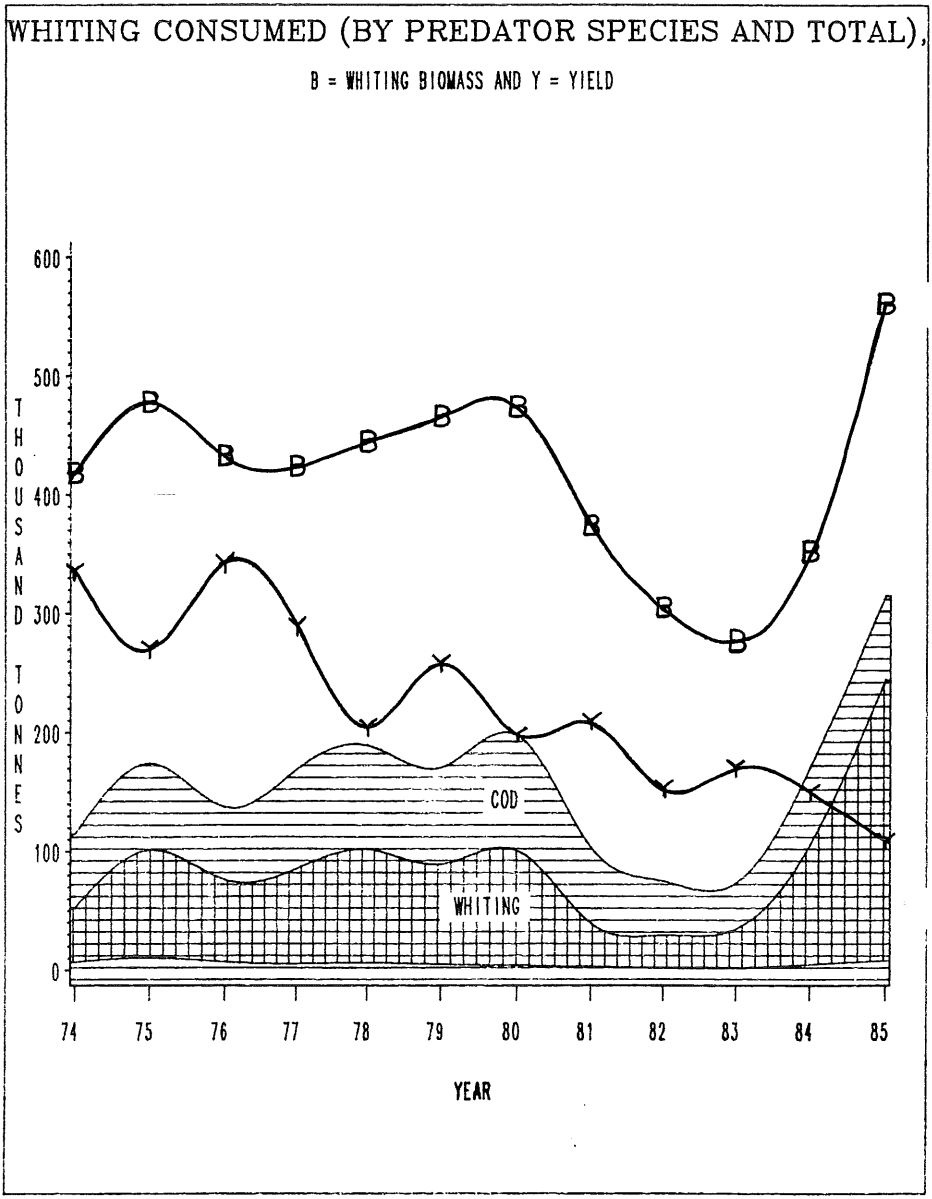


Figure 7.1.1c Prey biomass consumed by predator species.

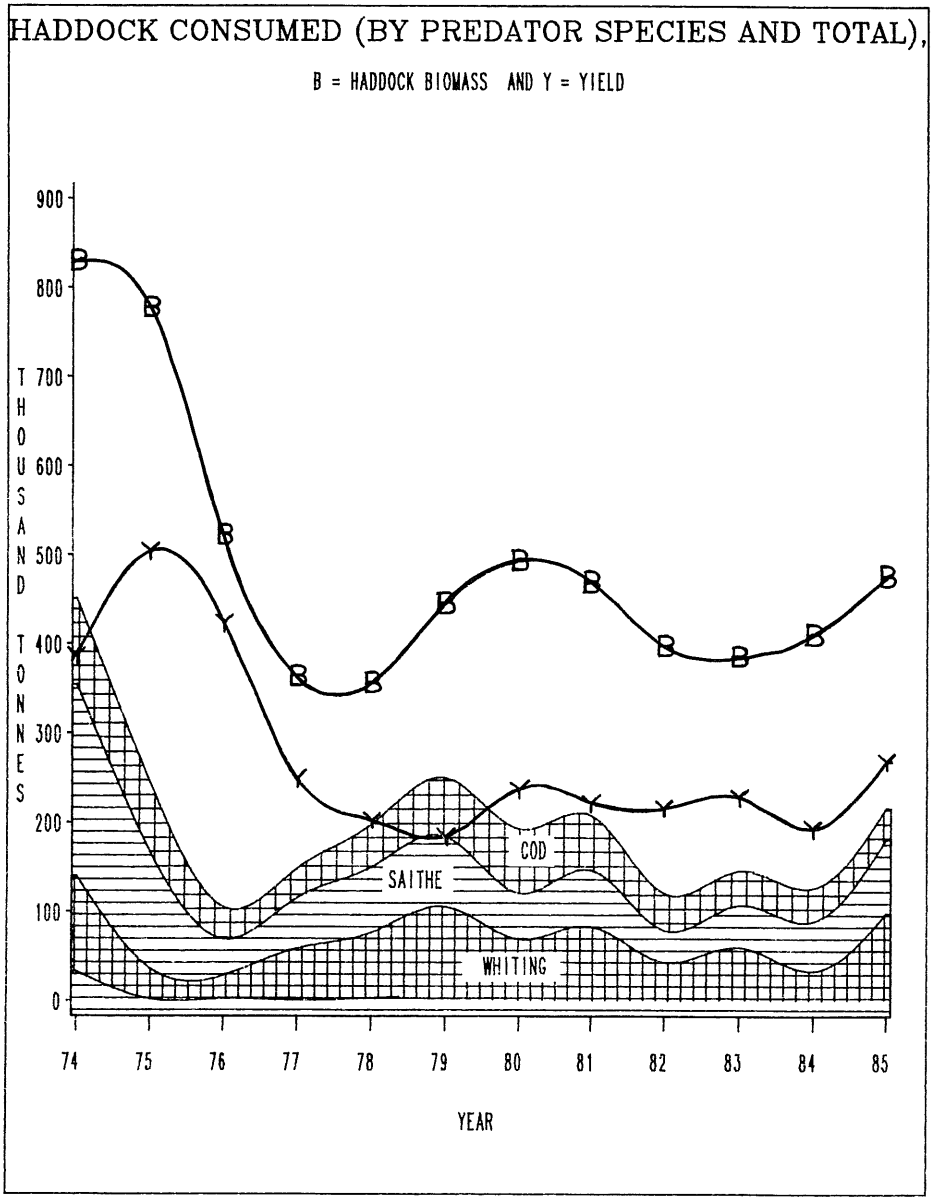


Figure 7.1.1d Prey biomass consumed by predator species.

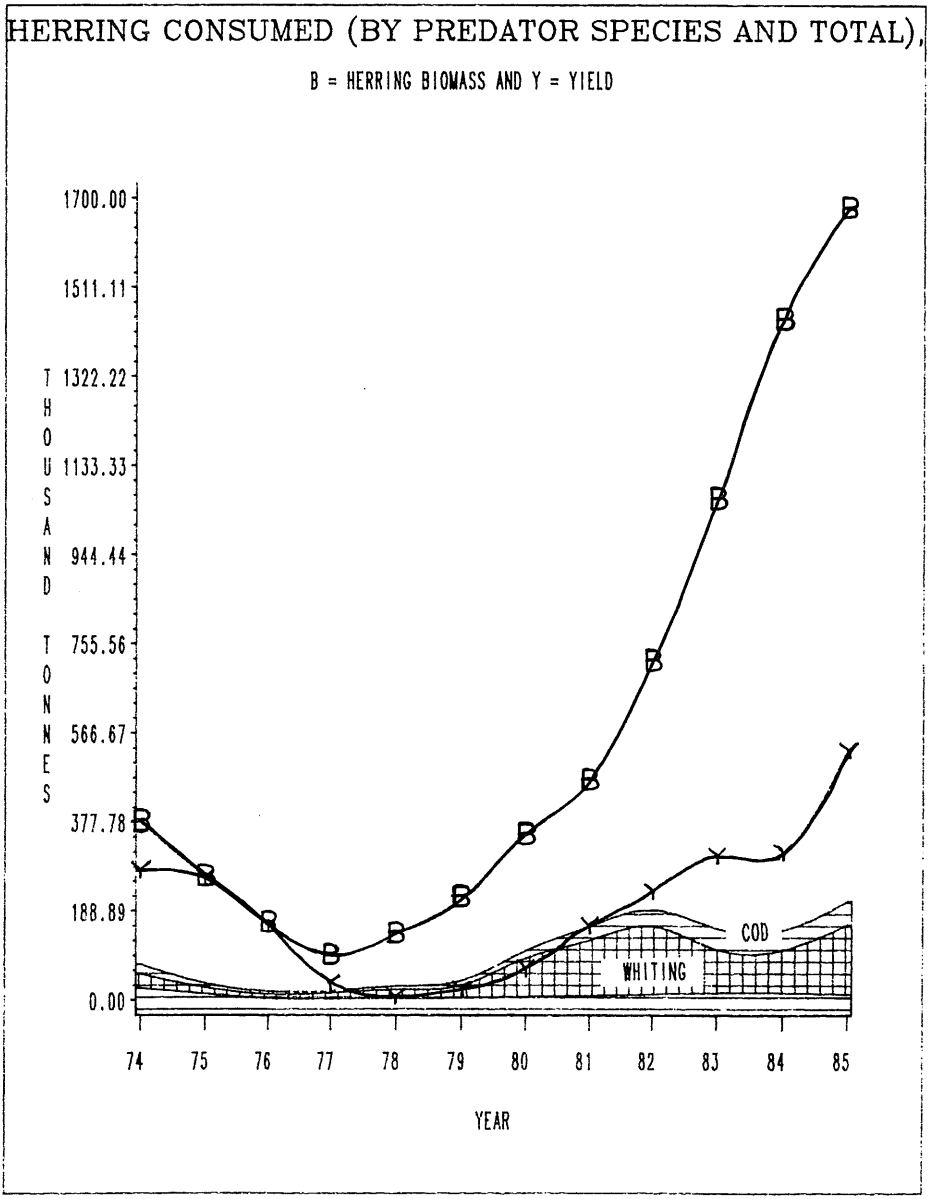


Figure 7.1.1e Prey biomass consumed by predator species.

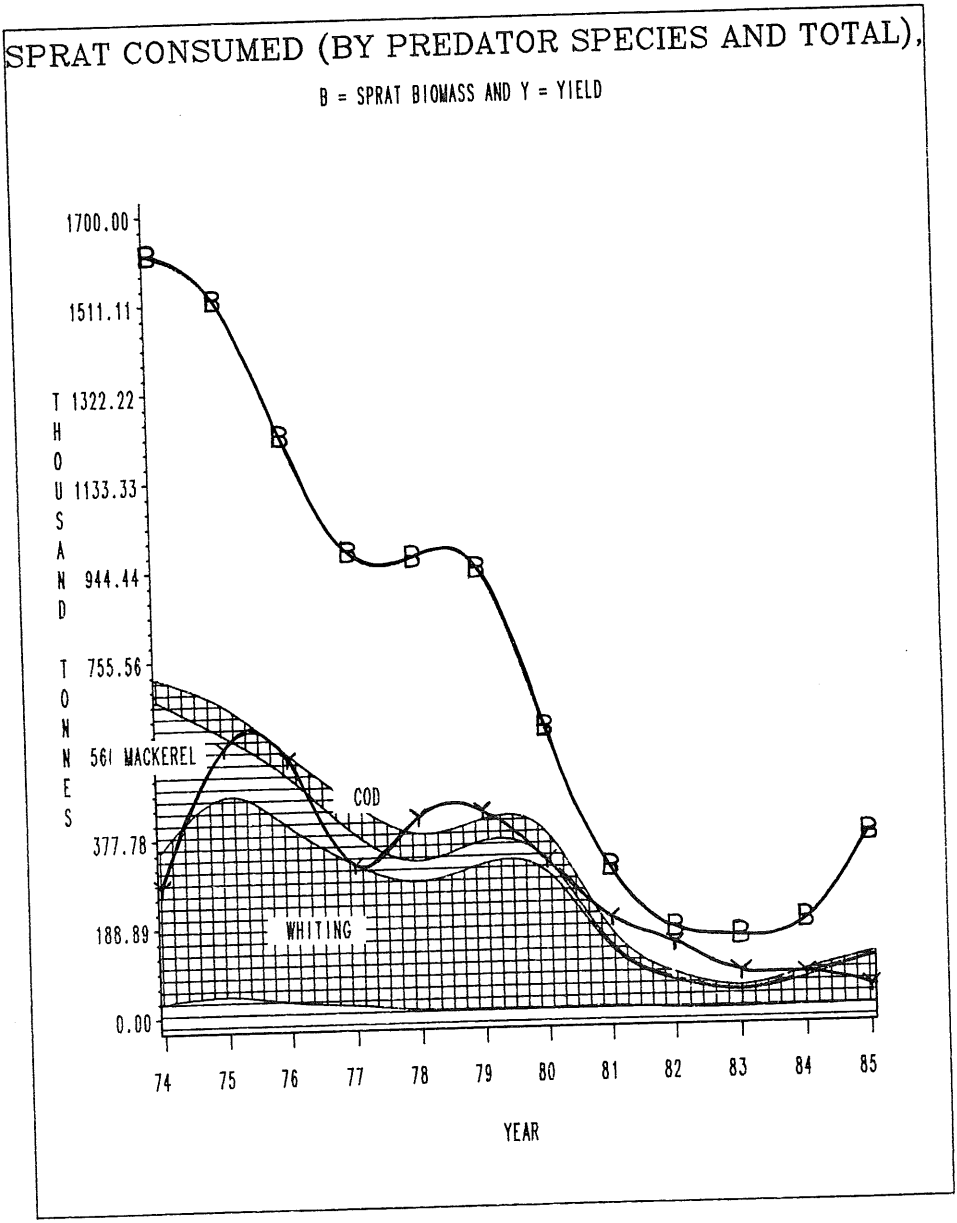


Figure 7.1.1f Prey biomass consumed by predator species.

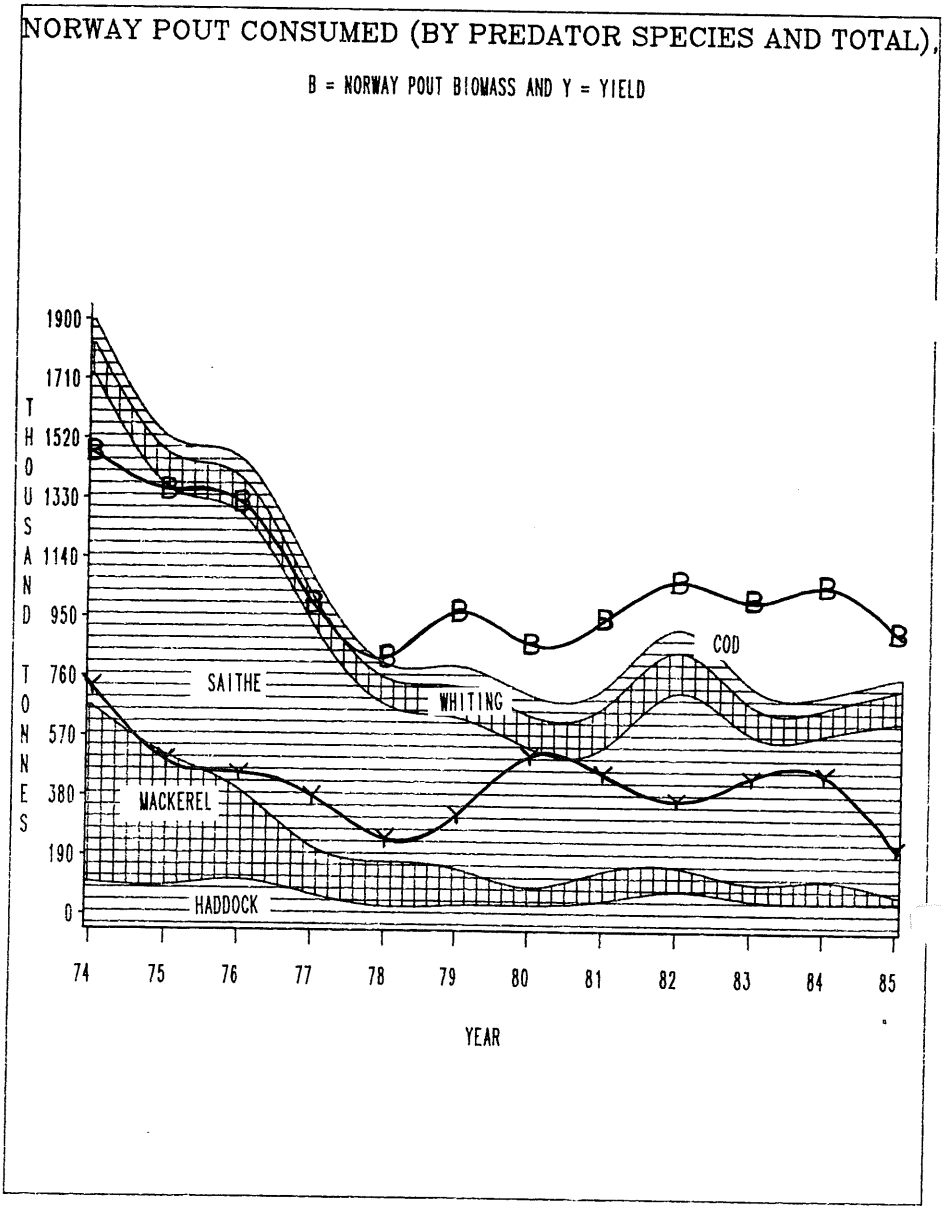


Figure 7.1.1g Prey biomass consumed by predator species.

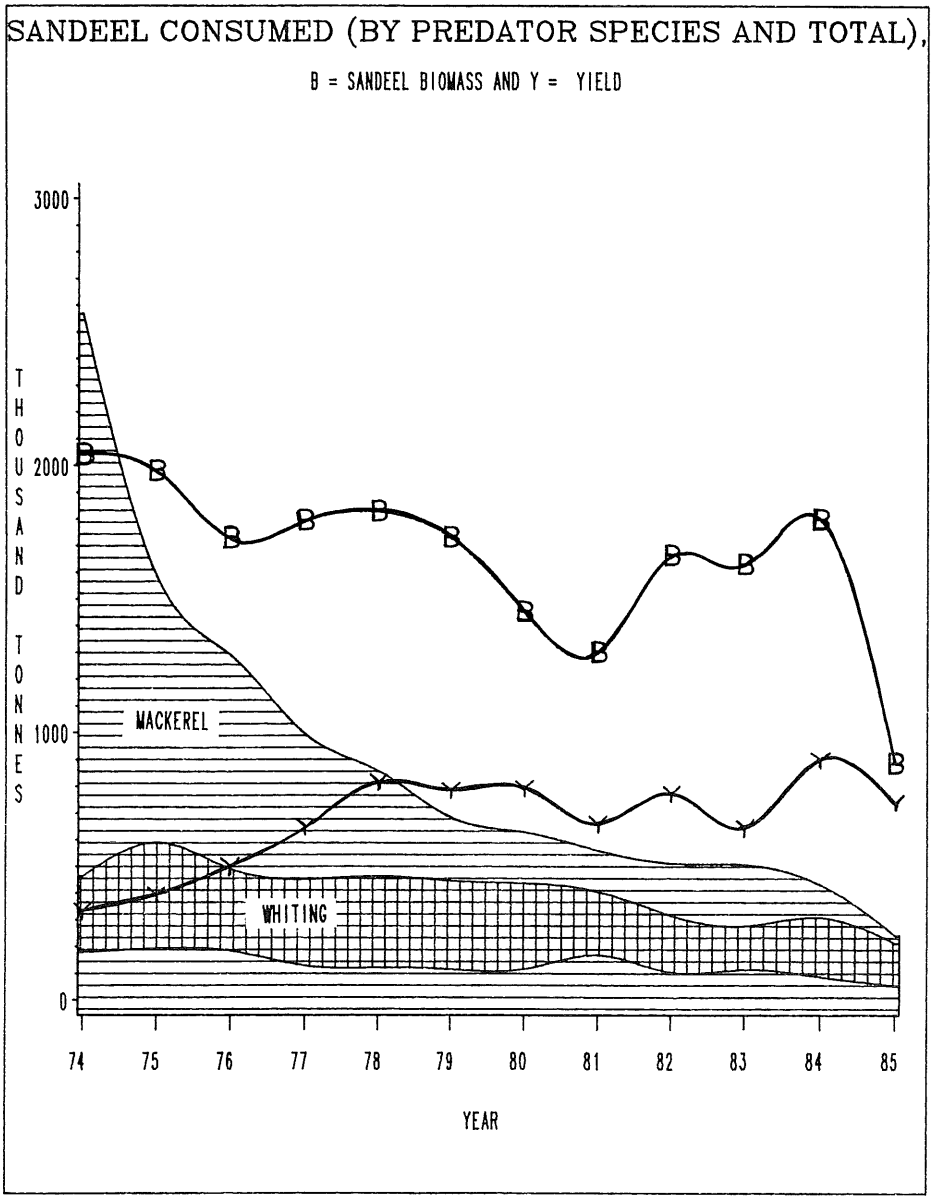


Figure 7.1.2a The consumption of predator species by prey species.

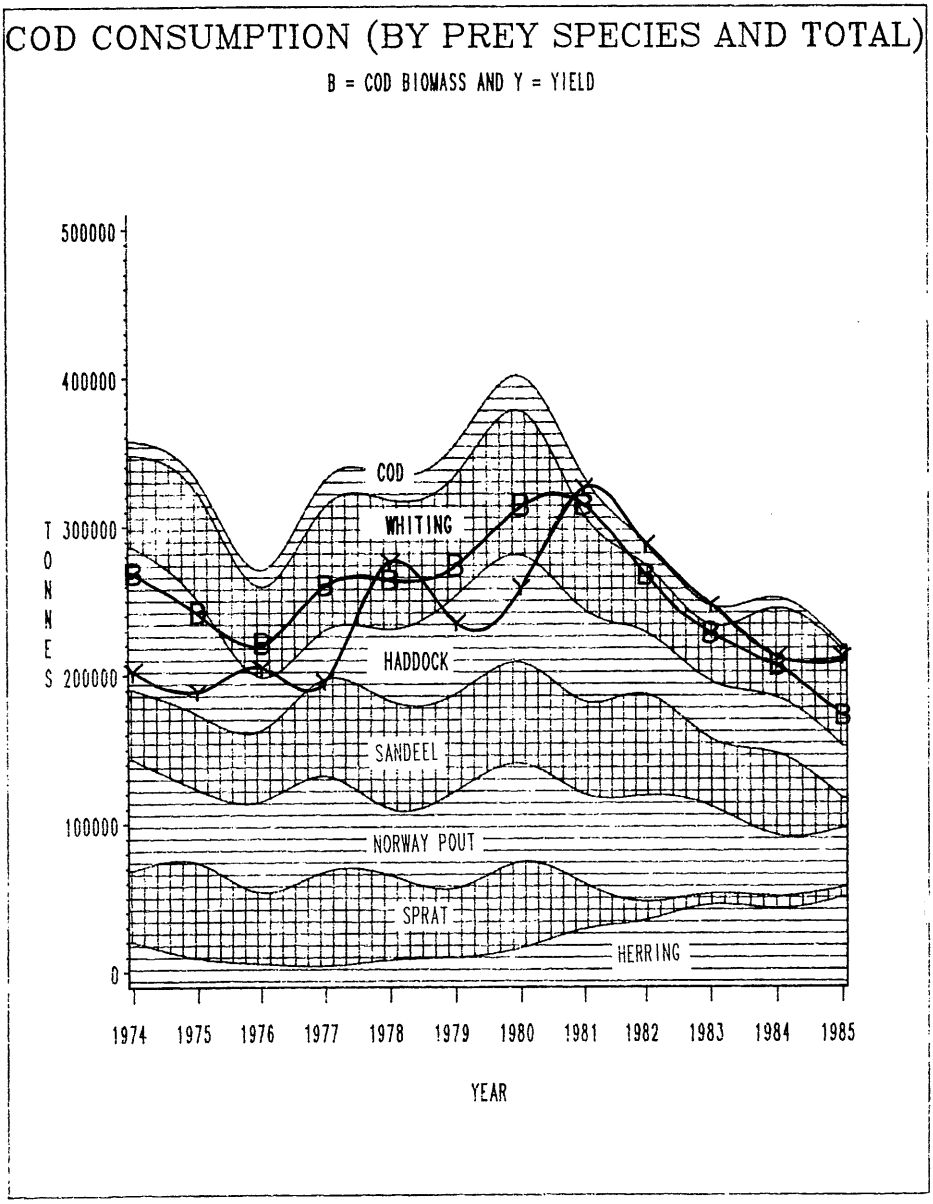


Figure 7.1.2b The consumption of predator species by prey species.

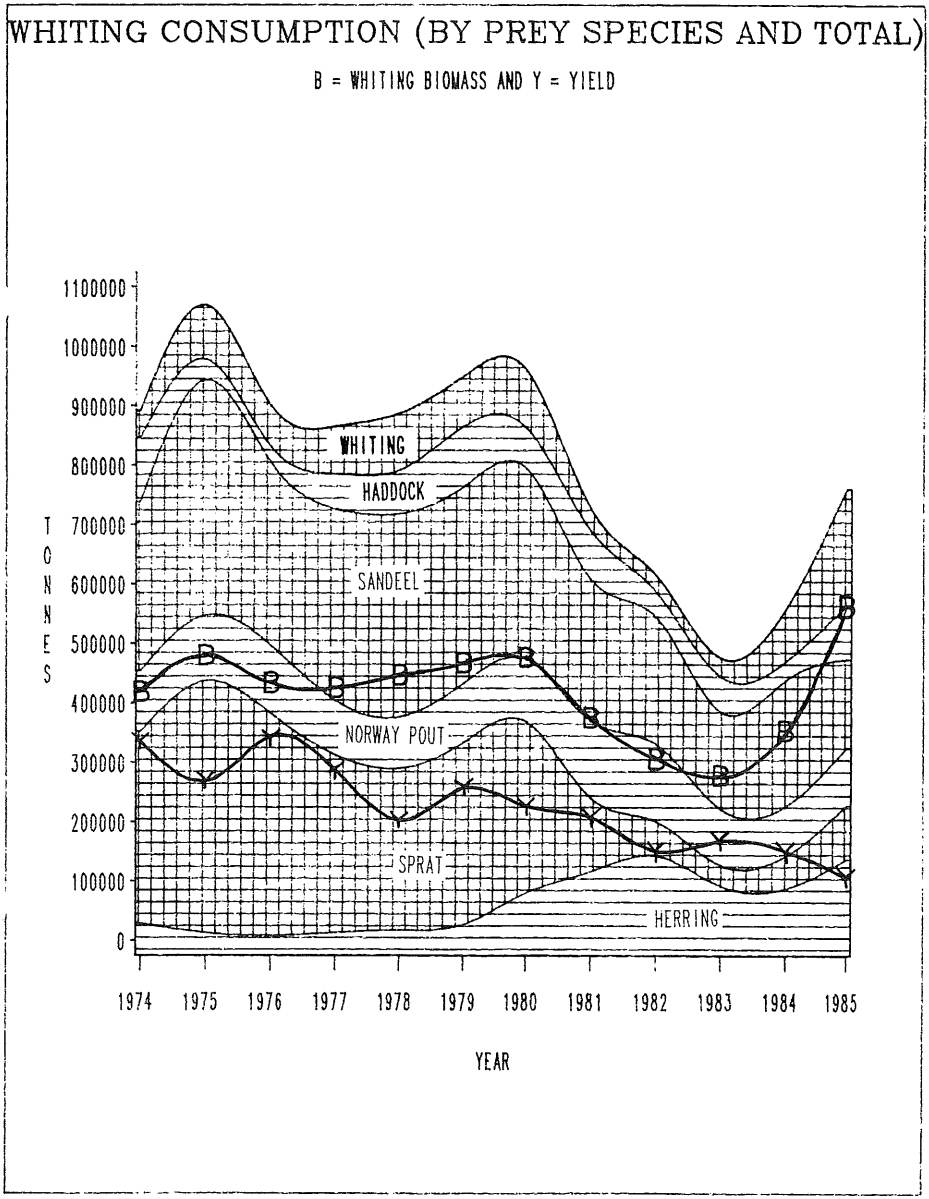


Figure 7.1.2c The consumption of predator species by prey species.

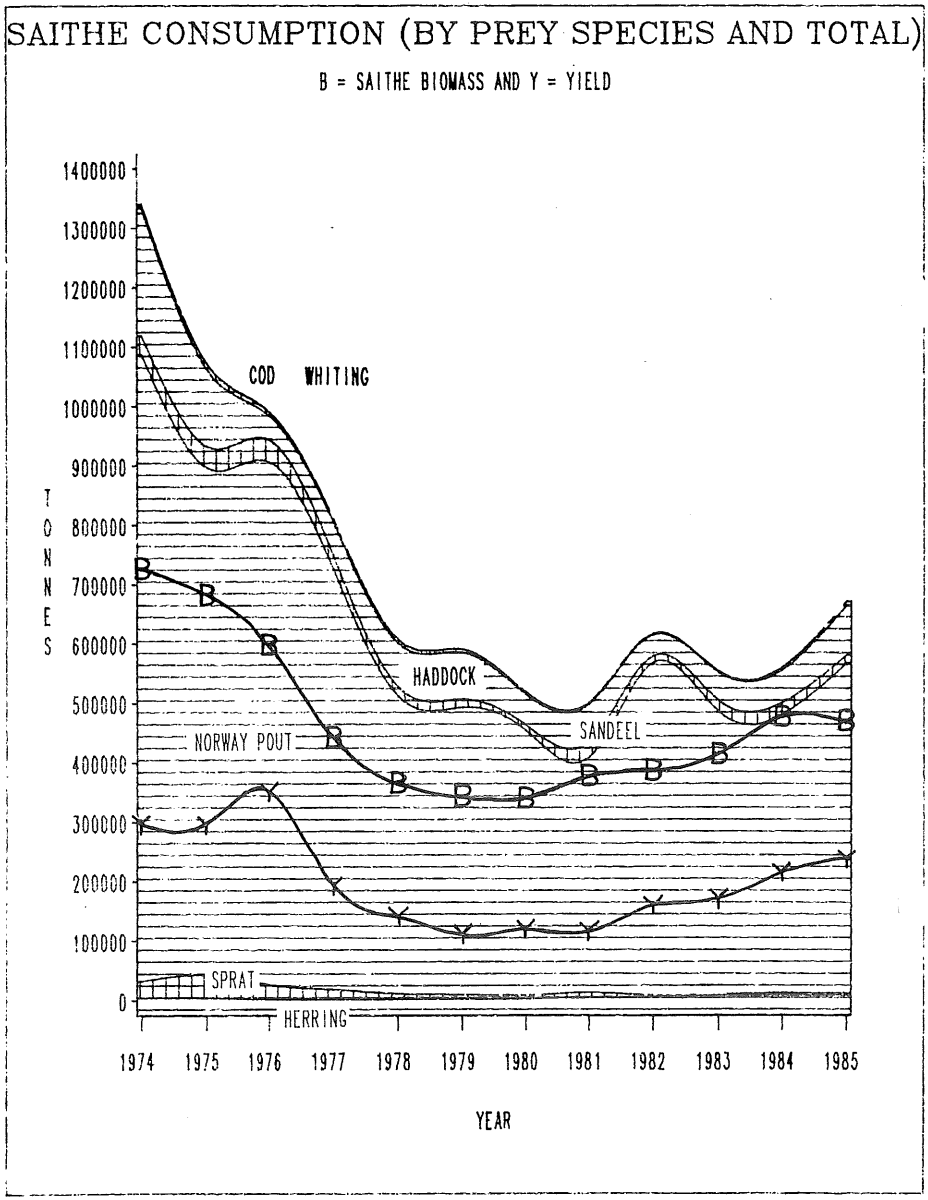


Figure 7.1.2d The consumption of predator species by prey species.

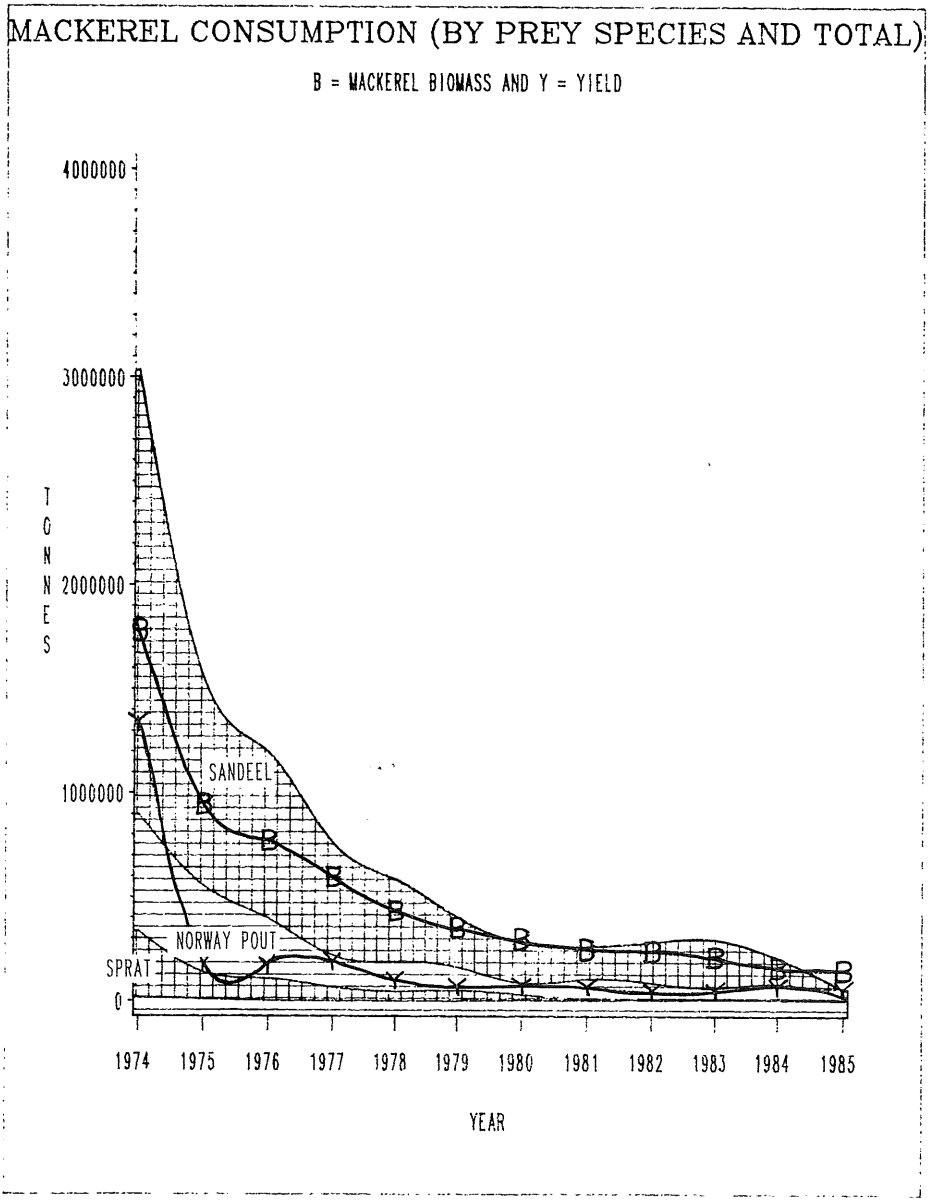


Figure 7.1.2e The consumption of predator species by prey species.

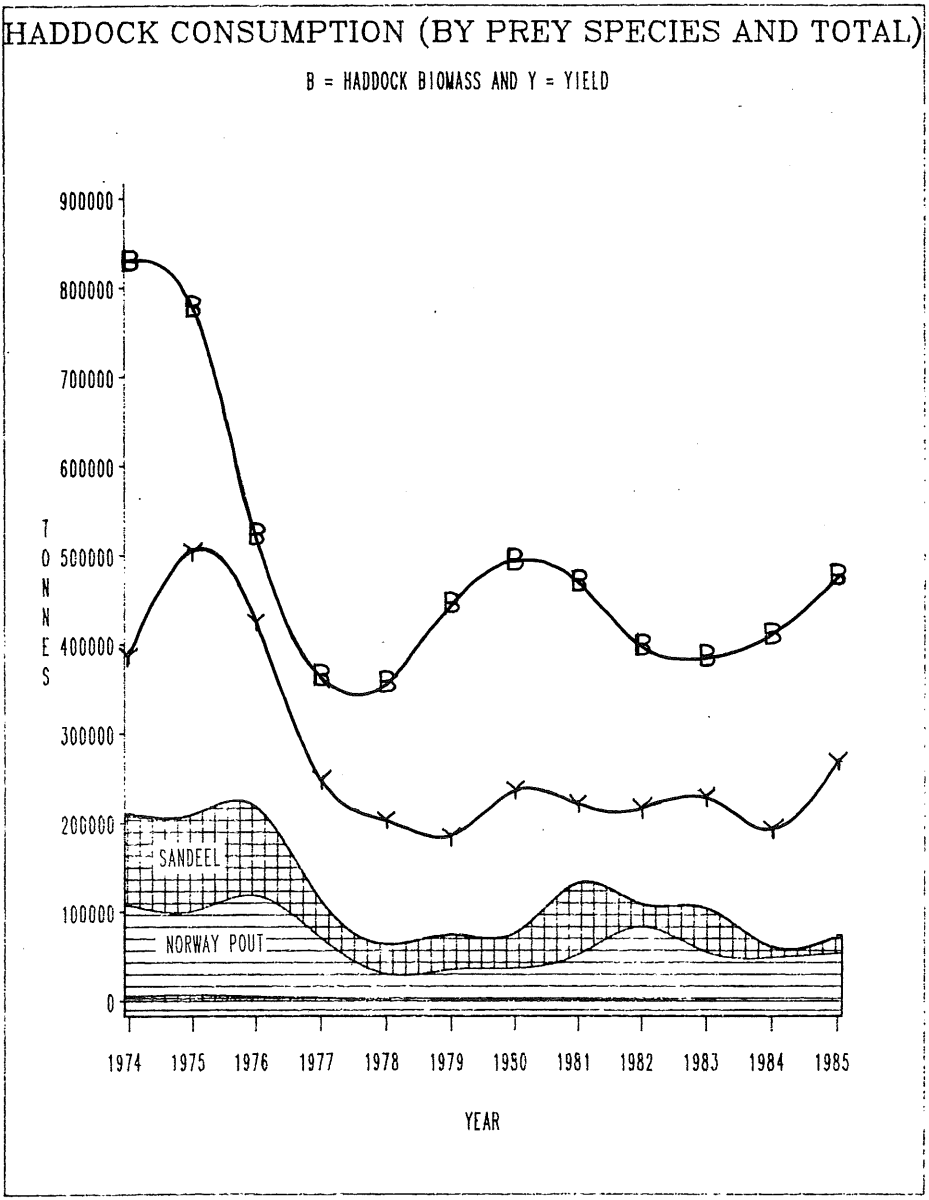
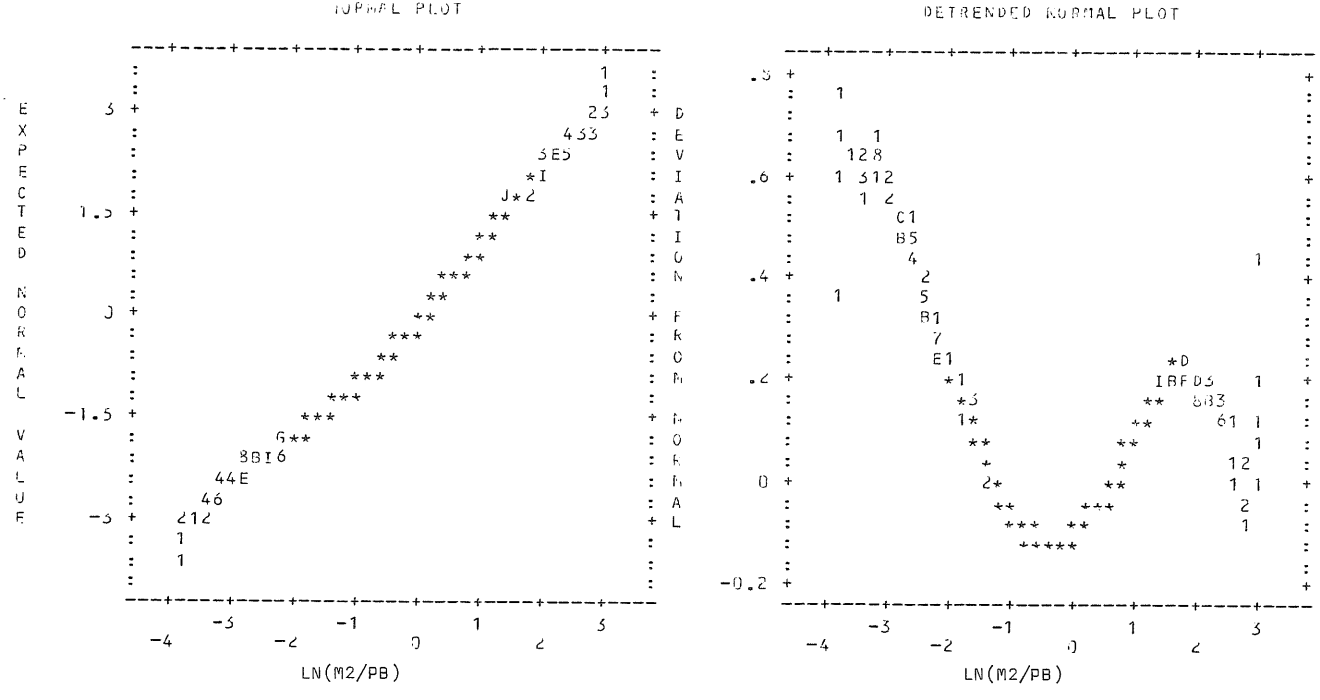


Figure 8.4.1 Plots showing the expected vs. fitted normal values and the deviations of the fitted normal values from expectation.



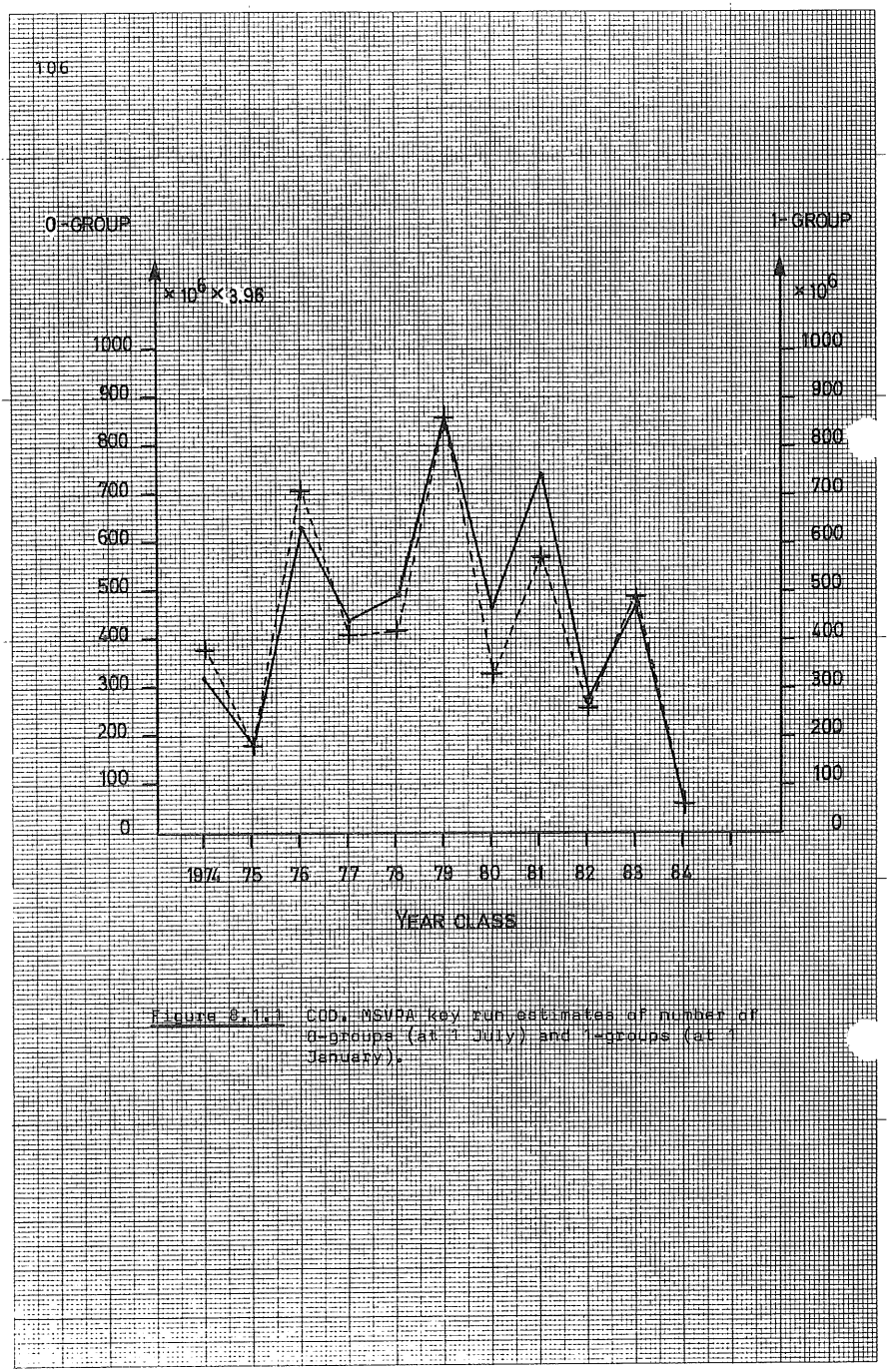


Figure 8.1.1 COD, NSVPA key run estimates of number of 0-groups (at 1 July) and 1-groups (at 1 January).

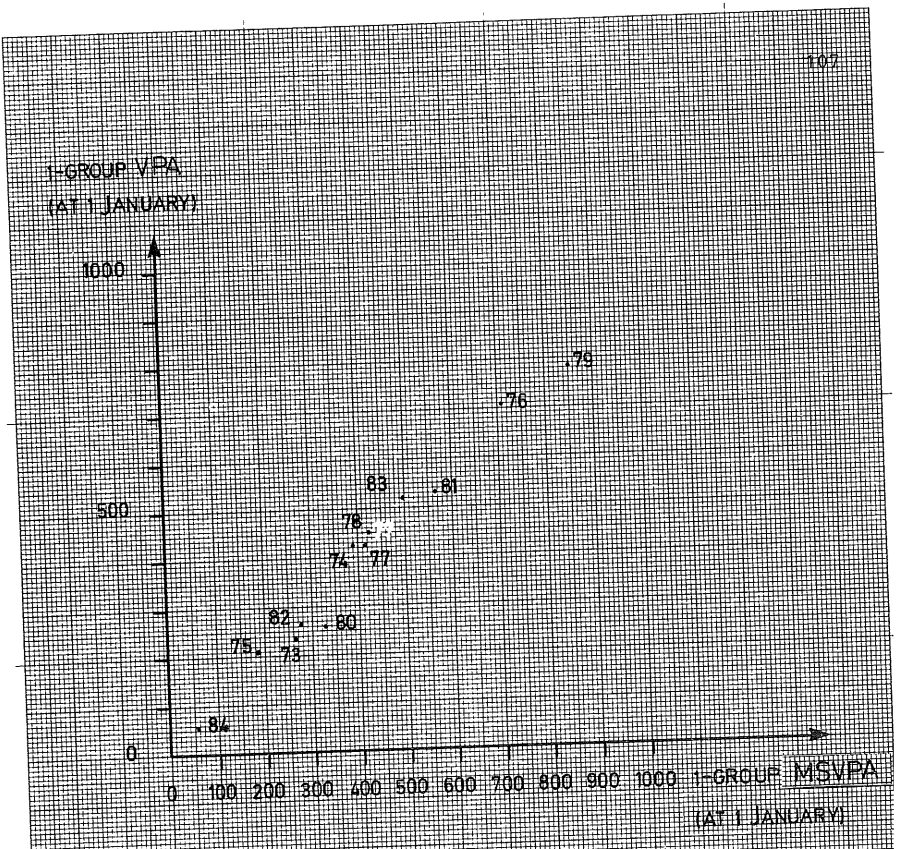


Figure 8.1.2 COD, MSVPA key run estimates of number of 1-groups plotted against the VPA numbers of 1-groups (year class indicated).

APPENDIX A

Working document for the
ad hoc Multispecies Assessment Working Group

November 1986

Tables of Weights in the Sea and Weights in the Catch for Use with the MSVPA Program

Erik Ursin

E. Ursin 4/6 1986.

Cod Body Weight in the Sea

Mid-quarter weights, kg

Q Y	1	2	3	4
0	0	0.000052	0.00598	0.0225
1	0.0519	0.116	0.230	0.377
2	0.576	0.682	0.829	1.12
3	1.51	2.00	2.28	2.65
4	3.30	3.99	4.58	5.04
5	5.45	5.87	6.81	7.53
6	7.76	8.18	8.39	8.72
7	9.00	9.81	10.80	10.9
8	10.9	11.2	11.6	11.9
9	12.2	12.5	12.8	13.0
10	13.3	13.5	13.7	14.0
11	14.2	14.3	14.5	14.7

Source:

Daan 1974 (Neth.J.Sea Res. 8(1):27-48)

Ages

(0,1)-(2,1):Fig 4. Eyefitted straight line through (0,-3.9cm) and (2,34.8cm).

(2,2)-(7,4): Table V, North

(8,1)-(11,4): Table IV, North

Condition factor: Fig 7.

Whiting Body Weight in the Sea E. Ursin 20/6 1986

Mid-quarter weights, kg.

Q Y	1	2	3	4
0	0	0.0010	0.0073	0.0192
1	0.0390	0.0635	0.0811	0.102
2	0.125	0.153	0.170	0.190
3	0.210	0.232	0.254	0.277
4	0.304	0.327	0.345	0.362
5	0.381	0.400	0.425	0.435
6	0.445	0.455	0.469	0.488
7	0.507	0.527	0.542	0.553
8	0.564	0.576	0.598	0.633
9	0.667	0.702	0.732	0.759
10	0.785	0.812	0.838	0.865

Source:

Ages (1,2)-(5,2) Jones and Hislop 1978. Table 31. Years 1967-74. Means of 4 areas 2nd quarter. Linear interpolation of lengths.

Ages (0,2)-(1,1) Knudsen 1963, Table XIII. Years 1956-57, raised to account for faster growth in recent years. Reference point: Jones and Hislop, age (1,2).

Ages (5,3)-(10,4) as in the catch 1974-85.

q = 0.0078 (Messtorff 1959).

Saithe Body Weight in the Sea E. Ursin 19/6 1986

Mid-quarter weights, kg.

Q Y	1	2	3	4
0	0	0.00001	0.0050	0.020
1	0.026	0.036	0.111	0.183
2	0.200	0.231	0.463	0.667
3	0.793	0.965	1.09	1.23
4	1.34	1.50	1.62	1.80
5	1.94	2.14	2.36	2.53
6	2.75	2.96	3.17	3.40
7	3.63	3.86	4.08	4.28
8	4.48	4.68	4.89	5.09
9	5.30	5.51	5.72	5.94
10	6.16	6.38	6.59	6.77
11	6.96	7.14	7.30	7.43
12	7.57	7.70	7.86	8.04
13	8.22	8.41	8.56	8.68
14	8.79	8.91	9.00	9.05
15	9.10	9.16	9.21	9.26

Source:

Bertelsen 1942 (Medd. Komm. Danm. F.-& H, Ser F,11(2))

Ages (0,2)-(2,3): Faroese Fjords!

Polonsky & Golubiatnikova

(C.M. 1970/F:23)

Ages (2,4)-(5,4): North Sea. Interpolation on smoothed curve of length. Obs. assumed at Aug. 15.

Ages (6,1)-(15,4) as in the Catch 1974-85.

q = 0.009 (Rep. Saithe W.G., C.M. 1974/F:2, Table 14).

Mackerel Body Weight in the Sea

Mid-quarter weights, kg.

E. Ursin 4/7 1986.

Q Y	1	2	3	4
0	0	0	0.010	0.035
1	0.080	0.180	0.220	0.230
2	0.215	0.275	0.330	0.310
3	0.270	0.340	0.385	0.365
4	0.315	0.385	0.425	0.405
5	0.355	0.425	0.460	0.445
6	0.390	0.465	0.495	0.480
7	0.430	0.500	0.530	0.515
8	0.460	0.535	0.560	0.550
9	0.495	0.565	0.590	0.580
10	0.530	0.595	0.620	0.605
11	0.560	0.625	0.650	0.635
12	0.590	0.650	0.680	0.660
13	0.620	0.670	0.705	0.680
14	0.645	0.695	0.735	0.700
15	0.675	0.710	0.760	0.715

Source:

As for weight in the catch.

Ages (1,3) and older are the same as in the catch.

Ages (0,3)-(1,2) were guessed assuming a birthday of 1st June. A smooth sigmoid was drawn from zero on the birthday to 220 g at age (1,3).

Haddock Body Weight in the Sea

Mid-quarter weights, kg.

E. Ursin 19/6 1986

Q Y	1	2	3	4
0	0	0.001	0.010	0.030
1	0.055	0.082	0.115	0.122
2	0.191	0.231	0.274	0.327
3	0.367	0.408	0.452	0.500
4	0.548	0.595	0.646	0.700
5	0.754	0.809	0.863	0.919
6	0.974	1.03	1.08	1.13
7	1.19	1.24	1.30	1.38
8	1.46	1.53	1.61	1.69
9	1.77	1.85	1.90	1.94
10	1.97	2.00	2.07	2.17
11	2.27	2.38	2.48	2.58

Source:

R. Jones, J. Cons. int. Explor. Mer, 41:50-62, 1983.

Ages (0,3)-(1,4): Table 3

Ages (2,1)-(2,3): Table 1

q = 0.01

Smoothed curve through 0 g at 1st March

Ages (2,4)- as in the catch 1974-1985.

Herring Body Weight in the Sea E. Ursin 3/7 1986

Mid-quarter weights, kg.

Q Y	1	2	3	4
0	0.0002	0.002	0.007	0.014
1	0.012	0.031	0.063	0.080
2	0.075	0.135	0.134	0.124
3	0.117	0.169	0.190	0.155
4	0.141	0.201	0.215	0.174
5	0.159	0.215	0.227	0.191
6	0.165	0.241	0.228	0.201
7	0.184	0.259	0.260	0.222
8	0.198	0.260	0.285	0.236
9	0.215	0.259	0.297	0.265

Source:

W.G. Rep. C.M. 1986/Assess:19 Table 2.8.1.
1985 data. Division IV b was used.
Ages (0,1) to (0,3): A smooth curve was drawn from age (0,4) backwards to an assumed birthday of Aug. 15 (age (-1,3)), passing below the sizes in the catch at ages (0,2) and (0,3).
Ages (0,4) and older as in the catch.

Sprat Body Weight in the Sea E. Ursin 3/7 1986
Mid-quarter weights, kg

Q Y	1	2	3	4	Source:
0	0	0.000005	0.00075	0.0033	Ages (0,2)-(0,4): W.G. Rep. 1978/Ass:6
1	0.0027	0.0047	0.0077	0.0104	Table 6.5.1.
2	0.0081	0.0108	0.0140	0.0173	Extrapolation to birthday (assumed 1st May)
3	0.0154	0.0175	0.0203	0.0232	of cube root of body weights.
4	0.0218	0.0249	0.0228	0.0246	Ages (1,1) and older as in the catch.

Norway Pout Body Weight in the Sea E. Ursin 2/7 1986

Mid-quarter weights, kg.

Q Y	1	2	3	4
0	0.000014	0.0012	0.0049	0.0069
1	0.0076	0.0112	0.0242	0.0261
2	0.0238	0.0259	0.040	0.044
3	0.042	0.041	0.053	0.056

Source:

Juveniles: W.G. Rep. 1978, Fig 2.3.1. Extrapolation to 1st Febr. (assumed birthday); q by quarters from Ursin 1963.

Otherwise as size in the catch except for a slight smoothing.

Sandeels Body Weight in the Sea E. Ursin 2/7 1986

Mid-quarter weights, kg.

Q Y	1	2	3	4	Source:
0	0.000012	0.00035	0.00132	0.00300	Ages (0,1)-(0,4): Extrapolation on the curve
1	0.0039	0.0061	0.0106	0.0162	of Macer 1965, Table 2, assuming birthday 1st
2	0.0099	0.0106	0.0179	0.0369	Jan. and
3	0.0150	0.0153	0.0233	0.0529	q = 0.003.
4	0.0204	0.0189	0.0248	0.0523	Ages (1,1) and older as in the catch.
5	0.0221	0.0197	0.0302	0.0320	
6	0.0185	0.0223	0.0318	0.0330	

To promote confusion, see W.G. Rep. C.M. 1978/G:12, Figs 3.2.2 and 3.2.3.
W.G. Rep. C.M. 1984/Assess:9, Tables 5.5.2 and 5.5.3.

Cod Body Weight in the Catch

Mid-quarter weights, kg.

Q Y	1	2	3	4
1	0.460	0.548	0.636	0.724
2	0.812	0.900	1.09	1.39
3	1.69	1.99	2.41	2.96
4	3.50	4.04	4.59	5.15
5	5.70	6.26	6.80	7.33
6	7.86	8.40	8.85	9.24
7	9.62	10.0	10.4	10.7
8	11.0	11.3	11.7	12.0
9	12.3	12.6	12.9	13.0
10	13.2	13.3	13.6	13.9
11	14.2	14.5	14.7	14.7

Source:

Rep. N.S. Roundfish W.G. 1986
(C.M. 1986/Assess:16)

Table 11.7. Mean weights for 1974-85 assumed to mid-year. Linear interpolation. Linear extrapol. for ages (1,1) and (1,2).

Whiting Body Weight in the Catch E. Ursin 19/6 1986

Mid-quarter weights, kg.

Q Y	1	2	3	4
0	0	0.0089	0.0267	0.0445
1	0.0624	0.0802	0.101	0.124
2	0.148	0.172	0.194	0.215
3	0.236	0.257	0.277	0.297
4	0.316	0.335	0.354	0.373
5	0.392	0.411	0.425	0.435
6	0.445	0.455	0.469	0.488
7	0.507	0.527	0.542	0.553
8	0.564	0.576	0.598	0.633
9	0.667	0.702	0.732	0.759
10	0.785	0.812	0.838	0.865

Source:

Rep. N.S. Roundfish W.G. 1986 (C.M. 1986/Assess:16) Table 19.7. Mean weights for 1974-85 assumed to relate to mid-year. Linear interpolation. Linear extrapolation for ages (0,2), (10,3) and (10,4). Data were smoothed by moving averages of 3 before interpolation.

Saithe Body Weight in the Catch

Mid-quarter weights, kg.

E. Ursin 20/6 1986

Q Y	1	2	3	4
0				
1	0.251	0.293	0.335	0.377
2	0.419	0.461	0.527	0.618
3	0.708	0.799	0.924	1.08
4	1.24	1.40	1.58	1.76
5	1.95	2.14	2.34	2.54
6	2.75	2.96	3.17	3.40
7	3.63	3.86	4.08	4.28
8	4.48	4.68	4.89	5.09
9	5.30	5.51	5.72	5.94
10	6.16	6.38	6.59	6.77
11	6.96	7.14	7.30	7.43
12	7.57	7.70	7.86	8.04
13	8.22	8.41	8.56	8.68
14	8.79	8.91	9.00	9.05
15	9.10	9.16	9.21	9.26

Source:

Rep. N.S. Roundfish W.G. 1986 (C.M. 1986/Assess:16)
Table 23.7. Mean weights for 1974-85 assumed to relate to mid-year. Linear interpolation for ages (1,1), (1,2), (15,2) and (15,4).

Mackerel Body Weight in the Catch

Mid-quarter weights, kg.

E. Ursin 4/7 1986

Q Y	1	2	3	4
0	0	0	0	0.105
1	0.120	0.195	0.220	0.230
2	0.215	0.275	0.330	0.310
3	0.270	0.340	0.385	0.365
4	0.315	0.385	0.425	0.405
5	0.355	0.425	0.460	0.445
6	0.390	0.465	0.495	0.480
7	0.430	0.500	0.530	0.515
8	0.460	0.535	0.560	0.550
9	0.495	0.565	0.590	0.580
10	0.530	0.595	0.620	0.605
11	0.560	0.625	0.650	0.635
12	0.590	0.650	0.680	0.660
13	0.620	0.670	0.705	0.680
14	0.645	0.695	0.735	0.700
15	0.675	0.710	0.760	0.715

Source:

W.G. 1985/Assess:7 and
W.G. 1986/Assess:12 (Appendixes on data req. by the multisp. W.G.)

Data was averaged for all years with new information and smoothed by fitting (by eye) of curves to data for each quarter.

Note: the increase is almost linear from age 4 to age 14.

Haddock Body Weight in the Catch
Mid-quarter weights, kg.

E. Ursin 19/6 1986

Q Y	1	2	3	4
0		0.0016	0.0272	0.0528
1	0.0784	0.1040	0.135	0.172
2	0.210	0.247	0.286	0.327
3	0.367	0.408	0.452	0.500
4	0.548	0.595	0.646	0.700
5	0.754	0.809	0.863	0.919
6	0.974	1.03	1.08	1.13
7	1.19	1.24	1.30	1.38
8	1.46	1.53	1.61	1.69
9	1.77	1.85	1.90	1.94
10	1.97	2.00	2.07	2.17
11	2.27	2.38	2.48	2.58

Source:

N.S. Roundfish W.G. 1986 (C.M. 1986/Assess:16)

Table 15.7. Mean weights for 1974-85 assumed to relate to mid-year. Linear interpolation.
Linear extrapol. for ages (0,2), (11,3) and (11,4).

Herring Body Weight in the Catch

Mid-quarter weights, kg

E. Ursin 3/7 1986

Q Y	1	2	3	4
0		0.005	0.009	0.014
1	0.012	0.031	0.063	0.080
2	0.075	0.135	0.134	0.124
3	0.117	0.169	0.190	0.155
4	0.141	0.201	0.215	0.174
5	0.159	0.215	0.227	0.191
6	0.165	0.241	0.228	0.201
7	0.184	0.259	0.260	0.222
8	0.198	0.260	0.285	0.236
9	0.215	0.259	0.297	0.265

Source:

W.G. Rep. C.M. 1986/Assess 19 Table 2.8.1.
1985 data. Division IV b was used.
This has almost the same mean weights for the year as "North Sea Total", and data is supplied by the quarter. Seasonal variation in age group 9 was made similar to younger ages by subtracting 23 g from age (9,1) and adding 23 g to age (9,4).

Sprat Body Weight in the Catch

Mid-quarter weights, kg.

E. Ursin 3/7 1986

Q Y	1	2	3	4
0	0	0.001	0.0030	0.0035
1	0.0026	0.0047	0.0077	0.0104
2	0.0081	0.0108	0.0140	0.0173
3	0.0154	0.0175	0.0203	0.0232
4	0.0218	0.0249	0.0228	0.0246

Source:

W.G. rep. 1978/H:3 Tab. 7.4

1982/Ass:6 Tab. 6.5.1

1984/Ass:9 Tab. 7.5.1

Norway Pout Body Weight in the Catch

Mid-quarter weights, kg.

E. Ursin 2/7 1986

Q Y	1	2	3	4	Source:
0			0.00534	0.00693	W.G. Rep. C.M. 1978/G:12
1	0.00756	0.0112	0.0242	0.0261	1983/Assess:7
2	0.0238	0.0259	0.0411	0.0437	1984/Assess:9
3	0.0424	0.0394	0.0559	0.0548	1985/Assess:8
					1986/Assess:15

Sandeels Body Weight in the Catch

Mid-quarter weights, kg.

E. Ursin 2/7 1986

Q Y	1	2	3	4
0	0	0.0012	0.0031	0.0046
1	0.0039	0.0061	0.0106	0.0162
2	0.0099	0.0106	0.0179	0.0369
3	0.0150	0.0153	0.0233	0.0529
4	0.0204	0.0189	0.0248	0.0523
5	0.0221	0.0197	0.0302	0.0320
6	0.0185	0.0223	0.0318	0.0330

Source:

Data from current MSVPA program, except that w(0,1) = 0.

APPENDIX B

Table showing how total F is partitioned (%) among the six fisheries (1 = roundfish human consumption, 2 = industrial demersal, 3 = industrial pelagic, 4 = herring, 5 = saithe, and 6 = mackerel).

Species	Age	Fisheries						F
		1	2	3	4	5	6	
Cod	0	-	1.000	-	-	-	-	-
	1	0.677	0.323	-	-	-	-	0.1808
	2	0.981	0.019	-	-	-	-	0.9936
	3	1.000	-	-	-	-	-	1.0351
	4	1.000	-	-	-	-	-	0.7227
	5	1.000	-	-	-	-	-	0.7494
	6	1.000	-	-	-	-	-	0.7005
	7	1.000	-	-	-	-	-	0.7165
	8	1.000	-	-	-	-	-	0.7006
	9	1.000	-	-	-	-	-	0.7793
	10	1.000	-	-	-	-	-	0.7580
	11	1.000	-	-	-	-	-	0.8201
Whiting	0	0.111	0.667	0.222	-	-	-	0.0473
	1	0.714	0.238	0.048	-	-	-	0.2221
	2	0.744	0.231	0.026	-	-	-	0.4269
	3	0.829	0.157	0.014	-	-	-	0.7307
	4	0.956	0.044	-	-	-	-	0.8660
	5	0.961	0.039	-	-	-	-	0.9674
	6	0.985	0.015	-	-	-	-	1.2494
	7	0.991	0.009	-	-	-	-	1.1995
	8	1.000	-	-	-	-	-	1.4252
	9	1.000	-	-	-	-	-	0.7064
	10	1.000	-	-	-	-	-	1.2000
	11	1.000	-	-	-	-	-	1.2000
Saithe	0	-	-	-	-	1.000	-	-
	1	-	-	-	-	1.000	-	0.0107
	2	0.182	-	-	-	0.818	-	0.1799
	3	0.130	0.043	-	-	0.826	-	0.2579
	4	0.156	0.031	-	-	0.813	-	0.4082
	5	0.130	-	-	-	0.870	-	0.5550
	6	0.133	-	-	-	0.867	-	0.5178
	7	0.149	-	-	-	0.851	-	0.4832
	8	0.203	-	-	-	0.797	-	0.4874
	9	0.200	-	-	-	0.800	-	0.4298
	10	0.200	-	-	-	0.800	-	0.3452
	11	0.200	-	-	-	0.800	-	0.3490
	12	0.200	-	-	-	0.800	-	0.3642
	13	0.200	-	-	-	0.800	-	0.3811
	14	0.200	-	-	-	0.800	-	0.4017
	15	0.200	-	-	-	0.800	-	0.3001

cont'd.

Species	Age	Fisheries						F
		1	2	3	4	5	6	
Mackerel	0	-	-	-	-	-	1.000	-
	1	-	-	-	-	-	1.000	0.0155
	2	-	-	-	-	-	1.000	0.0626
	3	-	-	-	-	-	1.000	0.1720
	4	-	-	-	-	-	1.000	0.1924
	5	-	-	-	-	-	1.000	0.2688
	6	-	-	-	-	-	1.000	0.2614
	7	-	-	-	-	-	1.000	0.2293
	8	-	-	-	-	-	1.000	0.3094
	9	-	-	-	-	-	1.000	0.2786
	10	-	-	-	-	-	1.000	0.3246
	11	-	-	-	-	-	1.000	0.2313
	12	-	-	-	-	-	1.000	0.3014
	13	-	-	-	-	-	1.000	0.3621
	14	-	-	-	-	-	1.000	0.4864
	15	-	-	-	-	-	1.000	0.6012
Haddock	0	0.143	0.857	-	-	-	-	0.0470
	1	0.560	0.440	-	-	-	-	0.2814
	2	0.917	0.083	-	-	-	-	0.7081
	3	0.958	0.042	-	-	-	-	1.1069
	4	0.950	0.050	-	-	-	-	1.0630
	5	0.975	0.025	-	-	-	-	0.8921
	6	1.000	-	-	-	-	-	0.8628
	7	1.000	-	-	-	-	-	0.9038
	8	1.000	-	-	-	-	-	0.7865
	9	1.000	-	-	-	-	-	0.7804
	10	1.000	-	-	-	-	-	0.5983
	11	1.000	-	-	-	-	-	0.9000
Herring	0	-	-	1.000	-	-	-	0.1414
	1	-	-	0.737	0.263	-	-	0.2020
	2	-	-	0.417	0.583	-	-	0.1670
	3	-	-	0.563	0.438	-	-	0.2420
	4	-	-	0.357	0.643	-	-	0.2019
	5	-	-	0.500	0.500	-	-	0.1927
	6	-	-	0.250	0.750	-	-	0.1122
	7	-	-	0.400	0.600	-	-	0.3283
	8	-	-	0.400	0.600	-	-	0.8344
	9	-	-	0.400	0.600	-	-	0.1204
Sprat	0	-	-	1.000	-	-	-	0.0041
	1	-	-	1.000	-	-	-	0.5081
	2	-	-	1.000	-	-	-	0.9768
	3	-	-	1.000	-	-	-	2.1319
	4	-	-	1.000	-	-	-	1.3267
	5	-	-	1.000	-	-	-	1.3267

cont'd.

Species	Age	Fisheries						F
		1	2	3	4	5	6	
Norway pout	0	-	1.000	-	-	-	-	0.0530
	1	-	1.000	-	-	-	-	0.5076
	2	-	1.000	-	-	-	-	1.6460
	3	-	1.000	-	-	-	-	1.5640
Sandeel	0	-	1.000	-	-	-	-	0.0995
	1	-	1.000	-	-	-	-	0.4287
	2	-	1.000	-	-	-	-	0.8913
	3	-	1.000	-	-	-	-	0.8254
	4	-	1.000	-	-	-	-	0.8451
	5	-	1.000	-	-	-	-	0.7802
	6	-	1.000	-	-	-	-	0.8780
	7	-	1.000	-	-	-	-	0.8780

APPENDIX C

Calculations used in M2 smoothing (Section 8.4).

$\alpha(sp)$ = LWTR slope for species (sp)

β = LWTRSQ coefficient

1) $\sigma = \sqrt{1/(2\beta)}$

2) $\mu(sp) = \sigma^2/\alpha(sp)$

3) Correction term (sp) = $0.5 \left[\frac{\mu(sp)}{\sigma}\right]^2$

4) Overall predation mortality =

= 4 x Exp [Constant + Interaction (Reference)+cor(Reference)]

5) Preferred size ratio =

= Exp $[\alpha(sp)/(2\beta)]$