

Fol. 41 Assess

Fiskeridirektoratet
Biblioteket

This report not to be quoted without prior reference to the Council*

International Council for the
Exploration of the Sea

C.M.1988/Assess:23

REPORT OF THE MULTISPECIES ASSESSMENT WORKING GROUP

Copenhagen, 1-8 June 1988

This document is a report of a Working Group of the International Council for the Exploration of the Sea and does not necessarily represent the views of the Council. Therefore, it should not be quoted without consultation with the General Secretary.

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

T A B L E O F C O N T E N T S

<u>Section</u>	<u>Page</u>
1 INTRODUCTION	1
1.1 Participants	1
1.2 Terms of Reference	1
1.3 Overview	1
1.4 Acknowledgements	4
2 TEST RUNS WITH THE MULTISPECIES VPA (MSVPA)	4
2.1 Fortran Programs	4
2.2 Catch-at-Age Data	5
2.3 Relative Food Composition Data	6
2.4 Estimates of Rations Used in MSVPA Runs	7
2.5 M1 Values Used in the Runs	7
2.6 Feeding Relationship Used in Runs	11
2.7 Weights at Age Used	11
2.8 The Key Run of the MSVPA	12
3 SHORT-TERM PREDICTION PROBLEMS	14
4 LONG-TERM YIELD	14
4.1 Introduction	14
4.2 Description of Long-Term Models	15
4.3 Parameterization of Models	15
4.4 Changes in Long-Term Yield Resulting from Changes in Various Fisheries	16
4.5 Herring/Haddock Sensitivity	17
4.6 Long-Term Effects of Changing the Minimum Mesh Size in the North Sea Roundfish (Including Saithe) Fishery	18
4.7 Sensitivity of Mesh Change Analysis to Assumptions About Natural Mortality	20
5 FEEDING STUDIES	21
5.1 Stomach Sampling Programme 1985-1987	21
5.2 Stomach Content Data Base	21
5.3 Predation On and Among O-Group Fish	22
5.4 Food Consumption	22
5.5 Future Stomach Sampling Programs	23
5.6 Multispecies Symposium	23
6 COMPARISON OF SUITABILITIES	24
6.1 The Problem	24

<u>Section</u>	<u>Page</u>
6.2 Comparing Fits of Basic Models to the Suitability Data Sets	25
6.3 Investigations of Reasons for Variation in Suitabilities	28
6.4 Summary	31
6.5 Comparison of Observed and Predicted Relative Stomach Content Composition	32
7 MSVPA PERSPECTIVES OF FEEDING RELATIONSHIPS IN THE NORTH SEA	32
7.1 Who Eats Who?	32
8 FOOD FOR THOUGHT	33
8.1 Alternative Forms of MSVPA	33
8.2 Uniqueness of MSVPA Equations	33
8.3 Smoothing of Suitabilities	35
8.4 Smoothing the M2 Values	37
8.5 Fisheries Interactions	38
8.6 Use of Survey Data	41
9 FORECASTING THE LONG-TERM EFFECTS OF SUBSTANTIAL CHANGES IN SOME FISHERIES	41
9.1 Industrial Demersal Fishery Increased by 25%	42
9.2 Roundfish - Human Consumption Fishery Increasing	42
9.3 No Mackerel Fishery	42
9.4 Herring Fishery Doubled	42
9.5 General Remarks	43
10 MULTISPECIES MODELS IN OTHER AREAS	43
10.1 Introduction	43
10.2 Multispecies Models for Arctic Regions	43
10.3 Exporting North Sea MSVPA Results to Other Areas	45
11 RECOMMENDATIONS	46
12 REFERENCES	47
Tables 2.3.1 - 9.4.1	50
Figures 2.5.1 - 10.3.1	113
Appendix A	152
Appendix B	153-154

1 INTRODUCTION

1.1 Participants

B. Bogstad	Norway
N. Daan	Netherlands
P. Degnbol	Denmark
H. Gislason	Denmark
T. Helgason	Iceland
S. Mehl	Norway
B. Mesnil	France
J.G. Pope (Chairman)	UK (England)
J. Rice	Canada
H. Sparholt	Denmark
K. Stokes	UK (England)
S. Tjelmeland	Norway
M. Vinther	Denmark

1.2 Terms of Reference

The terms of reference (C.Res.1987/2:3:17) are:

- a) continue the development of multispecies methods of assessment;
- b) consider and comment on the prototype questions proposed by ACFM in the minutes of its 4-14 May 1987 meeting;
- c) consider the report of the EEC Workshop on the Assessment of Technical Interactions in Mixed Fisheries and its implications for future work;
- d) evaluate the possibility of a simple generalization of the MSVPA estimates of M for the North Sea stocks for application in other areas;
- e) consider multispecies interactions with marine mammals and seabirds.

1.3 Overview

Previous meetings of the Multispecies Assessment Working Group (Anon., 1984, 1986b, and 1987a) have progressively refined the Multispecies Virtual Population Analysis (MSVPA) method as an assessment tool and developed appropriate methods for forecasting long-term and short-term yield with multispecies effects included. As in these past meetings, the current meeting has enabled the technique to be refined and its results extended. These multispecies assessments have previously been based upon the assessment data sets provided by the single-species assessment working groups of ICES and from the results provided by the coordinators of the 1981 ICES Stomach Sampling Programme. This year, additional stomach data were provided by the coordinators for the first and third quarters of 1985, 1986, and 1987. Species involved in this extra stomach sampling were cod, whiting, and

saithe. Clearly, incorporating these extra data into the MSVPA was a first priority for the Group since it both enables the calculations to be more soundly based and also allows the hypothesis of constant suitability of prey for predators to be tested. Section 2 of this report details modifications to the program needed to do this together with details of the data set used. The main developments to the data set were the new feeding data and improvements in the M1s (other natural mortality rates) used which resulted from new data and from an improved smoothing technique. Results from the key run of the MSVPA are also shown in this section. Predation mortality results are generally comparable with previous estimates. This suggests that the technique is coming of age with new data and programming developments, having only minor impacts on our perceptions of mortality in the North Sea.

Section 3 of the report continues the investigation of the effect of multispecies interaction on short-term advice. In past years, it had been reasonably established both in theory and practice that the use of high but constant levels of natural mortality need not affect the accurate estimation of status quo TACs, provided suitable assessment techniques were used. At this meeting, therefore, the important question was whether variations in natural mortality from year to year might upset the TAC prediction process. Time did not allow more than simple investigation to this problem using regressions between recruitment estimates made using SSVPA and MSVPA. The general impression to emerge from this work is that while short-term predictions might in principle be affected by multispecies effects, in practice this seldom seems to happen. There was an indication that haddock recruitment as estimated by MSVPA had increased relative to the single-species assessment in recent years, but it was noted that methods such as RCRTINX2 which gives the greatest weight to recruitment estimates in the most recent years will largely overcome such problems. Clearly, this aspect of the problem will warrant further consideration.

Section 4 of the report considers multispecies effects on long-term yield assessment. Modifications to the Shepherd method were adopted which produced results which were generally in close accord with those of the MSVPA forecast method MSFOR. This is valuable since it gives an independent check on the most controversial calculations. This year, in addition to calculating the effects of 10% change in effort of the standard fleets, calculations were made of the effects of mesh changes in a multispecies fishery. It has been noted in past meetings that increasing the effort in the roundfish fishery increased yield for a number of species due to the reduction in the predation mortality and it might, therefore, be expected that the mesh increase would produce the opposite effect of increasing predation mortality and decreasing yield. Preliminary analysis by Lewy and Gislason (1988), presented to the North Sea Roundfish Working Group, has suggested that this was the case, and ACFM consequently made a special request for the Working Group to present its view on this (see Appendix A). Findings in this report confirm the Lewy and Gislason results and suggest that an increase in mesh size in the roundfish and saithe fisheries would reduce yields in most fisheries. These results underline the inappropriateness of long-term advice being given by single-species

models which do not account for changes in predation mortality.

Calculations were also made of the likely change in value of the catch under mesh changes. This indicated that while the unit value of fish would increase, this would probably not compensate for the loss of yield that a mesh increase would entail. Some sensitivity analysis was conducted on these mesh change results to see if excluding 0-group fish from the analysis altered the conclusions. It was found that it did reduce the loss of yield that a mesh increase would cause to most stocks, but did not eliminate it.

Section 5 of the report sets out an overview of current and proposed feeding studies. Important conclusions reached relate to the need for further studies of predation between and on 0-group fish and the need to begin planning a new stomach sampling programme for 1991.

Section 6 is concerned with the investigation of the consistency of the suitability of prey for predators over time; the assumption that suitability is constant being central to the MSVPA. This study became possible with the availability of new stomach contents data from 1985, 1986, and 1987 for cod, whiting, and saithe. The questions asked were how much does suitability vary from year to year and, if it does vary, can the variation be explained by simply measured concomitant variables such as predator or prey biomass or overlap measures. Conclusions from a very detailed study indicate that suitability only varies by modest amounts from year to year. Some of this variation can be related to change in prey abundance but not to change in overlap measures.

Section 7 gives an overview of predation in the North Sea indicating who eats who and how much.

Section 8 is the Working Group's new ideas section. By tradition, the Working Group encourages speculation in this section. Of particular note this year is a substantial item on fisheries interactions using Principal Component Analysis as a method for interpreting fleet structures.

Section 9 shows the results of some further analyses suggested by ACFM (Appendix B) concerned with long-term advice under substantial changes in some aspects of the fisheries. Results are broadly in line with those found under more modest changes in Section 4.

Section 10 reviews multispecies work being conducted in other areas by Group members. In particular, a model of the North-East Arctic is presented. It is felt that multispecies research in boreal regions is important and should be encouraged by a special meeting of the Working Group in 1990 dedicated to this subject.

Consideration is also given to possible generalization of the MSVPA estimates for M for the North Sea stocks for application in other areas.

The Working Group has thus been able to address the majority of its terms of reference. With respect to the request for the

Working Group to consider technical interactions, and particularly the report of the EC Workshop on the Assessment of Technical Interactions in Mixed Fisheries and its implications for future work, the Working Group agreed with the desirability of more detailed work on technical measures. The Working Group noted, however, that the recently-formed European Commission's STFC Working Group on Technical Measures had undertaken to split catch-at-age data by EC national fleets. Since this is a major data source which will become available in due course, the Working Group considered it would be inappropriate to start a major new initiative at this meeting; it was, however, able to make some indicative analyses in Section 8. It also felt this work would be pursued vigorously under the next chairman.

The extra day available at this meeting compared to previous years was appreciated, but given the magnitude of the tasks to be undertaken, an extension by 2 days would be welcome.

1.4 Acknowledgements

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 and computer programs 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. It also noted with pleasure the availability of the IYFS data base.

2 TEST RUNS WITH THE MULTISPECIES VPA (MSVPA)

2.1 Fortran Programs

The MSVPA and MSFOR programs are extended versions of the programs used in the previous report.

The MSVPA program has been changed to allow for several years of observations of food composition in the way indicated in the previous report (Anon., 1987a).

An initial guess on the quarterly suitabilities is used to estimate predation mortalities and stock sizes. In each quarter for which food composition data are available, these stock sizes are used to estimate a new suitability matrix in the usual way. The guessed suitabilities are then replaced by a weighted average of the new suitabilities and a new set of stock sizes and mortalities estimated. The procedure is repeated until the average

suitability remains fairly constant.

The weight given to each suitability estimate should in some way reflect the precision with which the food composition is determined. With all the complications introduced by regurgitated stomachs, by weighting the samples with the abundance of the predator, by prey and predator ALKS, etc., it is very complicated to derive a statistically sound estimate of the reliability of each individual set of data on food composition. At present, an estimate of the number of stomachs sampled from each predator age group is used to weight the individual estimates of suitability.

However, an additional complication remains. In the MSVPA, the food composition of each predator age class is estimated from

$$\text{Food comp} = \frac{G \times N \times W\text{-stom}}{\sum G \times N \times W\text{-stom}}$$

where G is suitability, N is the average number of a particular prey age group, and W-stom is the average individual weight of the prey age group at ingestion. Assuming suitability to be constant, the average numbers of each prey age group can be estimated by the MSVPA, provided estimates of W-stom are available. In years and quarters with food composition data, such estimates exist, but in the remaining time, W-stom must either be calculated from an additional model of size selection or it must be assumed to remain constant with time. The present version of the program uses the latter simple option. Given several years of data on food composition and W-stom for a particular quarter, the program initially calculates a weighted average of W-stom where the weight given to each observation equals the number of stomachs sampled. This quarterly average is then used in all subsequent calculations.

The program allows for estimating suitabilities on a subset of the available stomach content data. It is also possible to use suitabilities estimated outside the model in the calculations.

The MSFOR program uses predation parameters and terminal stock sizes estimated by the MSVPA to make short- and long-term predictions. An option has now been provided for using stochastic recruitment, in which case the recruitment is drawn from a log-normal distribution with a mean and variance estimated from the results of the MSVPA from a specified time period.

The MSFOR may also be run in the single-species mode with either constant or stochastic recruitment.

2.2 Catch-at-Age Data

As in previous years, the single-species assessment working groups were requested, as part of their terms of reference, to supply quarterly age compositions, mean weights at age, and catch-at-age data for input to the MSVPA for 1986 and 1987.

Catch in numbers at age for 1986 and 1987 for mackerel, herring, sandeel (southern + northern stocks), and Norway pout were taken

2

1985. The present status of the single-species assessment for haddock, whiting, and mackerel is given in the report of the Working Group for 1988.

split created a special problem because the split catches in 1984 and 1987 were very badly sampled for age structure. Catch-at-age data for these two years were approximated by Dr Poul Eidsen at the Danish Institute of Fisheries and Marine Research based on average F at age from VPA for the period 1979-1983 and from IYFS estimates of year-class strength. The details can be found in the Working Group archive for 1988.

The quarterly catch at age of mackerel in 1974 was revised. The data which were used at the last meeting were taken from Anon. (1985). These data are in conflict with the yearly estimates for 1974 (E. Kirkegaard, pers. comm. preliminary VPA, Mackerel Working Group, 1985). A new estimate was made by using the quarterly catch in tonnes to split the total yearly catch at age into quarters. This changed the SOP for 1974 from 1.3 million t to 0.2 million t.

The revision of the quarterly catch at age of herring for the period 1974-1984 has now been finished. It proved impossible to obtain the annual catch-at-age data from the Herring Working Group by combining the quarterly data from each country. Therefore, the sums of the quarterly catch-at-age data were multiplied by appropriate factors to obtain the annual values from the Herring Working Group for each age group for each year. The same factor was used for all four quarters by age and year.

Finally, it should be mentioned that the 1985 catch-at-age data have not been updated. Small changes generally appear in these data in the second year they are used by the single-species assessment working groups. For this reason, the single-species working groups are requested to comment on any discrepancies that might exist in the quarterly catch-at-age data base used for MSVPA. The Working Group very much appreciates the provision of these data by the single-species working groups. It is particularly helpful when these data are provided in a timely fashion.

2.3 Relative Food Composition Data

Since the last meeting of the Working Group, the stomach content data base has been improved and extended. The 1981 data underwent a final revision which involved the correction of erratic data points and the application of more appropriate age-length keys. The results will be published in the Cooperative Research Report series in due course.

The data collections made in 1985, 1986, and 1987 have been largely analyzed and the results were made available by the species coordinators before the meeting (Anon., 1988a).

Table 2.3.1 gives an overview of the number of stomachs analyzed so far. It should be noted that data are not yet available for whiting in 1987 and that the results for whiting in 1986 refer only to part of the stomachs collected, with a bias towards the northern North Sea. Therefore, it was decided not to incorporate

the 1986 whiting data in any MSVPA runs at present.

Difficulties have been encountered in finding appropriate age-length keys for sprat in the third quarter of the three recent years, and there was no choice other than using the same ALK as applied in 1981. Also, for sandeels in recent years, ALKs have not always been satisfactory. For all other species, adequate ALKs have been collected by area during the surveys, when stomachs were collected.

2.4 Estimates of Rations Used in MSVPA Runs

Although the problem of estimating food rations of fish in the sea has been extensively discussed during former meetings and several adjustments have been introduced over the years, it is acknowledged that the scientific basis for choosing particular values is still very small. This results in discrepancies between rations used for similar species in different areas. For example, higher rations are employed for cod in the Baltic Multispecies Assessment Working Group than in the North Sea, which is at variance with the lower growth rate in the former. There seems to be a strong need for a coherent review of the experimental evidence on stomach evacuation rates in relation to geographical variation in stomach contents. However, there is no strong evidence that the values presently applied in the North Sea lead to unrealistic results and, for the time being, no further changes appeared to be required.

2.5 M1 Values Used in the Runs

During the 1986 meeting of this Working Group, new M1 values were obtained by estimating the consumption by "other" predators than the five MSVPA predators and by assuming that the diet of "other" predators was the same as the mean diet of the five MSVPA predators. However, from a technical point of view, the estimation was done in a very preliminary way by "smoothing" the M1 values by eye. Since the 1986 meeting, this "smoothing" has been re-worked by Sparholt (1987a) fitting the M2 values by age by species to an exponentially decreasing function by age. The function used was:

$$\ln [M2(\text{age})] = a + b \times \text{age}$$

Figure 2.5.1 shows the observed and fitted points.

The "smoothed" M2 values were then used to obtain the M1 values by multiplication with 0.48. The factor 0.48 was used because this was the fraction of the consumption by "other" predators to the consumption by the MSVPA predators. The output from the key run in Anon. (1987a) was used to obtain a first estimate of M1. These M1 values were then entered into the MSVPA and new M2 values were estimated. This procedure was repeated until the M2 values had stabilized.

Finally, the mortality components which stem from diseases and other non-predation causes were added. These were taken as 0.2 per year for cod, haddock, whiting, saithe, Norway pout, sandeel, and sprat, 0.1 per year for herring, and 0.15 per year for

in the MSVPA. However, new data on the amount of mackerel in the North Sea of both the North Sea stock and the Western stock are now available from the Mackerel Working Group (Anon., 1987b, 1988b). For 1986 and 1987, the percentage of mackerel present in the North Sea by age group, quarter of the year, and stock are given in Table 2.5.3. According to Anon. (1987b), as much as 0.8 - 1.1 million t of Western mackerel may have been in the North Sea for around six months in 1986. According to Anon. (1988b), the same was true for 1987. As the North Sea mackerel stock in the latter years is only about 1-2% of the Western stock, the North Sea stock can be ignored in the present context.

If this new information given by the Mackerel Working Group is correct, which the present Working Group has no reason to doubt, the Western mackerel seems to be a very important predator data for the North Sea ecosystem. The MSVPA could thus give misleading results if this component of the ecosystem is not properly modelled. For doing this, the kind of information given in Table 2.5.3 would be extremely useful to have for each year back to 1974. A possible way of dealing with the Western mackerel could then be to incorporate it into the MSVPA as a new predator assuming that its diet is identical to the diet of the North Sea mackerel. A VPA-type calculation should of course not be applied to just the North Sea catches from the Western stock. Alternatively, the total catch of mackerel by age and quarter could be put into the model and treated as the other predator stocks, although this mixed North Sea and Western immigrant stock would be hypothetical. In both alternatives, the mackerel will give large problems in the forecast because it will be difficult to predict the fraction of Western mackerel migrating into the North Sea each year.

The reason for this increased migration of Western mackerel in the latter years is unknown.

Horse mackerel

New data on the biomass and consumption of horse mackerel in the North Sea have become available since the last meeting of the Working Group. Horse mackerel have not been considered as a fish-eating species by this Working Group. However, the information now available on the diet and biomass of horse mackerel indicates that it might be erroneous to exclude horse mackerel as a fish eater.

Dahl and Kirkegaard (1987) examined 122 stomachs in July 1985 and 395 stomachs in August 1986 from the North Sea off the Danish coast.

In the 1985 samples, 43% of the stomach contents for the 20-24 cm size group of horse mackerel were MSVPA fish species, 96% in the size group 25-29 cm, 99% in the size group 30-34 cm, 100% in the size group 35-39 cm, and 100% in the size group 40-44 cm. Mainly haddock and herring were found in the stomachs and to a lesser extent mackerel.

In 1986, the amount of horse mackerel present in the North Sea was estimated from an acoustic survey in the area west of the Danish coast between 6° E and 8° E and between 55° N and 57° N. The

biomass of horse mackerel in this area was estimated to be 531,460 t. The horse mackerel's daily consumption of MSVPA species was estimated to be 9,400 t per day or 4,566 t per day depending on the evacuation rate used. The MSVPA species in this area constituted 74% of the diet and the rest was crustaceans and a small amount of other fish species.

Biomass estimates of horse mackerel were also available from Daan et al. (1988), based on catch rates in the English Groundfish Survey in August/September (Table 2.5.2). These estimates are only varying by a factor of 2 from year to year during the period 1977-1986. The mean biomass estimate for 1977-1986 was 427,000 t. This estimate seems low compared to the acoustic estimate mentioned above and the estimate of 1.6 million t made by Sparholt (1987a). One reason for the low estimate by Daan et al. (1988) could be that the catchability coefficient q for mackerel they used was calculated only based on the North Sea mackerel not taking into account the components in the EGFS catch based upon immigrants from the Western mackerel stock.

According to Anon. (1986a), the amount of Western mackerel immigrants present in the North Sea is 564,000 t in the third quarter of the year, i.e., about 3 times the amount of the North Sea mackerel. This means that the q value of Daan et al. (1988) for mackerel becomes unrealistically high. However, their data show at least that the amount of horse mackerel has been fairly constant since 1977.

Even if the biomass estimate of horse mackerel in the North Sea by Daan et al. (1988) is correct, the biomass is certainly so large that the horse mackerel is a potentially important species in the MSVPA context. Methods for its inclusion in MSVPA-type models thus seem indicated, but more firm estimates of biomass will be needed to do this.

Predation by grey seals

New data on the predation by grey seals have become available to the Working Group since its last meeting in 1986.

The estimate of the total consumption by grey seals from Prime and Hammond (1986), which was used in the procedure to obtain the M1 used during this meeting of the Working Group, has been split into species and age groups for cod, haddock, whiting, and saithe according to fecal samples [Sea Mammal Research Unit (SMRU), 1988]. Their data are shown in Table 2.5.4 together with the stock numbers at age from the key run from the 1986 report, and the mortality rate of cod, whiting, haddock, and saithe due to predation by grey seals.

This Working Group's estimate of the total consumption of fish by grey seals in 1985 was 57,283 t, of which cod, haddock, whiting, and saithe constituted 16,920 t.

The implicit grey seal predation mortalities based upon the 1986 MSVPA runs are also shown in Table 2.5.4. These are calculated by multiplying the M1 values by the fraction of the consumption by grey seals to the total consumption of other predators than the MSVPA predators. According to Sparholt (1987b), this fraction is

5.54%. As can be seen from Table 2.5.4, the value used in the present MSVPA for the grey seal predation on the gadoids is lower than the estimates from SMRU (1988) for cod and saithe, but higher for whiting and haddock. Furthermore, the trend of reduced predation mortality rate from age group 0 to the older age groups in the M1 values used in the MSVPA runs is not found by the Sea Mammal Research Unit (1988) where the maximum predation mortality rate seems to occur at ages 1-3.

Because of the small differences between the SMRU (1988) data and the data used in the key run, the Working Group decided not to change the M1 values during this meeting.

The Working Group appreciated very much the work done in obtaining the predation data on a sufficiently detailed level for use in the MSVPA context. The Working Group was of the opinion that the new information should be taken up together with equally detailed data on bird predation which probably can be expected to become available in the next couple of years. It may then be possible to deal with these other predators in a more detailed fashion.

2.6 Feeding Relationship Used in Runs

As in 1986, the Working Group chose to make runs using the Helgason-Gislason feeding relationship, i.e., assuming the biomass of other food to be constant.

2.7 Weights at Age Used

As in 1986, there are three sets of weights at age:

- 1) body weight in the sea;
- 2) body weight in the catch;
- 3) body weight in the stomachs.

However, compared to the 1986 data, the body weights in the stomachs have been changed by combining the new stomach data from 1985, 1986, and 1987 with the old stomach data from 1981.

For cod and whiting, this was done by the coordinators by summation over the years of the weight and number in the stomach by prey age, predator age, and quarter. By dividing the summed weight by the summed number, a mean weight was obtained. This was finally multiplied by 2 to correct for stomach contents being on average half digested. For saithe, a slightly different method was used. As a starting point, mean weights for each sampling year were obtained. The average means of these values were then calculated in the program by weighting with the number of stomachs examined each year by predator age and quarter.

These methods do not preclude the possibility that unrealistic values creep into the data base. During the meeting, some very low values of 0-group whiting and cod eaten by particular age groups of whiting and saithe, respectively, were spotted because

they created severe instability in the forecast runs. Although these values could be corrected for, the fact remained that the model is highly sensitive to input values of average prey weights in stomachs. In the future, the possibility of making an objective judgement of the prey weights obtained should be investigated and some smoothing procedure might be developed before the data enter the model.

2.8 The Key Run of the MSVPA

As at previous meetings of the Working Group, 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) the same consumption rations as used in Anon. (1987a) (see also Section 2.4 of this report);
- 3) the old stomach data from 1981 together with cod stomach data for 1985, 1986, and 1987, whiting stomach data for 1985, and saithe data for 1986 and 1987;
- 4) slightly revised residual natural mortalities given by Sparholt (1987b) and based on the same information on predation by "other" predators as used at the 1986 meeting;
- 5) the three sets of weight-at-age data;
- 6) revised quarterly catch-at-age data for herring;
- 7) terminal F values selected in a similar way as in the two previous Working Group meetings (Anon., 1986b, 1987a) based where possible on levels used by the single-species working groups;
- 8) maturity ogives instead of knife-edged maturity.

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

Mackerel and sprat catches created special problems with respect to choosing terminal Fs because no single-species VPAs were made for these two species by the relevant single-species assessment working groups. However, catch-at-age data by quarter for 1987 were given for mackerel by the Mackerel Working Group.

The input Fs for mackerel were chosen in a way that created similar stock numbers at age as in the last VPA from the Mackerel Working Group in 1986 and similar spawning stock biomass as found in the mackerel egg survey in 1986. The Fs were assumed not to deviate much from the mean level in recent years.

The input Fs for sprat were chosen in a way that gave relative year-class strengths in the MSVPA to those seen in the IYFS surveys.

Tables 2.8.1a-i present the MSVPA results for the species in-

cluded in the model (cod, whiting, saithe, haddock, herring, sprat, Norway pout, and sandeels). These tables are the equivalent to the conventional VPA tables, i.e., they give fishing mortality and population numbers, but in addition give the predation mortality caused by the predators (cod, whiting, saithe, mackerel, and haddock) in the model. Mortality of the 0-group is for the third and fourth quarters only. Tables 2.8.2a-c summarize the 1980-1985 averages for fishing mortality, natural mortality, and population size. The extremely high fishing mortality rates on 2- and 3-group Norway pout are of particular interest because they possibly indicate that residual natural mortality should be higher on these age groups as also pointed out by Bailey and Kunzlik (1984). This is not taken into account in the present MSVPA version.

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 M values (predation), there is generally good 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. This is caused by unrealistically high mean weights for 0- and 1-group herring used by the Herring Working Group. The total and spawning stock biomasses computed in the MSVPA and in the single-species working group reports are shown in Figures 2.8.1a-f for all species except mackerel and sprat where no biomass estimates were available from single-species working groups for the last two years and for saithe which has no predation mortality.

The differences observed between the MSVPA and the VPA estimates are mainly due to differences in weight at age and in the maturity ogive. Differences in natural mortalities only cause small differences in biomass estimates except for sandeel because MSVPA shows sandeels to have had very variable natural mortalities over time. The single-species working groups use constant natural mortalities over years, but variable mean weights and maturity ogive, whereas the MSVPA uses constant mean weights and maturity ogives 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 1980-1985 are shown in Table 2.8.3 for cod, whiting, haddock, and herring. There seems to be fairly good agreement between MSVPA and SSVPA for all age groups.

Table 2.8.4 shows the natural mortality values used by the single-species working groups in 1988 and the calculated natural mortality rates estimated by the current key run. In general, these change little except for 0-group fish. The single-species working groups should, therefore, decide whether to adopt the new values or to continue to use the existing values in order to preserve consistency.

3 SHORT-TERM PREDICTION PROBLEMS

In previous meetings, the question of predicting TACs, given the multispecies nature of the North Sea fisheries, was considered. In general, it was considered that the use of higher natural mortality levels would make little difference to the TAC prediction process. However, the possibility of variation in natural mortality might have short-term implications. These are best considered in the light of relationships of single-species and multispecies recruitment and the relationship of both to survey indices.

The relation between recruitment as estimated by the MSVPA and by the single-species working groups is generally good except for haddock (Figure 3.1a-e). For haddock, the MSVPA produced M2 levels for 1-group of 1.5 (total M = 2.2) in the mid-1980s compared to the total M of 1.65 used by the single-species working groups causing an upward shift in recruitment estimates.

The implications for short-term predictions were discussed in the last Multispecies Working Group report (Anon., 1987a). Since then, the North Sea Roundfish Working Group has updated the ACFM-recommended procedure implemented by the program RCRTINX2 to predict recruitment. This method uses greater weighting of the most recent VPA estimates of recruitment.

The RCRTINX2 procedure was applied to cod, whiting, and haddock using the same input as the Roundfish Working Group (Anon., 1988c), but with VPA year-class estimates substituted by MSVPA estimates. Output is presented in Tables 3.1-3.3. Major differences in year-class estimates are only found for haddock for the 1985, 1986, and 1987 year classes with increases in estimates of 33%, 66%, and 93%, respectively. This would seem to be due to increased saithe predation on 1-group haddock in recent years. This could possibly upset the TAC estimation process for haddock, but in fact the single-species assessment of the recruitment seems to fit survey results at least as well as the multispecies estimates, so the problem may well be due to some detail of tuning of the MSVPA which affects predator biomasses in the last year (c.f. Table 14.10 of the Roundfish Working Group report).

4 LONG-TERM YIELD

4.1 Introduction

In past reports, it has been noted that multispecies long-term yield predictions differ substantially from single-species predictions. This may in part be due to the sometimes higher levels of natural mortality used in multispecies models, but more to the fact that natural mortality in these mostly change in response to predator and prey abundance.

Thus, increasing fishing mortality on predators in a multispecies model is typically less likely to produce a reduction in yield than in a single-species model and also produces more complex effects on the yield of other species. In this section, particular attention has been concentrated on the effects of mesh changes on predictions of yield change in the North Sea fishery

in response to ACFM's request (see Appendix A) on this subject.

4.2 Description of Long-Term Models

The equations behind the MSFOR program are given in Gislason and Sparre (1987). The program provides long-term predictions of biomasses and catch of a number of fleets. It contains options for predicting both in single- and multispecies mode as well as for using constant and stochastic recruitment. If constant recruitment is chosen, the predictions are checked for convergence and the program stops when the maximum relative difference between the stock number at age after 2 consecutive years is less than 0.01%. With stochastic recruitment, the number of years predicted must be entered by the user. The output consists of average stock numbers, biomasses, and yields. In the stochastic case, the coefficient of variation is estimated as well.

Multispecies multiplicative steady-state models have been described in the 1984 and 1985 reports of the Working Group and in Shepherd (1984). In order to increase the comparability of the results from this model with the results of the MSFOR, the program was modified slightly by replacing the stock-recruitment relationship with a constant recruitment and also to read unsmoothed M2 values from the MSVPA output.

4.3 Parameterization of Models

MSFOR

The input tables of weight at age, M1, etc. used in MSFOR were the same ones used in the key run of the MSVPA. Recruitment was assumed either to be constant at the arithmetic mean (1974-1985) of the numbers of 0-group fish of each species in the third quarter from the key run (Table 2.8.1) or stochastic with arithmetic mean and log-normal variance from the same 0-group period. Recruitment estimates were entered in the third quarter of each forecast year. The annual fishing mortality by species and age was calculated as the mean (1980-1985) from the key run. The fishing mortality was partitioned amongst the six fisheries as described in the report of the 1985 Multispecies Working Group (Anon., 1986b) and tabulated in Appendix B of the 1987 Working Group report.

Shepherd forecast model

In previous years, this model has had a matrix of relative preferences for each predator-prey combination, input from which predation mortalities have been reconstructed. This year, difficulties were encountered with the M2 smoothing procedure used to produce the preference matrix (see Section 8.4) and M2 (prey, prey-age, pred, pred-age), as calculated by the MSVPA key run, were read in directly. As in previous years, all other data (e.g., catch weights, M1) were as used in the forecast MSVPA runs.

4.4 Changes in Long-Term Yield Resulting from Changes in Various Fisheries

Introduction

In order to examine the effects of changes in fishing level by various fleets in the North Sea, both the long-term models were run at the current fishing mortality situation and with the effort in each of the six fleets identified in past reports increased by 10%.

Yield at current fishing mortality levels

Table 4.4.1 shows the status quo baseline yields from both forecast models. The results of these two models are much more consistent than in past years due to M2s being used in an unsmoothed form in both models.

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

Results are shown in Table 4.4.2 as percentage changes from the baseline results. The MSVPA forecasts show that a 10% increase in this fishery leads to an increase of less than 10% in the yield of that fishery, the largest increase being for haddock and saithe, by 8%. There is also an overall increase in the industrial demersal fishery, with 4% increased yield of Norway pout and 2-3% increased by-catch of cod and haddock. The saithe yields in fisheries other than the roundfish fishery decrease and the herring catches increase by 3% totally.

The Shepherd model shows a very similar picture.

Equilibrium harvests with the industrial demersal fishery increased by 10%

Results are shown in Table 4.4.3. The MSVPA forecasts show that the yields of the industrial demersal fishery have an overall increase of 2-4% for Norway pout and sandeel. The by-catch of cod, whiting, saithe, and haddock increases by almost 10%. The yields from the roundfish fishery decrease somewhat. Overall, the yields of cod and haddock decrease, while whiting increases, as do the yields of Norway pout and sandeel.

The Shepherd model shows broadly similar results within fisheries, but overall cod and haddock also show increases.

Equilibrium harvests with the industrial fishery increased by 10%

Results are shown in Table 4.4.4. For the MSVPA forecast for this fishery, there is a 4% increase in herring and sprat catches and a 10% increase in whiting by-catch. The yields from the roundfish and industrial demersal fisheries decrease by less than 1%. A decrease of 7% in yield occurs in the herring fishery.

Overall, small decreases in catches occur except for sprat, mackerel, and saithe.

The Shepherd model shows a similar picture in the individual

fisheries, but in the overall results there are no decreases.

Equilibrium harvests with the herring fishery increased by 10%

Results are shown in Table 4.4.5. For the MSVPA forecast model, the herring yield increases by 5%. The catch of herring in the industrial pelagic fishery decreases by 4%, so that total herring catches increase only slightly (0.6%). The yields from the roundfish and industrial demersal fisheries decrease. However, the changes are less than 1%.

In the Shepherd model, the main results are the same, but the consequential changes in the roundfish fishery do not occur since the model does not allow for prey substitution.

Equilibrium harvests with the saithe fishery increased by 10%

Results are shown in Table 4.4.6. For the MSVPA forecast model, the yield from the saithe fishery decreases slightly (0.4%). There are increases in yield of Norway pout and haddock of about 10%. The yield of saithe in the roundfish and demersal industrial fisheries decreases. There is a slight increase in yield of cod, whiting, and herring.

The Shepherd model shows similar but less extreme results.

Equilibrium harvests with the mackerel fishery increased by 10%

Results are shown in Table 4.4.7. For the MSVPA forecast model, there is an increase in mackerel yield of 1.5%. There is also an increase in the yield of all other fish species, but less than 1%.

The Shepherd model shows similar results for mackerel, but some decreases overall for whiting and haddock.

Summary

At the last Working Group meeting, the MSFOR and Shepherd models produced similar percentage changes based on quite different baselines. This year, the baselines were similar. As in the previous report, the conclusions seem to be that increasing saithe fishing mortality might have wide implications to both human consumption and industrial fisheries. Decreasing the industrial demersal fishery produces a resultant loss of human consumption roundfish. Generally, the more species a fishery targets, the greater the ramifications. The results from both models are very similar, and this gives increased confidence in the internal workings of these detailed models.

4.5 Herring/Haddock Sensitivity

Sensitivity analysis on the forecast model at the 1986 meeting of the Working Group showed the herring yield to be particularly sensitive to haddock recruitment. A run this year using a 30% increase in haddock recruitment shows that the herring was not sensitive to haddock recruitment. This suggests that the previous sensitivity analysis result may have been due to inadequate

feeding data for some predation interaction which the inclusion of more feeding data has cured.

4.6 Long-Term Effects of Changing the Minimum Mesh Size in the North Sea Roundfish (Including Saithe) Fishery

In order to study the effects of mesh size changes mentioned in the ACFM request, both the multispecies (MSFOR and Shepherd) and single-species (SS) forecast models were run for 70, 85, and 120 mm minimum mesh sizes, the current one being the 85 mm mesh. These changes in mesh size have direct effects only on the fishing mortality of roundfish species including saithe. It is assumed that the fishing mortalities for other species remain as they are in the key runs.

Runs were based on constant recruitment, based upon recent averages (see Section 4.3).

Tables 4.6.1-4.6.9 show the results regarding catches in numbers and weight, average weight, and spawning stock biomass (SSB). Results are shown both for the SS and MSFOR mode. The tables also show yield and SSB results from runs with the Shepherd model. This model was run primarily to corroborate the MSFOR results. For whiting and haddock, the catches are separated into human consumption, discards, and industrial catches. For other species, catches and landings are synonymous.

Figures 4.6.1 and 4.6.2 show the total landings of all the species both in the SS and MSFOR models.

Changes in total landings are not the only characteristics of change in mesh sizes. Increasing the mesh sizes leads to higher average weight of landed fish which are in general more valuable. An attempt was made to calculate the total landings value. Prices of landed fish, in the case of roundfish species classified by size, were obtained from sources at hand (Agra Europe, 1988). These values refer to prices in several ports in the EEC in August 1987 and in this spring. Unweighted average prices were obtained from this source, the results being exhibited in Table 4.6.10. Linear regression of the price in ECUs per kg as a function of weight also appears in Table 4.6.10 for the roundfish species. Prices based upon these regressions were used to compute the value of total landings for three different mesh sizes. The results are shown in Table 4.6.11 and Figure 4.6.3.

These values of landings were calculated at steady state for the multispecies mode only. Note that the values refer to landings. Care has been taken to subtract discards from the catches. Differences between the MSFOR and Shepherd model results largely stem from a different partitioning of the catch into landings, discards, and industrial catch.

Using the MSFOR model, the total value of the landings is almost the same for the current 85 mm mesh and in the case of a reduction to 70 mm. The total landings would increase, but average value would decrease due to a reduction in average weight of the main species. On the other hand, an increase in the mesh size to 120 mm may cause a reduction both in total landings and in value

by about 18%.

Using the Shepherd model, the total value is rather similar for all three mesh sizes since the average value increases by almost equivalent percentages to the decrease in yield. Thus, the two models give somewhat conflicting results on this question, due mostly to the catch partitioning problem. However, there would at best seem to be no economic advantage in any mesh change from the current level. Both model results are based on the assumption that the biological effort, i.e., the fishing mortalities on the oldest fish, remains constant. On the other hand, as is argued in Section 8.7, the biological effort may increase by about 10% as a consequence of a mesh size increase from 85 to 120 mm, given that the physical effort remains constant. Thus, the total value of the landings may not be changed noticeably by increasing the mesh size. Or if the fisheries are managed in such a way that (maximal) fishing mortalities remain constant, a corresponding reduction in physical effort may lead to some savings in the effort costs and thus counterweight the reduction in landing values. Table 4.6.12 shows, for the Shepherd model only, that catches would decrease less if effort were increased as well as mesh size.

The following are comments on the results of these runs for each species.

Cod (Tables 4.6.1 and 4.6.11)

There are only minor differences in average weight in the catch, total catches, and spawning stock between the 70 and 85 mm mesh sizes in the single-species mode. In the MSFOR mode, however, this mesh reduction might increase the catch slightly. This is in agreement with the Shepherd model.

A change to 120 mm mesh size leads to a considerable increase in SSB and average weight. Consequently, the average value of the landings also increases. In the single-species mode, sustainable yield also increases. In the multispecies mode, this is no longer true. On the contrary, the total catch drops by about 18%, although the value of the landings falls only half as much due to an increase in average value.

This difference between the SS and MSFOR outcome is caused by increased cannibalism in the MSFOR mode as a result of the mesh change.

Whiting (Tables 4.6.2 and 4.6.11)

For whiting, there is the same tendency in both single- and multispecies models regarding mean weight and SSB, although these changes are much more drastic for whiting than for cod. The total value of the whiting landings is at its peak for the current mesh size and both reduction and increase in the mesh size would reduce the total value. However, for the Shepherd model, the reduction in value at the 120 mm mesh size would be very small.

Saithe (Tables 4.6.3 and 4.6.11)

There is no difference between the SS, MSFOR, and Shepherd runs for saithe as it is not a prey species in the multispecies models. There are only minor changes in mean weight, catches, and SSB caused by mesh size changes from 85 to 70 mm. An increased mesh size would on the other hand increase both weight and value of the catch.

Haddock (Tables 4.6.5 and 4.6.11)

Average weight of the landings increases in both single- and multispecies models with increased mesh size, in particular, for an increase from 85 to 120 mm. The total landings increase in the SS mode with increased mesh size, while in the MSFOR mode, there is a dramatic drop in catches when going from 85 to 120 mm.

This great difference between the two models is of course due to an increase in haddock predation mortality in the multispecies mode.

Other species (Tables 4.6.4, 4.6.6-4.6.9, and 4.6.11)

In the SS model, the remaining species are not at all affected by mesh size changes in the roundfish fleet as this fleet does not catch these species. In the multispecies models, changes in predation mortalities are responsible for changes in these stocks. Thus increased mesh size generally increases the predation mortalities and the stock of main predators (the roundfish) goes up. Thus these other species and their catches decrease with an increased roundfish mesh size, although the magnitude of the effect differs from species to species. As an example, the influence is stronger on herring than sprat.

Overall conclusion

The main conclusion of the mesh change analyses reported above is that accounting for multispecies effects substantially alters our perception of the benefits of increasing or decreasing mesh sizes. Both multispecies methods result in similar stories which conflict with the single-species assessment. The two multispecies methods have resulted in different partitioning of total landings for whiting and haddock, but these results should be treated with circumspection.

4.7 Sensitivity of Mesh Change Analysis to Assumptions About Natural Mortality

Multispecies model calculations of the effects of mesh changes in Section 4.6 are based upon estimates of natural mortality which vary with predator abundance. Single-species calculations reported in Section 4.6 were made with constant natural mortality estimates based upon the MSVPA results. In many cases, these two approaches show contradictory trends for changes in mesh size. For example, Table 4.6.1 shows the catch of cod increasing with mesh size in the single-species assessment, but decreasing in both multispecies interpretations. The multispecies results, therefore, change our previous perceptions of how yield might

change for this and other species with changes in mesh size. It, therefore, seems prudent to examine the extent to which these results might depend upon our partitioning of natural mortality into constant and variable fractions (M1 and M2).

The single-species assessment treats all natural mortality as though it were an M1 component, while the multispecies mesh assessments hold the M1 constant, but modify the M2 part, as estimated by MSVPA, with changes in abundance, according to the standard predation equations. Clearly, these results should be subjected to a full sensitivity analysis, but in the time available, it was only possible to consider one aspect - the partitioning of natural mortality on 0-group fish. Since some of the mortality occurs in the pelagic 0-group phase, it might be thought to be less accurately estimated than the levels on other ages and also, perhaps, more subject to density-dependent corrections. It seems most important to see if this mortality estimate were critical to our calculations. Extra runs were made, therefore, using only the Shepherd model with the same assumptions about M1 and M2 on ages 1 and older as used previously, but with

- a) 0-group M1(new) = M1 + M2, M2(new) = 0.0
 b) 0-group M1(new) = M1 + M2/2, M2(new) = M2/2

Results from these new runs are the same as in Section 4.6 at the current (85 mm) mesh size, but differ somewhat for the 70 mm and 120 mm mesh assessments. Table 4.7.1 shows the results for those two mesh sizes together with the results of the standard (Section 4.6) model. While the runs with reduced predation mortality on 0-group fish show a less extreme result than the full model, the broad conclusions are unchanged. It would appear that assumptions about natural mortality partitioning on 0-group fish are not critical to our interpretation of the effects of mesh change.

5 FEEDING STUDIES

5.1 Stomach Sampling Programme 1985-1987

Data collection for this project has been completed and all samples of cod and saithe have been completely analyzed. The whiting samples collected in 1985 have also been completed and the samples taken in 1986 and 1987 are in the process of being worked up. They will be available at a future meeting of the Working Group.

5.2 Stomach Content Data Base

The issue of an international stomach content data base was discussed by the species coordinators during their recent meeting (Anon., 1988a). Because of inconsistencies in analysis between various institutes in 1981, setting up a centralized data base would at this stage require a major and costly effort and would in practice not seem feasible in the short run. However, exchange of stomach content data collected after 1985 by means of magnetic tape is not causing any problems and the software developed in IJmuiden has been successfully applied to data for all three

species. This software can be easily transferred among VAX machines and has been implemented both in Aberdeen and Charlottenlund. However, transfer to the NORDB at ICES Headquarters is not possible.

Given the complexity of the data base, which incorporates data from different sources including stomach contents, information on abundance, and length-age compositions, it would seem that, in general, ad hoc requests could not be satisfactorily answered. Specific requests should be formulated in advance in order to have the relevant output be prepared in the appropriate format in advance of meetings. Therefore, it was concluded that, at least for the time being, more is to be gained from further standardization of software in use among the institutes involved. Once this has been achieved, bringing all data together in a common data base would be a relatively easy matter.

5.3 Predation On and Among 0-Group Fish

The MSVPA estimates of predation mortality on 0-group fish depend critically on the values for prey weights at the time of digestion. Since these post-larval fish may increase their weight by a factor of 10 within the third quarter of the year, the "average" prey weight cannot be unambiguously estimated and the MSVPA results are extremely sensitive to the input values. Therefore, in dealing with 0-group fish adequately, the quarterly time step poses severe limitations and a smaller time step is required.

Another important issue is that significant mortality appears to result from predation among 0-group fish. If such data are included in the model, the iterative procedure creates a snowball effect on stock numbers and numbers consumed, leading to unrealistic results. The inclusion of 0-group fish in the retrospective mode of MSVPA appears to be useful from a scientific point of view because it helps to indicate where important interactions can be expected. There are, however, problems with including 0-group fish and it may be worth considering excluding them from the forecast runs.

Obviously, there is a strong need for more detailed models for patterns of inter- and intraspecific regulation of numbers during the first 0-group phase. Such models require shorter time steps, but also a cohort-type approach by size classes within the age group to take account of the feature that only larger individuals can prey on smaller ones. Realistic simulation of the long-term effects of multispecies interactions will critically depend on the development of such models. Undoubtedly, model development must be backed up by direct observations, and it is envisaged that only an extensive, cooperative research program could yield answers, which might be used in quantitative models.

5.4 Food Consumption

Predation mortalities estimated in MSVPA are directly related to the rations applied. There appear to be considerable discrepancies between estimated rations from the same species which are

applied in different regions. This indicates that there is still considerable uncertainty about the appropriate levels of food consumption by fish in the sea. Evacuation experiments have been carried out for a number of years in different institutes, but the interpretation of the results varies among the scientists involved. A coordinated analysis of all experimental work should provide a better basis for selecting appropriate values to be used in multispecies assessment, and it is recommended that an ICES workshop be set up to do this.

5.5 Future Stomach Sampling Programs

Although the stomach content data collected for cod, whiting, and saithe in different quarters do not suggest that suitabilities vary dramatically between years, the availability of data from more years obviously has a smoothing effect on outliers, particularly if these are due to low abundance of a particular prey in the years of sampling. For haddock and mackerel, the suitabilities in all quarters are based entirely on the data collected in 1981, when herring abundance was relatively low. For the other three species, the situation has been much improved in the first and second quarters, but for the remaining part of the year, the situation is the same as for haddock and mackerel. This means that overall the MSVPA is still largely depending on one year of data and it would seem appropriate to repeat a full-scale exercise in 1991.

Such a repetition would not solve the problems encountered in dealing with predation in 0-group fish unless special care is taken in this respect. Since multispecies interactions during this phase have been identified as critical in respect of long-term predictions, any large-scale stomach sampling program should be extended to incorporate other important predators such as horse mackerel, but also to include stomachs of 0-group fish smaller than 10 cm. This might only be achieved by having the Pelagic 0-Group Gadoid Surveys revised in that year, preferably as a sequence of repeated surveys over a large area in the North Sea.

In order to allow for the development of a comprehensive sampling scheme in 1991 and to consider the logistics in detail, a meeting of a planning group would be required in 1989 because research vessel cruise schedules are generally fixed at least one year ahead.

5.6 Multispecies Symposium

During the various discussions, several ideas were brought forward with reference to relevant contributions to the 3-day ICES Symposium on Multispecies Models Relevant to Management of Living Resources to be held in The Hague in 1989. These include:

- cod-capelin interactions in boreal waters;
- review of results of stomach evacuation experiments;
- review of rates of food intake of fish in the sea;
- measures of overlap in relation to multispecies assessment with reference to both biological and technical interactions;

- modelling multispecies interactions in the 0-group phase.

Papers on these subjects would be particularly welcomed by the conveners of the Symposium.

6 COMPARISON OF SUITABILITIES

6.1 The Problem

One assumption of the MSVPA is that suitabilities remain consistent over time. This assumption can be partially tested because data on stomach contents of cod, whiting, and saithe are available from more than one year. The MSVPA was, therefore, run with several combinations of stomach contents data sets, as follows:

KEY RUN - all available stomach contents data were used in estimating suitabilities;

NS81 - only the stomach data collected in 1981 were used;

NS85 - only data collected in 1985 were used for cod and whiting (first and third quarters); only data collected in 1981 were used for saithe, mackerel, and haddock;

NS86 - only data collected in 1986 were used for cod (first and third quarters) and saithe (third quarter); only data collected in 1981 were used for other predator species and quarters;

NS87 - only data collected in 1987 were used for cod (first and third quarters) and saithe (third quarter); only data collected in 1981 were used for other predator species and quarters.

For the purpose of testing how suitabilities change over time, the five data sets have many shortcomings. Additional feeding data are only available for the first and third quarters, so there is only information on part of the potential variation in suitabilities. Moreover, in every data set, the suitabilities for some predators are determined using data collected in a different year; the predators which fall into this category change from set to set. Moreover, even for mackerel and haddock, their suitabilities as predator change from set to set indirectly as a consequence of changes in other suitabilities even though their stomach content data were the same in each case. These partial, but non-replicated redundancies of suitabilities among the four single year sets (NS81-NS87) make it challenging to determine the degree to which separate estimates of individual suitabilities are statistically independent. In turn, this makes determining expected variance components and degrees of freedom for tests of significance of various comparisons very difficult. Extensive algebraic manipulations might produce better estimates of variance components and degrees of freedom than will be used here. Only complete sets of stomach data from additional years will provide the ability to fully test the assumption of stability of suitabilities.

For this meeting, the statistical analyses were conducted as if cases were independent. Hence, we are possibly underestimating

variance attributable to various factors, but overestimating degrees of freedom. There is no assurance that these effects cancel. However, by using highly restricted data sets (only one year's stomach data for only one predator in any year), our estimates of stability are going to be conservative, given what information we have.

6.2 Comparing Fits of Basic Models to the Suitability Data Sets

Which model to fit to suitabilities?

This question was addressed at length in previous meetings and also in Section 8.3 of this report. The same basic model (kernel model) was accepted last year with terms for predator species (PD), prey species (PY), quarter (Q), and a size effect as:

$$\text{Ln}(\text{SUIT}) = \text{PD} + \text{PY} + \text{PD} * \text{PY} + \text{Q} * \text{PD} + \text{Q} * \text{PY} \\ + [\text{ln}(\text{weight ratio})]\text{PRED} + [\text{ln}(\text{weight ratio})]^2$$

where weight ratio was [(weight of the predator)/(weight of the prey)] in the stomach and * indicates the set of interactions of two factors or a factor and a covariate.

What to compare among fits?

Fit to the key run (using all stomach content data), the kernel model accounted for 41% of the variance in suitabilities. The error mean square was 2.09 (Table 8.3.1). Because individual estimates should be less accurate when based on fewer data, the error mean square should be larger for fits to the suitabilities based on the restricted data sets. The mean square error term is of additional interest because it is an index of the spread in individual cases around their estimates. How much the mean square error increases from the key run fit to the restricted data fits gives some insight into the variation in estimates of suitability from individual data sets.

Variations in the parameter estimates themselves among fits to the restricted data sets, and differences from key run estimates also reflect the magnitude of change in suitabilities among years. Changes in the parameter estimates reflect systematic changes in suitability of particular predator-prey combinations, whereas increases in mean square error reflect a decline in ability to estimate the parameters precisely.

A third set of comparisons is possible by fitting the kernel model to the combined set of suitabilities from each restricted run. The increase in variance overall in the combined data set, compared to the sum of the variances (sum of squares total) for the four separate sets, is a direct indication of variation in suitabilities among years. That increase in total sum of squares can be converted directly into a measure of the increased variation per parameter estimate when data from four separate years are used to estimate suitabilities.

Increase in MSO ERROR with restricted data sets

How the kernel model fits the four restricted data sets varies in many details (Table 6.2.1). All model terms are significant in all fits, but this is probably due to the very high power of the tests (i.e., the very large number of error degrees of freedom). The mean square errors for fits to NS81 and NS85 are only slightly larger than for the key run (2.28 vs 2.16), whereas the values are quite a bit larger in NS86 (2.79) and NS87 (2.32). Using these values to provide rough approximators to coefficients of variations for the suitabilities around their estimates suggests that the CV is fairly stable around 145% for the key run and NS81 and NS85, but increases to 165-170% for NS86.

Few effects in the kernel model show noteworthy changes in their relative amounts of variance explained. The predator, prey, and predator-prey interaction terms are especially consistent at around 2%, 7%, and 14% of the total variance, respectively. The two weight ratio effects show considerably more variation. The variance explained by the squared ratio covariate ranges from less than 1% (NS87) to over 4% (NS86), and the ratio nested by predator species ranges from under 4% (NS87) to over 7% (NS86). The quarter interactions with predator and prey are particularly large in NS85. We can tentatively conclude that the overall interactions among the predators and prey remain very similar across the data sets. The details of the size preferences do change more from year to year.

Changes in parameter estimates among the fits

Table 6.2.2 shows parameter estimates fitted to each of the four separate data sets. With 50 parameters estimated for each data set, some variation in individual estimates is to be expected. In actuality, there is marked consistency among the fits, particularly when relative order of parameter estimates within a factor is considered, rather than absolute value of the estimates. Among the predators, saithe and whiting have generally negative estimates, whereas cod, haddock, and mackerel are generally positive, with cod generally lower than mackerel and haddock.

For prey, only cod and whiting show large variation in parameter estimates among the restricted data sets, and in no cases are their values significantly different from zero. Those estimates significantly different from zero are consistent in direction and relative magnitude among data sets (sandeel - negative; Norway pout, sprat, and sometimes herring - positive).

More variability is naturally present in the predator-prey interaction coefficient estimates (not shown in Table 6.2.2), but again overall there is marked consistency. Of the 16 parameter estimates which are significantly different from zero in any run, half are significant in at least three of the four sets, and always in the same direction. Only NS85 stands out as having a number of parameter estimates which are large in that run, but near zero in all others. Among the species, the saithe predator interaction with Norway pout is consistently large and negative, whereas its interaction with sandeels is comparably larger and positive. Whiting also has consistently large interaction with both species, but the signs are always negative, implying those

prey are disproportionately underused by whiting. Predation by both cod and whiting on whiting is consistently high (larger positive parameter estimates). There is more information obtainable by thorough examination of these parameters, but for the purposes of shedding light on the consistency of suitabilities among data sets, they support the assumptions of MSVPA. In fact, the most consistent patterns generally appear for cod, whiting, and saithe species for which there are different data in at least some of the runs.

The other parameters of particular interest are the slopes of the weight ratio terms. The square common covariate term is quite different for the NS86 set than for the others, which differ little. Correspondingly, in NS86, the nested slopes of the first power weight ratio term are twice the magnitude of those slopes in other sets. Among the other data sets, relative magnitude of the slopes of the individual predator's size preference functions varies substantially. As with the variance explained by the model terms, the size preference functions show more variation among data sets than do the predator and prey identity parameters.

Variance of pooled data sets

The sum of the residual error variance in NS81, NS85, NS86, and NS87 is 14,829. For the combined data sets, the residual error variance is 16,726 (Table 6.2.3), for an increase of 11.3%. This is the additional variation contributed by two variations in suitabilities for the same predator-prey-quarter-age combinations among years. The mean square error of the full run (2.63) suggests a coefficient of variation for the overall suitabilities of 16%. That value compares favourably with its equivalent in the restricted runs, being smaller, in fact, than in the NS86 value, and only 7% larger than the average of CVs estimated for the individual restricted runs.

Although the lack of independence in many of the cases of the combined data sets makes some models of the overall data statistically questionable, a model containing some year effects was fit to the data. An overall year effect was not included (it was not likely that overall suitabilities would change among years), rather year interactions with predator species, with prey species, and with the nested weight ratios were fitted to the combined data set.

The additional terms captured only an extra 7.9% of the variance at a cost of 37 additional degrees of freedom. This suggests that not only is the variation in suitabilities among years not large, it is also not a general change, but rather is specific to particular predator-prey-age-quarter combinations. Modelling such specific and local variation promises to be challenging.

Summary

We considered interannual changes in suitabilities from several views. All suggested the variation was around 8-15% over four years, and not obviously systematically related to the type of predator or prey.

6.3 Investigations of Reasons for Variation in Suitabilities

Possible reasons for change

As originally formulated, suitability should have the effect of the geographic overlap of the predator and prey removed before the value is calculated. This has not been possible with the MSVPA, so the suitability values calculated in the program may reflect a degree of overlapping of predator and prey as well as the true suitability of the prey for the predator. Correspondingly, changes from year to year in spatial overlap may produce some of the observed changes in suitability values.

It has also been suggested that prey biomass levels may affect the suitability values in at least two possible ways. At high prey biomass levels, predators may switch their feeding pattern to feed proportionately heavier on the abundant prey, leading to increases in suitability. Predators switching away from prey which become rare would lead to changes in suitability with a similar sign. Alternatively, if prey biomass increases sharply, it is possible that feeding patterns of predators do not keep pace with the increase. This pattern could lead to a decline in suitability with an increase in biomass.

To investigate that these possibilities were affecting the suitabilities calculated in the MSVPA, several additional analyses were run. Both direct relationships between suitability and overlap and biomass estimates, and relative effects of how changes in suitabilities were related to changes in overlap and biomass were examined.

Measures of overlap and biomass

The biomasses of predators and prey (of the appropriate age and quarter) were taken directly from the MSVPA runs. Data for all predator and prey combinations could be examined, although only for the first and third quarters. In other quarters, no additional feeding data were available, so there is only a single estimate of suitabilities in those quarters.

To calculate overlaps, data from the IYFS for the first quarter of 1981, 1985, 1986, and 1987 were used. Information was produced by the ICES computer section based on the IYFS data base for all years, but the data for 1981 could not be used except for sprat because of restricted coverage of the North Sea given by the three countries which have submitted data for that year to date. Instead, estimates were based on information provided in Daan and Kuitert (1981) and Corten and Kuitert (1981). Sample units were individual statistical squares within the North Sea. Following the formulation of the MSVPA and developed in Houghton (1986), the index of geographic overlap (RHO) in any single year was:

$$RHO(jklm) = \frac{\sum_{i=1}^n x_{ijk} \times y_{ilm}}{\sum_{i=1}^n x_{ijk} \times \sum_{i=1}^n y_{ilm}}$$

where n = number of statistical squares surveyed in the year, x is the abundance of the jth age group of the kth species at square l, and y is the abundance of the lth age group of the mth species at square i.

The IYFS did not provide reliable estimates of mackerel or saithe abundance as predators nor for sandeels as prey. Moreover, with no new data on haddock feeding, only cod and whiting could be used as predators for investigations of the relationship between suitability and overlap. Also, the IYFS data did not reflect abundance of age groups older than 4, so the data available for the analyses were further restricted. Suitabilities of older age groups of predators and prey were averaged and used as the suitability estimate for that age.

As a final caution, the SPSS-X program used to match the suitability and overlap data was not familiar to any Working Group participants. According to the SPSS-X documentation, the matching should have been made properly, but detailed checking would be desirable. Unfortunately, this was not possible in the time available for the meeting, but should be pursued in order to validate the results which follow.

Fitting models with additional terms to the suitabilities

To investigate the possibility that predators switch feeding as prey biomass changes, a model run was fit to the suitabilities, adding a prey biomass term to the kernel model. The prey biomass term was nested under both prey species and prey age. The first nesting was included because prey switching, if it were found, would focus on specific prey species whose biomasses were changing. The age specific nesting was required because biomass overall generally declines with age of prey, and this effect would dominate an analysis using general prey biomasses only.

The added term in the kernel model captures an additional 10% of the variance in the data set of the first and third quarter suitabilities for predator and prey species, with all age groups except prey over age 5. The distribution of explained variance among model terms also changes substantially with the addition of the prey biomass term (Table 6.3.1). Variance due to predator and prey main effects decreases greatly, as do the interactions of those two main effects with quarter. Apparently many of the differences in suitabilities among the quarters and particularly among prey do arise directly from differences in prey biomass. This halving of the variance captured in the species and quarter terms of the kernel model is a much bigger effect than the additional 10% of variance captured overall in the argued model.

Table 6.3.2a shows the common parameters of these two models. The parameter estimates of the prey biomass nested within prey and age are reassuringly coherent. Aside from herring, it is suggested that suitability actually declines as biomass increases. The effect is largest for sprat and sandeels, but shows no consistent pattern with prey age (Table 6.3.2b). This suggestion that predator use of prey may not track fluctuations in prey biomass was not further investigated.

Very few data were available for model fitting runs including overlap as a covariate. The single model explored had log overlap as a covariate in the kernel model, but the weight ratio covariate had to be dropped. In its place, age terms for predator and prey were included as fixed factors. Although this model fits the data about as well as the kernel model fits the full data set ($r^2 = 0.419$), almost all the variance was captured by the various prey by predator age and species interactions (Table 6.3.3). The overlap covariate was particularly weak, to the point where the very small F (0.05) suggests either the overlap estimate is a poor one, or the matching of overlap values to cases was faulty. Both the index itself and the matching warrants careful examination.

For cod and whiting, regression models were also used to try to predict log suitability directly from log overlap. Residuals of these models were then fitted to logs of predator and prey biomasses.

The regression showed no relationship of suitability to overlap for cod (Table 6.3.4), nor of the residuals with either cod or prey biomasses. For whiting, the association of suitability with overlap was significant ($P < 0.01$), but the r^2 was only 0.097. The slope was negative, suggesting the anomalous situation that as overlap increases, whiting use prey less. More plausibly, this may be indicating simply that the preferred prey for whiting are less widely distributed than are less preferred prey. The residuals of the whiting regression were also marginally associated with prey biomass, again contrary to some expectations. Possibly the preferred prey of whiting are not just less widely distributed, but also less abundant than are some less preferred prey.

Analyses of changes in suitabilities among years

To try to get a direct look at how changes in suitabilities arose from changes in biomasses and overlaps of predators and prey, additional regression analyses were conducted. In these analyses, changes in suitability between specific pairs of years were regressed on changes in biomass for the same pair of years. Analyses were done separately for the first and third quarters.

In the first quarter, differences in suitabilities were not related to differences in either predator or prey biomass for any pair of years. In the third quarter, significant effects were present in all contrasts except NS81 with NS86, when the relationship of the differences approached significance (Table 6.3.5a). In all cases, little variance was explained by the relationship, as the largest r^2 value is only 0.020. In each pair of years, the change in prey biomass was the significant pre-

dicator of change in suitability, and in all cases the slope was negative. This is another suggestion than an increase in prey biomass leads to a decrease in suitability.

To try to increase the sensitivity of the analyses, all runs were repeated using difference in log suitabilities and biomasses. These runs were expected to be less sensitive to differences in magnitude of the measures. The r^2 values were consistently larger for these runs (Table 6.3.5b), with some reaching as high as 0.184. All were significant. The prey biomass term was consistently much more important than the predator biomass term, and the slope was always negative. The predator biomass term was significant in half of the runs, three in each quarter. The sign of the predator term was variable, however. Of the six significant cases, four were positive, suggesting that as predators become more abundant they become more catholic in their tastes. In the two cases of significant negative slope, explanations are less apparent.

The final set of runs regressed changes in log suitability on both changes in log biomasses of predators and prey, and changes in log overlap. These analyses could only be done for cod and whiting for the first quarter. The species were analyzed separately.

For cod, the change in overlap term never captured significant amounts of variation in the changes in suitabilities. Moreover, only in the comparison of 1984 and 1985 were any of the biomass terms significant (Table 6.3.6). In that case, a negative association of change in predator biomass and change in suitability was present. This effect, if real, suggests that for age groups of cod as a predator, either those whose biomasses increased most from 1985 to 1987 ate fewer things, or those whose biomasses decreased most ate more things.

For whiting, the overlap term was significant for two of the six comparisons. In both cases, the slope was negative, suggesting reciprocal changes in overlap and suitabilities; as prey overlapped more with whiting, relative usage decreased. The prey biomass term had a negative slope in all comparisons. In three cases, the slope was significant. Again, this suggests that as prey become more abundant, they are used proportionately less than when they are less abundant.

6.4 Summary

These analyses are preliminary and hurried. More detailed and careful analyses are warranted. Nonetheless, several messages appear consistently. First, interannual variation in suitabilities does not appear to be great; year-to-year differences seem to be around 10%. This is a reassuring conclusion for MSVPA. To the extent that suitabilities do change, the largest factor seems to be changes in prey biomass. The relationship is generally negative, with suitabilities lower for prey when they are more abundant. The effect seems to be stronger in the third quarter than the first and stronger for some predators (whiting) than for others (cod). Changes in overlap, if we have measured them correctly, appear not to be particularly influential on suita-

bility values.

6.5 Comparison of Observed and Predicted Relative Stomach Content Composition

In 1985, the Working Group attempted to compare observed prey fractions in the first quarter in 1982 with model predictions which indicated that the agreement between these two was much higher than between the observed prey fractions in 1981 and 1982. Since more extensive data are available now, it was intended to explore these comparisons further this year because they allow a global evaluation of the feeding model in the MSVPA on the basis of entirely independent data sets. However, due to other priorities, this approach had to be skipped. It is recommended that this issue be pursued in more detail before the next meeting of the Working Group.

7 MSVPA PERSPECTIVES OF FEEDING RELATIONSHIPS IN THE NORTH SEA

7.1 Who Eats Who?

Table 7.1.1 shows the total biomass and consumption estimates for all years 1974-1987.

As appears from Table 7.1.1, the total biomass decreased about 50% from 1974 to 1981 and has since then remained stable at around 5-7 million t. The total yield has shown a decrease from about 3.1 million t to about 2.4 million t. The decrease mainly occurred before 1977. Since 1977, the total catch has remained stable. The amount of MSVPA species eaten has shown a slightly different pattern with a more gradual decrease from 1974 to 1984 where it was only 30% of the amount predated in 1974. Since 1984, the amount predated has again increased a little.

The biomass of predators decreased from about 3.5 million t in 1974 to about 2.0 million t in 1978 and has remained at that level since. The yield per unit biomass of MSVPA species has increased from about 30% in 1974 and 1975 to about 40% since 1976. The amount eaten per unit biomass has shown the opposite trend so that total eaten and total yield per unit biomass for all years is close to 90%. The amount eaten per unit predator biomass has fluctuated much from 1979 to 1987 with a decreasing trend. This is probably caused by the decrease in the mackerel stock and the reduced amount of big fish in the other stocks due to increased fishing mortality.

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 they are not considered as prey in the MSVPA. For cod, it can be seen that the predation is very small compared to its biomass. For whiting, haddock, and herring, it is about 1/4 - 1/2 of the biomass, and for sprat, Norway pout, and sandeel, it is about equal to their biomasses.

Figures 7.1.2a-e compare the biomass and annual yield of predator with the prey biomass consumed. For cod, whiting, saithe, and haddock, it is between 1-3 times their biomass. For haddock, it is considerably lower.

8 FOOD FOR THOUGHT

As in previous years, this section is used to record some background calculations, but more importantly, it is a section where new ideas can be tried out. To encourage this, the Working Group has a convention of allowing its individual members to insert items in Section 8 with minimal criticism.

8.1 Alternative Forms of MSVPA

The possibility of using a simpler form of MSVPA was considered. This would use the average M2 levels generated by each predator on each prey by MSVPA over the 1974-1987 reference period. These would then be expressed as M2 per predator biomass for this period:

$$M2(i,a,j,b,*)/Biomass(i,a,*)$$

where the indices i,a indicate predator species, j,b indicate prey species and biomass, and * indicates the averaging period.

In earlier years when MSVPA cannot be used due to the lack of catch-at-age data for some species of prey it would be possible to estimate M2 based only on the change of predator biomass. While not strictly correct since it would not allow for changes in total prey abundance, it would indicate whether M2s were generally higher in the 1960s and perhaps help to interpret recruitment changes.

While such a model was considered feasible and desirable it was not possible to implement the design in the period of the Working Group.

8.2 Uniqueness of MSVPA Equations

Little progress was observed on the issue of whether the basic non-linear equations of the MSVPA model have a unique solution or not. In the report of this Working Group from its 1986 meeting (Anon., 1987a), a path for investigation based on the multi-species cohort analysis (Pope, 1979) was outlined. Cohort analysis does not require the determination of mortalities and thus has a simpler implicit structure than the MSVPA equations. Hence, uniqueness studies look more promising along this road.

This cohort thinking as introduced in the previous report needs some corrections, however. Equation (1) in Section 6.2 of the 1986 report of the Working Group reads:

$$N(j,b,y) = C(j,b,y)e^{M1/2} + N(j,b+1,y+1)e^{M1} \\ + e^{M1/2} \Gamma \frac{\bar{N}(j,b,y)\bar{N}(i,a,y)\text{Ration}(i,a)\text{SUIT}(i,a,j,b)}{j,b \sum_{k,c} \text{IN}(k,c,y)\text{SUIT}(i,a,k,c)\text{wt}(k,c) + O(i,a)} \quad (1)$$

Here, one addition has been made, namely the term $O(i,a)$, which covers external food available to cohort (i,a) . Unfortunately, the reasoning following equation (1) in the 1986 report is not valid.

As in the previous report, the approximation

$$N(j,b,y) = \sqrt{N(j,b,y)N(j,b+1,y+1)}$$

can be used to simplify the equations.

In a cohort-recursion step, stock sizes for year $y+1$ are known, but those for year y have to be calculated from equation system (1). We are interested in knowing whether there is only one solution to this system.

Let us introduce the variables $x = \sqrt{N}$. Also, simplify the indexing by using only one index, say i , for the species-age pair (i,a) and drop the year index. Furthermore, define the following constants:

$$\begin{aligned} NP(j) &= C(j,b,y)e^{M1/2} + N(j,b+1,y+1)e^{M1} \\ A(j) &= e^{M1/2} \sqrt{N(j,b+1,y+1)} \\ B(i) &= \text{Ration}(i,a) \sqrt{N(i,a+1,y+1)} \\ C(k) &= \text{wt}(kc) \sqrt{N(k,c+1,y+1)} \\ S(i,j) &= \text{SUIT}(i,a,j,b) \end{aligned}$$

Note that $NP(j)$ is actually the stock size in number $N(j,b,y)$ (in the cohort analysis) in case of no predation mortality.

Equation system (1) can now be expressed as

$$x^2(j) = NP(j) + x(j)A(j) \Gamma \frac{x(i)S(i,j)B(i)}{j \quad \phi(i)} \quad (2)$$

where

$$\phi(i) = \sum_k \text{Ex}(k)S(i,k)C(k) + O(i) \quad (3)$$

is the total available food for i . Now the analysis of Magnus and Magnusson (1983) may be more easily carried out. Note that a division by $x(j)$ turns equation (2) into a form in line with their thinking. The Working Group did not find time to carry the analysis any further!

It is interesting to note that, at least in the case of no "other food", all possible solutions lie on an ellipsoid. This can be seen by multiplying equation (2) with the ratio $A(j)/C(j)$ and then sum over j . This yields the quadratic form

$$\sum_j \frac{A(j)}{C(j)} x^2(j) = \sum_j \frac{A(j)}{C(j)} NP(j) + \sum_j x(i) S(i,j) B(i) \quad (4)$$

Any valid solution to the equation must lay on this ellipsoid which thus constrains the solution space to be finite. This is important for an analysis akin to that of Magnus and Magnusson. It would be particularly useful to develop necessary, as opposed to sufficient, conditions for uniqueness.

8.3 Smoothing of Suitabilities

Introduction

The concept of suitability is central to the MSVPA. At present, it is estimated and used in a disaggregate fashion within the MSVPA model. Thus, each age of each prey has a suitability for each age of each predator. To reduce the number of estimates and to smooth them would clearly be desirable providing such smoothed values captured a reasonable amount of the variability of the smoothed estimates. This sub-section is thus concerned with the smoothing process. Section 6 of this report used the various smoothing models to further investigate the variability of suitability with time.

Background to the model

Two models were fitted to the suitabilities. One was a linearized version of the Andersen and Ursin (1977) model of food selection, the other a variant of the kernel model (see Section 6.2) used at the last meeting.

The linearized version of the Andersen and Ursin model is:

$\ln \text{SUIT}(i, a, j, b, q) =$

$$\ln Q(i, j, q) + \frac{\mu(i)}{\sigma(i)^2} \ln \frac{w(i, b)}{w(j, a)} - \frac{1}{2\sigma(i)^2} \left[\ln \frac{w(i, b)}{w(j, a)} \right]^2 - \frac{\mu(i)^2}{2\sigma(i)^2}$$

where i and a are indices of predator species and age, j and b of prey species and age, q is quarter, w is body weight, μ and σ are size preference parameters, and $Q(i, j, q)$ is a coefficient expressing the general vulnerability of species j to predation by i .

As noted in previous reports, the body weight of prey in the sea and the body weights of prey at ingestion often differ substantially and it is not possible to decide which weight to use in equation (1). Assuming prey weight to follow a log-normal distribution, Gislason and Sparre (1987) derived a complicated version of equation (1) which takes the difference into account. Their

equation is, however, not easily linearized, and the Working Group, therefore, decided to use equation (1) with body weights at ingestion as derived from the stomach content analysis.

The second model (ANOVA) is more related to an analysis of variance and describes $\ln(\text{SUIT})$ as a sum of predator and prey main effects, predator-prey, predator-quarter, and prey-quarter interactions, and a log weight ratio covariate term for each predator. A log weight ratio square term was not included in the model as this term was shown to explain very little of the variance at the previous meeting of the Working Group. $\ln(\text{SUIT})$ is hence modelled by:

$$\ln(\text{SUIT}) = \text{PD} + \text{PY} + \text{PD} * \text{PY} + \text{PD} * \text{Q} + \text{PY} * \text{Q} \\ + \ln(\text{weight of predator/weight of prey})$$

where PD is a predator species factor, PY a prey species factor, Q is quarter, and * indicates interactions between factors.

This model was fitted using both weight of prey in the sea and weight of prey at ingestion.

Results of fitting suitability

The results of fitting the two models to a data set consisting of suitability estimates for the first and third quarters with only 1981 data, with 1985 data replacing 1981 as far as possible, and with 1986 data replacing 1981 as far as possible, are presented in Table 8.3.1.

The Andersen and Ursin model explains approximately 51% of the total variance and the ANOVA approximately 41% of the total variance both in the case of weights at ingestion and of weights in the sea.

In terms of the amount of variation explained per fitted parameter, the two models come out approximately the same.

The size preference parameters estimated by the Andersen and Ursin model are given in Table 8.3.2, except for haddock for which the fitting resulted in a positive curvature parameter. For cod and whiting, the estimated average prey weight ratio does not look unreasonable. For saithe, an estimate of 23,500 as the ratio of the average weight of saithe to the average weight of its prey seems unreasonable.

The unreasonable levels of prey weight ratio probably stem from two sources:

- 1) the difficulty of fitting the curvature term to all species separately in a reliable fashion;
- 2) the suppression of suitability terms of zero due to the use of logarithmic transformation.

For comparison, the overall prey weight ratio estimates obtained from the key run are also shown and are more valid.

8.4 Smoothing the M2 Values

The model

The rationale for smoothing the M2s (for input to Shepherd's long-term prediction model - see Section 4.3) and the basis of the estimation procedure have been outlined in the 1985 and 1987 reports of the Working Group. As in previous years, the model was applied to $\ln(M2)$ values corrected for predator biomass (PB). As in the previous report, the model fitted contained main effects for predator (PD) and prey (PY) species, a predator-prey interaction, a common weight ratio squared term, and a weight ratio term nested within predator to provide species-specific weight preference ratios, i.e.,

$$\ln(M2/PB) = PD + PY + PD * PY + \ln(wpred/wprey) * PD \\ + [\ln(wpred/wprey)]^2$$

It was noted that, in previous Working Groups, the weight ratio had been calculated using prey weights observed in stomachs. Although this is ecologically more correct, it does not produce appropriate preference estimates for input to Shepherd's long-term prediction model. This year, therefore, prey weights in the sea were used to calculate the weight ratio.

In the previous Working Group (1987 report), a 34-level model was fitted to produce final estimates. This was due to structural difficulties encountered with the statistical package SPSS-X. This year, the statistical package GLIM was utilized and it was not necessary to fit the 34-level model.

Results

Table 8.4.1 shows the estimates calculated from the model. The most notable features compared to last meeting's equivalent table (1987 report, Table 4.3.2) are the high relative preferences for cod by both mackerel and saithe. At the last meeting, the effect for saithe was noted, but certain data were excluded on the bases of partial disbelief and pragmatism. This year, the extra data from 1985-1987 suggest that such data exclusion is not justifiable, hence the saithe effect reappears. The mackerel effect is due to age 3-7 mackerel eating 0-group cod; these data have not been excluded to be consistent with the treatment of saithe preying on cod.

It is also notable that the estimated weight ratio preferences of predator species are much changed from the previous meeting. Last meeting, the analysis produced biologically attractive results, and it was suggested that the M2 smoothing procedure might be a useful investigative tool for feeding strategies and foraging constraints. This year, the analysis has produced less encouraging estimates perhaps due to the use of prey weight in the sea rather than in the stomach.

An essential difficulty with the smoothing procedure may be that the analysis does not take account of zero observations. One possible route to overcome this difficulty is (within the GLIM package) to use a Poisson error distribution with a long link

function. Such a model should produce zero preference values when no observations occur, rather than the currently unsatisfactory values estimated, for example, for mackerel eating haddock or whiting.

Finally, although the M2 smoothing has been carried out, it should be noted (see also Section 4.3) that Shepherd's long-term prediction model has been used this year with raw M2 (prey, prey-age, pred, pred-age) values read in directly from the key run. This is because the smoothed values used failed to predict sensible overall M2 values.

8.5 Fisheries Interactions

ACFM is now well aware of the causes and implications of TAC incompatibility, especially in the North Sea roundfish fishery, and of the necessity to incorporate some constraints in its advice.

The issue was examined by the North Sea Roundfish Working Group this year (Anon., 1988c), but that Group could not make any firm recommendation on how the compatibility should be implemented in practice due to the excessive aggregation of fleets into the human consumption component, and to the consequential oversimplification of treating it as a fully mixed fishery.

The essence of the problem is, therefore, to set up a typology of the fleets fishing in the North Sea in order to identify those groups of fleets which consistently have similar targets and by-catch compositions, both in terms of species and age groups. Preferably, this partition should be done on a quarterly basis as most fleets do change their pattern of fishing seasonally. Considering the way in which catch forecasts are computed, the fleet groups should correspond to fishery units in which it can be validly assumed that each unit of effort equally applies to the species and ages constituting the typical mix of the groups. In other words, the relationship:

$$F_{asqf} = Q_{asqf} * E_{qf}$$

where Q is either a catchability or a reference fishing mortality matrix, should be strictly applicable in the delineated groups.

Several types of analyses were attempted during this meeting. The simplest consisted in plotting each species against every other species. The fishing mortalities used were the standard average fishing mortalities for the human consumption fisheries (landings + discards) in the years 1974-1987 such as given in summary tables in the report of the North Sea Roundfish Working Group. These plots are given in Figures 8.5.1 - 8.5.6. It would be expected that if, overall, the relationship mentioned above had held true, a strong correlation would appear on these plots. In fact, no synchronism is apparent, and the mortalities exerted on cod are relatively more stable than on the other species. Depending on the year, the fishery manages to direct its effort preferentially on particular species at the expense of the others. The only case of rather distinct correlation is between haddock and whiting (Figure 8.5.4).

The same average F data have been treated in a Principal Component Analysis (PCA) in which the years are taken as observations and the species as variables. Both are projected on the plane of factors 1 and 2 (Figure 8.5.7) which together account for 78% of the total variance. The first factor is mostly associated with haddock and saithe, while the second factor discriminates between cod and whiting. It is noticeable that the points for years are quite dispersed, which confirms that some specialization of the fishery does occur.

These results still do not exclude the hypothesis of a mixed fishery. A good part of the variations may be due to the behaviour of some fleet components. The analysis was, therefore, pursued further with another PCA in which the cases were the human consumption and the industrial fishery, respectively, in 1985, 1986, and 1987, and the variables were the corresponding fishing mortalities on ages 1-5+ of cod and saithe, and ages 0-5+ of haddock and whiting. These were taken from the tables of input data given for the last data year in the reports of the North Sea Roundfish Working Group for 1986-1987, which means that they may differ from the back-calculated values obtained in this year's meeting of the Group.

This analysis just confirms the obvious in the sense that the first factor is clearly associated with the human consumption fishery and orthogonal to the factor related to the industrial fishery. The plot (Figure 8.5.8) also confirms what is known of the age and species compositions of either fishery. The first axis, however, discriminates saithe from a group of adult cod-haddock-whiting in the human consumption fishery. This plot also shows that the industrial fisheries are a strong competitor for whiting.

This analysis based on aggregated data is still too primitive to help significantly. A last attempt was, therefore, made to carry out an analysis on fishing mortalities by fleet and by quarter. The basic data for 1985-1987 were received from Aberdeen and processed in the standard way of the North Sea Roundfish Working Group (extension of catch-at-age composition of the same fishery in the same quarter to unsampled fleets, application of the Scottish samples data on discard to other HC fleets on the basis of the same ratio of weights discarded to weights landed). The total fishing mortalities at age for the years, as given in the latest report of the Working Group, were then prorated to the landings and discards in numbers at age in each quarter for each fleet. For the human consumption fleets, F_s at age for the landings and discards were eventually summed up. The age ranges retained for the analysis were ages 1-8 for cod, 1-7 for haddock and whiting, and 2-8 for saithe. The fleets labelled "others" in the data base were excluded as comprising variable entities at any time, as were the fleets with too many missing species and the industrial fleets. It had been expected that the analysis would be performed on data for individual fleets, but these were not consistently defined over the various species' data sets. The fishing mortalities were, therefore, summed within national fleets. For each of these, we thus had four sets of fishing mortalities (one for each species) in selected if not all years and quarters.

The PCA retained five factors accounting for 81% of the total variance. Ancillary statistics all indicate that the extraction leaves out a part of the variance which is decreasing with age, and this is especially true for cod. The first factor is clearly associated with haddock (ages 2-7) and whiting (ages 3-7), factor 2 with adult cod (negatively), factor 3 with adult saithe, and factor 4 with young haddock and whiting, in an industrial-like fishery. In all projections of the variables on the factors' planes, the points for cod showed a distinct curved pattern.

Plots of the projections of the observations in each quarter onto the planes of factor 1 x factor 2 and factor 1 x factor 3 are given in Figures 8.5.9 - 8.5.12. All indicate a relative similarity of behaviour in a group essentially composed of Belgium, England, France, Germany, and the Netherlands (noted H), although part of the French fleet (presumably the larger vessels) differs by its preference for saithe in the first two quarters. In all seasons, Scotland makes up a different group, essentially directed towards haddock, although some of the components of the Scottish fleet might belong to the group mentioned above. The picture is somewhat unclear for Denmark and Norway since most of the data in the set used were allocated to the industrial fisheries and, therefore, excluded from this analysis. As a consequence, there are no data for whiting and haddock from the human consumption sector in these countries in most years/quarters.

Since the fourth factor was of lesser importance, no plot of projections was made with it. Figure 8.5.13 is given just to summarize its effects; the highest positive scores reflect a targeting at young haddock and whiting. This behaviour is apparent in the latest part of the year for Denmark and especially for Scotland which, in contrast, shows negative scores in the early half of the year.

This analysis provides no evident conclusions with regard to the objective assigned as it lacks the essential input of the competent working group to adequately treat the data. At first view, it confirms that some degrees of flexibility do exist in at least some of the fleets in some seasons and that, with a proper management of the quotas over sectors and seasons, the TAC compatibility is attainable. If no such initiative is taken at national levels, there is obviously a group of fleets which may encounter difficulties in avoiding major disruptions in their activity when the quota for some species (cod essentially) is exhausted, or will legally continue their operations towards other species with the consequence that the TAC will be ineffective in limiting fishing mortalities due to discards.

The exercise suggests that a further disaggregation of the fleets should be done or, if this is already the case, that the fleet partitions should be consistently maintained in the data bases for the four roundfish species. It also shows that a seasonal breakdown throughout the assessment stage is required in order to deal with more stable by-catch matrices. It had been expected that seasonal catch predictions for every species and fleet would be feasible with the data used in the analyses, but this could not be achieved. It would have been of interest to see how the quota allocation key used in the EEC matches the actual prefer-

rences of the fleets. It is also likely that a disaggregation of the data by North Sea areas would help in delineating homogeneous species mixes, although no actual spatial model is available yet.

These comments show that a number of issues relevant to technical interactions are open for further work and speculation. Although less complex conceptually than the full multispecies interaction, they require as much input for interpretation of the analyses and cannot be adequately handled in overloaded working groups such as this one and the North Sea Roundfish Working Group which in any case would not deal with flatfish. ICES still does not have the right forum to evaluate the management implications in the North Sea on a regional basis.

Data which will become available from the work of the EEC STFC Working Group on Technical Measures should help with the data situation for the mixed-fishery problem.

8.6 Use of Survey Data

The stomach sampling programmes developed in the North Sea so far have been associated with international trawling surveys. The abundance data by size class and age-length distributions derived from these surveys have been directly applied in the primary analysis, in order to obtain weighted averages of stomach content composition by age class for the entire population.

During the present meeting, the IYFS data base developed at ICES was used to estimate a measure of overlap between various predator age classes and prey age classes. This was used in Section 6.3 as a possible explanatory variable for interannual changes in suitability.

Survey data for the abundance of "other predators" presently included under the M1 term might be used to split the generated M1s among the various prey accordingly. Therefore, it is envisaged that, in the future, more use of survey data will be made and it would be extremely useful if data from national surveys in other quarters were made available. The amount of information presently available in the various national data sets is enormous and facilities for exchanging these data should be enhanced.

9 FORECASTING THE LONG-TERM EFFECTS OF SUBSTANTIAL CHANGES IN SOME FISHERIES

Responding to a request from ACFM (see Appendix B), the Working Group has provided a set of forecast runs. The runs have been made using both the MSFOR and Shepherd models and always with constant recruitment based on averaging of recent levels (see Section 4.3).

Several of the runs will drive the stock biomasses to levels far from what they have been in the period for which we have data. That is, an appreciable extrapolation has been performed. The results given are, therefore, only indicative of directions in which changes will occur and should be treated cautiously.

9.1 Industrial Demersal Fishery Increased by 25%

An increase of 25% in the industrial demersal fishery has been considered using both the MSFOR and Shepherd models. Results are shown in Table 9.1.1. Results for both models are broadly comparable with minor yield decreases in the human consumption fishery and with large increases in the landings in the industrial demersal fishery, particularly of roundfish species.

9.2 Roundfish - Human Consumption Fishery Increasing

Increases of 25%, 50%, and 75% in the roundfish fishery were considered using both the MSFOR and Shepherd models. Results are shown in Tables 9.2.1-9.2.3. These show broad agreement for the two models under the three levels of effort change, with the roundfish fishery catches increasing progressively for all species. Some decreases occur in the industrial demersal fishery for whiting and saithe, but there are increases in cod, haddock, and the industrial species. There are also increases in the herring catches. Overall, only the yield of saithe decreases.

As a footnote, the effect of changing the exploitation of whiting in the two industrial fisheries by 100% was considered using only the MSFOR model. Results are shown in Table 9.2.4. Whiting catches increase sharply in the industrial catches with some increases in other species catch. Whiting catches decrease in the human consumption fishery, but increase overall by 10%.

9.3 No Mackerel Fishery

The question of what effects the recovery of the mackerel stock to its historical levels might have was addressed by eliminating the mackerel fishery. This would not in itself, however, recover the mackerel stock. Results are shown in Table 9.3.1. Apart from the obvious loss to the mackerel fishery, the yield of other species declines substantially according to the MSFOR model while the Shepherd model shows more modest losses and even some slight gains for whiting and haddock.

9.4 Herring Fishery Doubled

A decline in the herring stock has been considered by the device of increasing herring mortality by 100% in the directed human consumption fishery. Results (Table 9.4.1) from the MSFOR and Shepherd models are similar, except that the Shepherd model has only a consequential effect on the industrial pelagic fishery. This is because the Shepherd model considers predation mortality only as a function of predator abundance and does not consider abundance of alternative prey. Both models predict an increase in herring fishery catches and a decrease in the industrial pelagic, herring catches.

9.5 General Remarks

A synthesis of Sections 4.4 and 4.6 would seem to suggest that increasing fishing pressure on predators would generally increase yield though not necessarily value. In future years, it may be useful to construct the gradient of total yield and value on the fishing mortality of each age of each species.

It should be noted that neither the MSFOR or Shepherd models used in these sections have used a stock/recruitment relationship of any kind.

10 MULTISPECIES MODELS IN OTHER AREAS

10.1 Introduction

Multispecies problems are not unique to the North Sea and Baltic Seas, and the Working Group is consequently always interested to hear of developments in other regions and suggestions for suitable models for these regions.

10.2 Multispecies Models for Arctic Regions

Introduction

The Working Group realizes that the MSVPA, as implemented for the North Sea, may not be suitable for some other areas, mainly northerly areas with simpler ecology, but more severe climatic and oceanographic conditions. There is a need for a multispecies model adaptable to areas like the Barents Sea, Newfoundland, or Icelandic waters. These areas differ from the North Sea, at least in the following respect:

- Species of fish are fewer. In particular, there are not many predator species which are fished and at the same time likely to be subjected to heavy predation.
- As these areas are vast, open, and with heavy currents, migration of fish is likely to play a major role, particularly regarding overlapping of predators and prey.
- Oceanographic and climatic factors are likely to cause larger disturbances of the ecosystem.

Consequently, the Working Group discussed multispecies models suitable for Arctic regions. This activity was initiated by a report by the Norwegian participants on their Barents Sea model called MULTSPEC.

Objectives of an Arctic model

A multispecies model for Arctic regions would have to be both retrospective and predictive just as the present MSVPA model.

In the retrospective mode, such a model would be used, like the MSVPA, to calculate predation mortalities (for the few prey species) and feeding rations of all the species included or at

least of the predators. Stock size estimation would, however, not be of importance since, for the predators, classical VPA results would not be affected, as there is not likely to be any predation mortalities on those species. For the prey, in particular capelin, acoustical abundance estimates are available and any VPA-type estimation is not likely to be successful.

Predictive analysis, on the other hand, would differ considerably from predictions in the MSVPA model. As already mentioned in the introductory sub-section, food- and temperature-dependent growth rates are probably of much more importance in these Arctic regions than is the case in the North Sea. Hence, variable feeding level has to be included similar to the one in the Andersen and Ursin model. Thus, the retrospective analysis has to include estimation of the corresponding parameters. Food supply will also be largely influenced by the spatial overlap of predators and prey, and this can only be modelled sensibly in the Arctic regions if migration is taken care of. Even a (simple) behavioural description of how predators follow their prey is called for.

All this is highly governed by oceanographic conditions. Oceanographic models are maturing which may be able to give even long-term predictions of currents, etc. At any rate, a suitable multi-species model should be able to accept predictions from other models of guessed values on currents and temperature profiles.

In the predictive mode, the model would be used to predict bio-masses and catches given external fishing mortality rates. The prediction would, as is the case in the present MSVPA model, take predation into account, but feeding rate and consequently growth rate will also be influential.

Model entities

As regards fish in an Arctic multispecies model, cod and capelin are the most important species, although haddock may be considered a relevant predator species and herring and (young) red-fish would have to be added to the list of prey. Of other food items, shrimp are considered to be of major interest as are amphipods as these may be the only food item for which the cod and capelin are competing and thus causing a circuit in the otherwise tree-like food web!

Predation by seals is assumed to be of a significant magnitude, so the seal population should, if possible, be included. The same may be true for sea birds and whales. It must be born in mind that both seal and whale populations are increasing due to moratoriums on catches.

Levels of aggregation

In contrast to the North Sea MSVPA, spatial disaggregation is considered essential in Arctic multispecies models in connection with migration. The number and size of areas will vary. MULTSPEC is implemented with seven areas, whereas at Iceland, two areas might suffice.

Age group disaggregation is obviously needed, and some partici-

pants expressed the need for size classification within each age group. This of course is related to the question whether growth and/or migration is considered to be deterministic or have a stochastic element. It was pointed out that, instead of size classification, statistical information (variance, etc.) could be carried along and updated in the model.

Since the model is highly dynamic, the time step cannot be too large. A monthly step would in most cases be appropriate. Variable time steps could be used.

Current work and models

As has already been pointed out, the MSVPA model used by the Working Group for the North Sea is not suitable for export to Arctic regions. The alterations needed seem to be so extensive that they amount to developing a new model.

A working paper (Tjelmeland, 1988) describing the Barents Sea model under development in Bergen was presented to the Working Group. This model may evolve to become suitable as a general Arctic multispecies model. It does contain some extra modules not considered essential or implementable in other regions, but these modules can be detached. On the other hand, the Bergen model is still in the development phase and any of its parameters (e.g., those describing migration) are based on guesswork.

Activities in this field in Iceland were described in Section 6.8.2 of the report of the 1985 meeting of this Working Group (Anon., 1986b). The work reported on there has been continued, but actual multispecies model construction has not been initiated yet.

In Newfoundland, some important modules of an integrated multispecies model have been developed. These deal with capelin population dynamics, capelin migration relative to oceanographic factors, and cod migration relative to capelin abundance.

Conclusion

As the Multispecies Assessment Working Group is not only concerned about multispecies modelling of the North Sea, it stresses the importance of supporting work on a suitable multispecies model for Arctic regions. For this reason, the Working Group recommends holding a special meeting on this subject. Such a meeting would benefit from an environment where such models are already in progress, as is the case in Bergen.

10.3 Exporting North Sea MSVPA Results to Other Areas

As requested by ACFM, the Working Group considered the possibility of using some form of a simple generalization of the MSVPA results in other areas.

Time did not allow for a detailed analysis of the problem and only one idea among several was considered.

In Figure 10.3.1, the logarithm of the mean weight of the North

Sea MSVPA prey is plotted against the logarithm of the quarterly natural mortality rate for 1981. A clear relationship between the size of the prey and the natural mortality is seen as well as a considerable variance around the regression line. If this relationship between weight and natural mortality is universal, it is possible to get M values for species from other areas based only on information on weight at age. To test this hypothesis, a similar plot was made with 1983 data from the MSVPA from the central Baltic Sea (Anon., 1988d). This plot is shown in Figure 10.3.2. As can be seen from the figures, the slopes of the two regression lines are approximately equal, while their levels differ by about 0.6. This means that the level of natural mortality in the Baltic is only 55% of the North Sea level.

This higher natural mortality level found in the North Sea could be seen in the light of the high level of predators, 2.1 million t in 1981 for the MSVPA predators. To the predation by these MSVPA predators should be added that by other predators which is 48% of the predation caused by the MSVPA predators. In the central Baltic (an area of about half the size of the North Sea), the amount of cod was 0.9 million t in 1983. As cod is almost the only predator in the Baltic, the predation pressure per unit area in the Baltic is only about 58% of the predation pressure per unit area in the North Sea, assuming the biomass of predators to be a measure of the predation pressure. This should indicate an M level in the Baltic equal to 58% of the M level in the North Sea if the M level is proportional to the predation pressure. This is close to the observed level of M from the MSVPA of the central Baltic stocks. This could indicate that the North Sea relationship between weight of a prey and its natural mortality could be transferred to other areas if corrections for predator density are made.

However, these considerations must of course be regarded as very premature. The test using the central Baltic MSVPA is perhaps probably dubious because the MSVPA for the central Baltic is preliminary (Anon., 1988d). For instance, the cod consumption rate used in the Baltic seems high compared to the one used in the North Sea, and the very low natural mortality rates for some of the small prey in the Baltic seem odd.

11 RECOMMENDATIONS

- 1) The Chairman should 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. However, since these change marginally from previous estimates, they may prefer to retain existing smoothed values of M2 to preserve consistency in TAC estimation.

- 3) 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.
- 4) ACFM should also note that preliminary investigations of the effects of a mesh increase to 120 mm in the North Sea also indicate that this may have the opposite effect to that predicted from single-species assessments.
- 5) This Working Group, therefore, strongly recommends that it should provide all long-term advice for the nine North Sea species included in the MSVPA since this cannot properly be considered by single-species assessments.
- 6) The Working Group recommends that an ICES workshop should be convened to review stomach evacuation experiments.
- 7) ACFM should note that the preliminary tests of the constant suitability assumption on which MSVPA is based indicate that it is tenable.
- 8) The Working Group recommends that a full-scale sampling programme of stomachs should be repeated in 1991 in order to extend the basis for multispecies assessment. In order to allow for a careful evaluation of the main priorities and to define the logistics, a planning group should meet in 1989 so that cruise programmes can be adopted early in 1990.
- 9) The Working Group recommends that a special meeting of the Multispecies Assessment Working Group should be convened on a study of multispecies models in boreal regions. This would most appropriately be held in Bergen, Norway in early 1990.
- 10) Noting the important contribution that groundfish survey results make to its work, the Working Group recommends that ACFM encourage and facilitate the exchange of national survey data.

12 REFERENCES

- Agra Europe, 1988. Eurofish Report. Agra Europe (London) Ltd., Tunbridge Wells, Kent, England. No. 278, 28 April 1988, p. BB/2.
- Andersen, K.P. and Ursin, E. 1977. A multispecies extension to the Beverton and Holt theory of fishing, with accounts of phosphorus circulation and primary production. Medd. Danm. Fisk. - Havunders. NS.7.
- Anon. 1984. Report of the ad hoc Multispecies Assessment Working Group. ICES, Doc. C.M.1984/Assess:20.
- Anon. 1985. Report of the Mackerel Working Group. ICES, Doc. C.M. 1985/Assess:7.

- Anon. 1986a. Report of the Mackerel Working Group. ICES, Doc. C.M.1986/Assess:12.
- Anon. 1986b. Report of the ad hoc Multispecies Assessment Working Group. ICES, Doc. C.M.1986/Assess:9.
- Anon. 1987a. Report of the ad hoc Multispecies Assessment Working Group. ICES, Doc. C.M.1987/Assess:9.
- Anon. 1987b. Report of the Mackerel Working Group. ICES, Doc. C.M.1987/Assess:11.
- Anon. 1988a. Report of the meeting of coordinators in the stomach sampling project 1985 to 1987. ICES, Doc. C.M.1988/G:27.
- Anon. 1988b. Report of the Mackerel Working Group. ICES, Doc. C.M.1988/Assess:12.
- Anon. 1988c. Report of the North Sea Roundfish Working Group. ICES, Doc. C.M.1988/Assess:21.
- Anon. 1988d. Report of the Working Group on Multispecies Assessments of Baltic Fish. ICES, Doc. C.M.1988/Assess:4.
- Bailey, R.S. and Kunzlik, P.A. 1984. Variation in growth and mortality rate of Norway pout Trisopterus esmarkii (Nilsson). ICES, Doc. C.M.1984/G:70.
- Corten, A. and Kuitert, J. 1981. Report on the International Young Fish Survey 1981: herring data. ICES, Doc. C.M.1981/H:17.
- Daan, N. and Kuitert, C.J. 1981. Report on the catches of cod, haddock, whiting and Norway pout during the ICES Young Herring Survey 1981. ICES, Doc. C.M.1981/G:71.
- Daan, N., Bromley, P.J., Hislop, J.R.G., and Nielsen, N.A. 1988. Ecology of North Sea fish. Int'l. Symp. on Ecol. North Sea Fish, Texel, Netherlands, 15-21 May 1988.
- Dahl, K. and Kirkegaard, E. 1987. The diet and consumption of horse mackerel (Trachurus trachurus) in the eastern North Sea August 1986. ICES, Doc. C.M.1987/H:43.
- Gislason, H. and Sparre, P. 1987. Some theoretical aspects of the implementation of multispecies virtual population analysis in ICES. ICES, Doc. C.M.1987/G:51.
- Harding, D., Woolner, L. and Dann, J. 1986. The English groundfish surveys in the North Sea 1977-1985. ICES, Doc. C.M.1986/G:13.
- Houghton, R.G. 1986. Variations in the spatial overlap between fish prey and predators according to the English groundfish survey. Working Doc. M:13 submitted to 1986 Multispecies Working Group meeting.

- Lewy, P. and Gislason, H. 1988. Long term effects of minimum mesh size changes for North Sea Round fish species. Comparison of multispecies and single species approaches. Working Doc. submitted to 1988 Multispecies Working Group meeting.
- Magnus, R.J. and Magnusson, K.G. 1983. Existence and uniqueness of solutions to the multispecies VPA equations. ICES, Doc. C.M.1983/D:20.
- Pope, J.G. 1979. A modified cohort analysis in which constant natural mortality is replaced by estimates of predation levels. ICES, Doc. C.M.1979/H:16.
- Prime, J.H. and Hammond, R.S. 1986. The diet of grey seals in the North Sea assessed from faecal analysis. In: The impact of grey and common seals in North Sea resources. 1986 Report to the EEC, Contract No. ENV 66 UK(H).
- Schutz, N. 1987. First results of cod stomach investigations in the western Baltic (ICES Sub-divisions 22 and 24) since 1978. ICES, Doc. C.M.1987/J:25.
- Sea Mammal Research Unit. 1988. Multispecies fishery assessment in the North Sea: estimation of mortality caused by marine mammals. Report to the EEC, Contract with DGXIV-B-1.
- Shepherd, J.G. 1984. A promising method for the assessment of multispecies fisheries. ICES, Doc. C.M.1984/G:4.
- Sparholt, H. 1987a. The biomass of predator stocks not included in the North Sea MSVPA model. ICES, Doc. C.M.1987/G:52.
- Sparholt, H. 1987b. A suggestion for residual natural mortalities, M1, to be used in the North Sea MSVPA model. ICES, Doc. C.M.1987/G:53.
- Sparholt, H. 1988. A model for estimation of natural mortality rate, stock size and emigration of the Skagerrak-Kattegat and the Western Baltic herring stocks, based on catch-at-age data, acoustic data, and young fish survey data. ICES Symp. Baltic Sea Fish. Resources, 29 February - 3 March 1988, Rostock, BAL/No.24.
- Tjelmeland, S. 1988. MULTSPEC - A multispecies approach to management of the Barents Sea. Working Doc. submitted to 1988 Multispecies Working Group meeting.

Table 2.3.1 Total number of stomachs analyzed by year and quarter.

Species	1981				1985		1986		1987	
	1	2	3	4	1	3	1	3	1	3
Cod	4,146	2,430	2,329	2,513	2,705	2,561	2,977	3,733	2,497	3,808
Whiting	7,832	4,211	3,727	3,447	6,650	6,144	3,644	2,712 ¹	-	-
Saithe	547 ²	185 ²	899 ²	559 ²	-	-	-	2,102	-	994
Mackerel	248 ³	1,277 ³	2,737 ³	683 ³	-	-	-	-	-	-
Haddock	2,810	3,795	5,825	4,966	-	-	-	-	-	-

¹ Only part of the stomach collection analyzed.

² Samples refer to collections in 1980, 1981, and 1982 combined.

³ Samples refer to collections in 1980, 1981, 1982, and 1983 combined.

Table 2.5.1 M1 values obtained from fitting data to an exponential curve (see text). Mortality rates per year.

Species	Age							
	0 ¹	1	2	3	4	5	6	7+
Cod	0.46	0.48	0.25	0.21	0.20	0.20	0.20	0.20
Whiting	0.38	0.56	0.36	0.28	0.23	0.21	0.20	0.20
Saithe	0.10	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Mackerel	0.08	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Haddock	0.62	0.72	0.31	0.23	0.20	0.20	0.20	0.20
Herring	0.22	0.32	0.21	0.15	0.13	0.11	0.10	0.10
Sprat	0.32	0.61	0.56	0.50	0.46	-	-	-
Norway pout	0.40	0.75	0.64	0.54	-	-	-	-
Sandeel	0.26	0.49	0.45	0.39	0.36	0.34	0.31	-

¹Only representing second half of the year, and given in mortality rate per half year.

Table 2.5.2 Biomass estimates (in '000 t) of "other" predators than the five MSVPA predators, based on catch rates in the English Groundfish Survey (EGFS) (Daan *et al.*, 1988).

Species	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Mean
<u>Squalus acanthias</u>	78	254	64	140	88	47	88	43	71	881	175
Other sharks	5	24	7	14	5	3	5	12	11	12	10
<u>Raja spp.</u>	539	388	330	248	527	665	293	335	182	377	390
<u>Lophius piscatorius</u>	105	71	60	46	13	20	21	27	18	19	40
<u>Brosme brosme</u>	8	4	4	4	2	1	1	1	-	-	2
<u>Molva molva</u>	43	35	36	20	16	12	21	57	14	37	?
<u>Merluccius merluccius</u>	8	12	17	11	10	5	8	17	7	12	?
<u>Sebastes spp.</u>	5	28	52	21	8	9	12	66	7	28	23
Western mackerel	-	-	-	-	-	-	-	-	-	-	-
<u>Scophthalmus maximus</u>	20	14	18	15	3	48	1	5	5	9	14
<u>Scophthalmus rhombus</u>	6	7	1	2	3	5	4	4	2	2	4
<u>Lepidorhombus wiffiaqonis</u>	56	12	10	20	26	12	11	32	6	40	22
<u>Hippoglossus hippoglossus</u>	7	1	8	-	-	7	6	1	1	9	4
Total	885	873	608	550	708	838	564	616	354	1,426	743
<u>Trachurus trachurus</u>	305	282	479	586	501	294	507	492	462	358	427
Mackerel ¹	755	543	434	337	290	282	250	195	225	175	349
Catch rate kg/h mackerel ²	6.3	15.0	18.3	4.6	2.0	10.7	4.6	11.9	5.9	-	8.8
Catch rate kg/h horse mackerel ²	2.2	5.2	17.9	11.1	3.2	9.2	8.3	28.2	12.5	-	10.9

¹Biomass estimates from VPA of the North Sea mackerel (Anon., 1986a).

²From Harding *et al.* (1986).

Table 2.5.3 Estimated percentage of each mackerel stock that was present in the North Sea during each quarter of 1986 and 1987.

Age	1	2	3	4
<u>North Sea stock</u>				
1	100	100	100	100
2	80	100	100	80
>3	80	100	50	70
<u>Western stock</u>				
1	-	20	30	30
2	10	10	50	70
>3	10	+	50	70

+ = less than 5%.

Table 2.5.4 Annual amount of gadoids consumed by grey seals in the North Sea in 1985 and corresponding mortality rates.

Species	Age	1985 MSVPA stock numbers (thousands)	Number consumed by grey seals in 1985 (thousands) from SMRU (1988)	Partial natural mortality caused by grey seals	
				from SMRU (1988)	from Sparholt (1987b)
Cod	0	-	4,260	-	0.0260
	1	55,212	6,448	0.1168	0.0160
	2	207,419	4,803	0.0230	0.0030
	3	23,677	2,980	0.1259	0.0006
	4	12,845	44	0.0034	-
	5-11	5,767	-	-	-
Whiting	0	-	2,454	-	-
	1	4,550,364	13,987	0.0031	0.0200
	2	1,444,481	4,934	0.0034	0.0090
	3	175,062	1,770	0.0101	0.0040
	4+	118,251	3,480	0.0294	0.0020
Haddock	0	-	415	-	0.0580
	1	2,924,902	1,104	0.0004	0.0288
	2	1,233,135	1,133	0.0009	0.0061
	3	118,569	948	0.0080	0.0017
	4	57,770	754	0.0131	-
	5+	23,225	636	0.0274	-
Saithe	0	-	260	-	-
	1	184,975	281	0.0015	-
	2	212,611	454	0.0021	-
	3	248,631	206	0.0008	-
	4	118,293	130	0.0011	-
	5-8 9+	41,466 2,090	55 -	0.0013 -	- -

Table from SMRV (1988) report with MSVPA numbers based upon the 1986 MSVPA.

Table 2.8.1a Output from MSVPA key run for cod. Last age group is a plus group.

FISHING MORTALITY		COD								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0850	.1440	.0580	.2291	.1166	.1868	.1527	.1643	.2482	.1667
2	.8219	.7607	.9753	.8597	1.0627	.8367	.8983	1.0079	.9504	1.0690
3	.7191	.8025	.8590	.7236	.9485	.9270	.9311	.9602	1.2204	1.1488
4	.7090	.6647	.8004	.5828	.8109	.5376	.7314	.7197	.7681	.8397
5	.7119	.7908	.6128	.5707	.9616	.7341	.5716	.6791	.7762	.7460
6	.7030	.6803	.9125	.4547	.7490	.5437	.6006	.6426	.8429	.7740
7	.6559	.7473	.8659	.5549	.7347	.6595	.7195	.7286	.6895	.7147
8	.7221	.5414	.4969	.6117	.8708	.5083	.7091	.6326	.7229	.7248
9	1.1287	.9462	.4604	.5342	1.0076	.7728	.6285	.6681	.6889	.5950
10	.6956	.9239	.9486	.3930	.7991	.7382	.7010	.6972	.5803	.5203
11	.6000	.6002	.6002	.6002	.8013	.6334	1.1465	.2155	.9520	.5592
MEAN F WEIGHTED BY STOCK NUMBERS FOR	.6897	.6903	.8123	.5765	.8525	.7336	.6831	.8197	.9059	.8813

AGE	1984	1985	1986	1987
0	.0000	.0000	.0000	.0000
1	.2300	.1666	.2160	.1323
2	.9883	.9506	1.0106	.8597
3	.9665	.9396	1.0510	1.2502
4	.7340	.8073	.9657	.7463
5	.6862	.7131	.7773	.8193
6	.6922	.6452	.9275	.7392
7	.7410	.6217	.7616	.9182
8	.8125	.8065	.6806	.6523
9	.8319	.6580	.6476	.5143
10	.9318	.4289	1.1788	1.0413
11	.9567	.9504	.7490	.7490
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.7577	.8354	.8473	.7728

Mortality of 0-group is for 3rd and 4th quarter only

STOCK NUMBERS		COD								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	288541.	425091.	204644.	772428.	465016.	474929.	953614.	370505.	630674.	307136.
2	122692.	111302.	179299.	91777.	290274.	180511.	176376.	358530.	118158.	216671.
3	24248.	34816.	35546.	46981.	26630.	68529.	53535.	49072.	86914.	30343.
4	32031.	8405.	11887.	11535.	17321.	7775.	20766.	15866.	13976.	19354.
5	9434.	12907.	3540.	4371.	5273.	6303.	3718.	8182.	6325.	5308.
6	1993.	3790.	4792.	1570.	816.	1650.	2477.	1719.	3397.	2389.
7	948.	808.	1572.	1575.	816.	783.	785.	1112.	740.	1197.
8	793.	403.	313.	541.	740.	320.	331.	313.	439.	304.
9	514.	316.	192.	156.	240.	254.	158.	134.	136.	175.
10	164.	136.	100.	99.	75.	72.	96.	69.	55.	56.
11	433.	121.	80.	58.	87.	49.	38.	115.	41.	47.
TOTAL STOCK BIOMASS ON 1. JANUARY	326636.	285284.	285656.	262091.	353708.	320201.	354350.	427724.	353409.	315484.
SPAWNING STOCK BIOMASS ON 1. JANUARY	169116.	141669.	118092.	99757.	114271.	102785.	117716.	129305.	132941.	117541.

AGE	1984	1985	1986	1987
0	0.	0.	0.	0.
1	581310.	112375.	527401.	290895.
2	110781.	222366.	42896.	211360.
3	50178.	28601.	59450.	10916.
4	7194.	14778.	8592.	16172.
5	6843.	2827.	5397.	2678.
6	2061.	2820.	1134.	2031.
7	900.	845.	1211.	367.
8	480.	351.	371.	463.
9	121.	174.	128.	154.
10	79.	43.	74.	55.
11	40.	37.	63.	30.
TOTAL STOCK BIOMASS ON 1. JANUARY	263183.	277818.	226818.	248441.
SPAWNING STOCK BIOMASS ON 1. JANUARY	100112.	96422.	92231.	82824.

cont'd.

Table 2.8.1a cont'd.

PREDATION MORTALITY		COO								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.7874	.7601	.6939	.5729	.5702	.4919	.5209	.4288	.4079	.3547
1	.3876	.2393	.2639	.2696	.3497	.3238	.3456	.4985	.3402	.3730
2	.1678	.1107	.0940	.1077	.1109	.1088	.1111	.1392	.1390	.1238
3	.1305	.0621	.0565	.0643	.0727	.0569	.0750	.0857	.0717	.0806
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

AGE	1984	1985	1986	1987						
0	.4041	.3457	.3529	.9107						
1	.2510	.3164	.2184	.2637						
2	.0958	.0886	.0880	.0761						
3	.0459	.0530	.0408	.0543						
4	.0000	.0000	.0000	.0000						
5	.0000	.0000	.0000	.0000						
6	.0000	.0000	.0000	.0000						
7	.0000	.0000	.0000	.0000						
8	.0000	.0000	.0000	.0000						
9	.0000	.0000	.0000	.0000						
10	.0000	.0000	.0000	.0000						
11	.0000	.0000	.0000	.0000						

Mortality of 0-group is for 3rd and 4th quarter only

NORTH SEA DATA 1974 - 1987 (MULTISPECIES WORKING GROUP 1988)

WITH STOMACH CONTENT DATA FOR COO, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.8.1b Output from MSVPA key run for whiting. Last age group is a plus group.

FISHING MORTALITY		WHITING								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.0589	.0605	.0762	.0920	.0638	.0447	.0661	.1137	.0320	.1623
1	.4397	.2490	.2262	.4791	.1813	.2911	.1267	.1998	.2443	.2874
2	.9145	.7940	1.0083	.5586	.4281	.5340	.4458	.3325	.3365	.4734
3	1.0839	1.0791	1.2691	.9288	.7240	.8262	.8249	.7683	.5224	.7335
4	.9726	1.0771	1.1314	1.0312	.8858	.7505	1.0325	1.0048	.7302	.7619
5	1.0637	1.0582	.8265	.8666	.7551	.9577	1.1855	1.0618	.9397	.9496
6	1.9985	.9721	1.2720	1.0493	1.1820	1.0286	1.4540	1.4086	1.2135	1.0242
7	1.1648	1.0853	.7455	.8360	1.6045	.9029	1.1571	1.3727	.9564	1.2792
8	.8891	1.2307	.6574	2.2173	1.7511	1.0045	1.9675	1.0598	1.3312	1.3788
9	2.3431	1.4816	.7125	.3927	.7077	.5364	.7599	.7375	.7571	1.2543
10	1.2000	1.2013	1.2000	1.2000	1.3731	1.0093	1.3711	1.1593	.9852	1.0352
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.8796	.6986	.9125	.6430	.4791	.5579	.5191	.4848	.4701	.5871

AGE	1984	1985	1986	1987						
0	.0546	.0343	.0305	.0160						
1	.3137	.2360	.3242	.0941						
2	.4990	.3177	.3434	.3778						
3	.8589	.6077	.6154	.5876						
4	1.0784	.9278	1.1201	1.0982						
5	1.0570	1.0241	1.0916	.9262						
6	1.3518	1.1402	1.4368	1.7061						
7	1.2323	1.3387	1.3950	1.4874						
8	1.4108	2.4062	1.6609	1.0793						
9	2.2000	2.9464	1.8968	1.2522						
10	1.1693	1.4022	1.1711	1.2521						
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.6346	.4187	.4610	.3904						

Mortality of 0-group is for 3rd and 4th quarter only										

STOCK NUMBERS		WHITING								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	3341000.	6518170.	4216888.	4247252.	4591669.	4947942.	4694112.	2216941.	1994489.	1808230.
2	2035538.	908541.	2211548.	1377963.	1071867.	1446042.	1383064.	1565620.	542126.	569741.
3	414807.	520197.	271157.	529538.	515970.	450664.	546234.	573538.	697949.	244903.
4	59254.	96591.	124861.	53978.	147514.	176327.	139005.	168957.	185153.	286809.
5	8335.	16810.	25143.	30814.	14676.	46315.	63273.	37657.	46604.	67179.
6	1569.	2265.	4633.	8733.	10272.	5467.	14076.	15328.	10276.	14340.
7	9253.	170.	688.	1043.	2455.	2532.	1570.	2643.	3001.	2439.
8	654.	2364.	47.	267.	370.	404.	840.	404.	548.	944.
9	63.	220.	565.	20.	24.	53.	121.	96.	115.	119.
10	29.	7.	54.	301.	14.	14.	32.	62.	54.	62.
TOTAL STOCK BIOMASS ON 1. JANUARY	498863.	515365.	548239.	482056.	477899.	543604.	544667.	476819.	372686.	314232.
SPAWNING STOCK BIOMASS ON 1. JANUARY	362542.	280034.	379756.	320855.	307804.	357401.	367904.	384212.	298035.	245771.

AGE	1984	1985	1986	1987						
0	0.	0.	0.	0.						
1	2414410.	2236485.	3873180.	5053939.						
2	506446.	727566.	682731.	1167650.						
3	227245.	202468.	345376.	322215.						
4	82300.	68501.	78392.	133283.						
5	101603.	21476.	20763.	19629.						
6	20571.	28095.	6136.	5549.						
7	4131.	4284.	7239.	1175.						
8	556.	986.	920.	1469.						
9	195.	111.	73.	143.						
10	37.	22.	6.	12.						
TOTAL STOCK BIOMASS ON 1. JANUARY	280640.	265015.	347639.	462720.						
SPAWNING STOCK BIOMASS ON 1. JANUARY	191771.	180111.	206374.	275621.						

cont'd.

Table 2.8.1b cont'd.

PREDATION MORTALITY		WHITING								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.5427	.9011	.8446	.8688	.8799	1.0151	1.4007	.9704	.9715	.6447
1	.3026	.2719	.3323	.3378	.4142	.4237	.4114	.6486	.4486	.4253
2	.1298	.0952	.1011	.1037	.1184	.1195	.1145	.1554	.1381	.1257
3	.0934	.0679	.0650	.0693	.0698	.0700	.0685	.0824	.0869	.0770
4	.0572	.0388	.0378	.0412	.0427	.0444	.0435	.0532	.0536	.0458
5	.0290	.0205	.0210	.0220	.0224	.0233	.0223	.0269	.0289	.0239
6	.0254	.0196	.0188	.0197	.0182	.0190	.0186	.0221	.0249	.0204
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

AGE	1984	1985	1986	1987
0	.7858	.7040	.9037	1.7464
1	.3258	.3905	.3148	.3643
2	.0978	.1074	.0875	.0886
3	.0603	.0612	.0568	.0498
4	.0350	.0359	.0346	.0294
5	.0185	.0187	.0180	.0145
6	.0171	.0160	.0157	.0120
7	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000

Mortality of 0-group is for 3rd and 4th quarter only
 NORTH SEA DATA 1974 - 1987 (MULTISPECIES WORKING GROUP 1988)
 WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.8.1c Output from MSVPA key run for saithe. Last age group is a plus group.

FISHING MORTALITY										
SAITHE										
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0084	.0004	.0025	.0852	.0039	.0045	.0098	.0279	.0050	.0004
2	.0628	.1570	.1847	.1566	.1457	.2476	.1308	.1536	.1777	.1377
3	.4493	.3620	.7378	.1817	.2663	.2045	.2765	.1460	.3345	.2721
4	.5093	.7734	.8045	.5548	.5419	.4083	.2910	.3071	.4398	.4447
5	.3654	.6987	.9158	.9566	.5697	.4776	.5787	.3204	.7091	.6675
6	.5982	.5340	.6985	.6970	.4310	.3777	.5837	.5790	.5505	.7608
7	.6762	.5344	.5773	.3690	.2859	.4490	.5329	.5689	.5354	.9310
8	.5064	.5327	.5992	.4659	.2787	.3928	.3757	.8294	.5267	.9691
9	.4223	.2889	.3977	.3519	.2679	.2262	.4527	.4476	.6638	.7807
10	.3670	.2679	.4258	.2796	.2582	.1808	.3467	.4449	.3792	.4407
11	.3462	.2054	.4350	.2193	.2693	.2438	.3525	.5492	.3173	.4409
12	.3604	.3720	.5041	.4843	.2676	.2673	.2451	.7133	.3771	.3427
13	.6820	.4149	.4618	.3713	.5587	.1554	.2913	.5458	.4700	.4688
14	.3096	.4015	.6969	.6188	.3972	.2768	.2316	.6813	.6040	.3429
15	.2923	.3001	.3000	.3001	.3572	.2401	.3432	.6202	.4982	.5233
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.5347	.5795	.7079	.6600	.4729	.4024	.4991	.4820	.5577	.6820

AGE	1984	1985	1986	1987						
0	.0000	.0000	.0000	.0000						
1	.0002	.0023	.0004	.0087						
2	.0946	.0124	.0516	.1621						
3	.5709	.5191	.1873	.3481						
4	.6810	1.0216	1.0912	.5182						
5	.5524	.5497	.8808	.4721						
6	.7851	.4300	.4459	.3151						
7	.5042	.3338	.2526	.2071						
8	.5977	.3008	.2088	.2251						
9	.4322	.2364	.2909	.2661						
10	.3664	.2253	.1978	.4712						
11	.2582	.2381	.4626	.3421						
12	.2797	.2595	.4004	.4441						
13	.2107	.1328	.2155	.2991						
14	.4298	.2649	.2712	.3652						
15	.3352	.1951	.3772	.3652						
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.6465	.5790	.7292	.4261						

Mortality of 0-group is for 3rd and 4th quarter only										
STOCK NUMBERS										
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	480029.	190378.	120592.	129893.	117854.	268058.	172306.	212942.	349442.	516278.
2	266144.	389715.	155803.	98482.	97662.	96110.	218483.	139697.	169550.	284673.
3	184041.	204639.	272705.	106051.	68942.	69116.	61429.	156944.	98086.	116212.
4	87464.	96146.	114351.	106759.	72401.	43249.	46124.	38145.	111041.	57475.
5	44580.	43030.	36324.	41879.	50187.	34476.	23539.	28229.	22972.	58565.
6	50285.	25327.	17517.	11901.	13173.	23245.	17508.	10805.	16776.	9255.
7	32388.	22598.	12156.	7133.	4853.	7008.	13044.	7996.	4958.	7920.
8	13889.	13485.	10842.	5587.	4038.	2985.	3662.	6268.	3707.	2376.
9	4547.	6853.	6481.	4875.	2871.	2502.	1650.	2059.	2339.	1792.
10	2891.	2441.	4203.	3565.	2808.	1798.	1634.	859.	1078.	925.
11	1546.	1640.	1529.	2248.	2207.	1775.	1229.	946.	451.	604.
12	805.	895.	1093.	810.	1478.	1380.	1139.	707.	447.	269.
13	293.	460.	505.	541.	409.	926.	865.	730.	284.	251.
14	124.	121.	249.	261.	305.	191.	649.	529.	346.	145.
15	121.	189.	169.	258.	269.	472.	283.	753.	436.	301.
TOTAL STOCK BIOMASS ON 1. JANUARY	796557.	745692.	702153.	493785.	411131.	369306.	367641.	396279.	429250.	445509.
SPANNING STOCK BIOMASS ON 1. JANUARY	445529.	359001.	295398.	237367.	218567.	212587.	199702.	175499.	164014.	180901.

AGE	1984	1985	1986	1987						
0	0.	0.	0.	0.						
1	478086.	159326.	222874.	295425.						
2	422840.	391357.	129324.	182397.						
3	203087.	314713.	316462.	100559.						
4	72481.	93943.	153321.	214846.						
5	30164.	30033.	27690.	42156.						
6	24597.	14215.	14191.	9396.						
7	3541.	9184.	7571.	7439.						
8	2556.	1751.	5385.	4815.						
9	816.	1151.	1061.	3578.						
10	672.	434.	744.	650.						
11	487.	381.	283.	500.						
12	318.	308.	246.	146.						
13	156.	197.	198.	135.						
14	129.	104.	141.	129.						
15	204.	210.	148.	204.						
TOTAL STOCK BIOMASS ON 1. JANUARY	524105.	614577.	650652.	599641.						
SPANNING STOCK BIOMASS ON 1. JANUARY	159244.	154232.	173388.	203908.						

cont'd.

Table 2.8.1c cont'd.

PREDATION MORTALITY		SAITHE								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
14	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
15	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
AGE	1984	1985	1986	1987						
0	.0000	.0000	.0000	.0000						
1	.0000	.0000	.0000	.0000						
2	.0000	.0000	.0000	.0000						
3	.0000	.0000	.0000	.0000						
4	.0000	.0000	.0000	.0000						
5	.0000	.0000	.0000	.0000						
6	.0000	.0000	.0000	.0000						
7	.0000	.0000	.0000	.0000						
8	.0000	.0000	.0000	.0000						
9	.0000	.0000	.0000	.0000						
10	.0000	.0000	.0000	.0000						
11	.0000	.0000	.0000	.0000						
12	.0000	.0000	.0000	.0000						
13	.0000	.0000	.0000	.0000						
14	.0000	.0000	.0000	.0000						
15	.0000	.0000	.0000	.0000						

Mortality of 0-group is for 3rd and 4th quarter only
 NORTH SEA DATA 1974 - 1987 (MULTISPECIES WORKING GROUP 1988)
 WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND Haddock

Table 2.8.1d Output from MSVPA key run for mackerel. Last age group is a plus group.

FISHING MORTALITY		MACKEREL									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1	.0067	.0247	.0103	.0072	.0000	.0244	.0204	.0195	.0141	.0058	
2	.1106	.0276	.1964	.0888	.0615	.0223	.0732	.0540	.0881	.0978	
3	.0773	.1265	.2517	.2241	.2149	.1073	.1225	.1971	.1833	.2398	
4	.1822	.1855	.1429	.2981	.2251	.1869	.1842	.0729	.2416	.2893	
5	.2353	.1784	.2069	.1342	.2316	.2740	.3111	.2263	.1700	.2527	
6	.2200	.2870	.1715	.2347	.1071	.1669	.3396	.3704	.2019	.1210	
7	.1028	.1759	.2677	.4314	.0290	.0966	.2630	.3857	.2598	.2062	
8	.2421	.4229	.3154	.4726	.3831	.1357	.2720	.2698	.2944	.3505	
9	.0901	.3785	.2713	.5571	.2931	.0699	.3009	.2618	.2017	.2689	
10	.0457	.1914	.3590	.4699	.5174	.2668	.1614	.2426	.2157	.2376	
11	.0395	.0593	.2143	.6721	.0867	.3302	.2967	.1346	.1670	.1839	
12	.1426	.0620	.0764	.3752	.1398	.2300	.4097	.5412	.1839	.2291	
13	.1280	.1005	.0324	.1536	.4120	.4075	.2347	.3196	.4367	.1318	
14	.0280	.0890	.0895	.0337	.1582	.2897	.6391	.7945	.5504	.8826	
15	.6790	.3602	.2535	.4059	.5713	.2927	.2914	1.4402	.4108	.7472	
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.2221	.2538	.2396	.3766	.2365	.2078	.2810	.3255	.2493	.2898	

AGE	1984	1985	1986	1987							
0	.0000	.0000	.0000	.0000							
1	.0041	.0145	.0353	.0495							
2	.1495	.1713	.0766	.1913							
3	.5808	.5906	1.0225	.0320							
4	.5316	.8589	1.2066	.4146							
5	.6224	.6547	.4071	1.0871							
6	.6500	1.0984	.2362	.1792							
7	.4892	1.0170	.6087	.1165							
8	.3115	.7029	.7377	.6902							
9	.4867	.6500	2.2229	.5296							
10	.4796	.8784	.6318	1.3926							
11	.2569	.7265	1.4482	.1288							
12	.2730	.4594	2.7142	.6092							
13	.1753	.6092	.5103	2.1506							
14	.1255	.2706	1.0644	.0830							
15	.6811	2.0861	.3660	1.0648							
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.4885	.8089	.6166	.2355							

Mortality of 0-group is for 3rd and 4th quarter only											
STOCK NUMBERS		MACKEREL									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
1	483478.	543322.	293256.	176387.	31821.	104757.	148070.	221090.	235951.	27891.	
2	197378.	413372.	456212.	249819.	150730.	27389.	87991.	124867.	186624.	200244.	
3	350778.	152100.	346093.	322661.	196751.	121998.	23054.	70390.	101819.	147082.	
4	264678.	279468.	115396.	231603.	221964.	136604.	94319.	17555.	49748.	72957.	
5	1269717.	189865.	199822.	86065.	147951.	152545.	97534.	67822.	14048.	33630.	
6	256380.	863747.	136722.	139840.	64772.	101016.	99827.	61506.	46346.	10201.	
7	84956.	177094.	557940.	99131.	95183.	50090.	73430.	61183.	36553.	32598.	
8	82761.	65976.	127838.	367441.	55427.	79582.	39144.	48588.	35806.	24264.	
9	40921.	55917.	37202.	80265.	197154.	32523.	59803.	25668.	31930.	22960.	
10	12335.	32186.	32961.	24411.	39576.	126584.	26103.	38096.	17004.	22462.	
11	8908.	10143.	22876.	19814.	13133.	20305.	83439.	19119.	25727.	11796.	
12	7752.	7371.	8228.	15892.	8708.	10365.	12561.	53380.	14383.	18737.	
13	8578.	5786.	5962.	6561.	9399.	6557.	7032.	7178.	26741.	10300.	
14	37346.	6496.	4503.	4968.	4843.	5358.	3755.	4786.	4488.	14873.	
15	48613.	78213.	15406.	8312.	8045.	9948.	9672.	2142.	4336.	3761.	
TOTAL STOCK BIOMASS ON 1. JANUARY	983134.	887540.	744856.	610658.	447643.	356846.	300721.	249766.	227525.	208521.	
SPAWNING STOCK BIOMASS ON 1. JANUARY	810129.	715365.	532668.	458331.	361162.	310626.	263919.	186798.	141858.	124717.	

AGE	1984	1985	1986	1987							
0	0.	0.	0.	0.							
1	6996.	510455.	109619.	175784.							
2	23842.	5987.	433047.	91074.							
3	156287.	17673.	4349.	345244.							
4	99604.	75254.	8426.	1346.							
5	47021.	50379.	27441.	2170.							
6	22483.	21719.	22531.	15719.							
7	7779.	10102.	6233.	15314.							
8	22830.	4105.	3145.	2919.							
9	14710.	14391.	1750.	1294.							
10	15103.	7782.	6466.	163.							
11	15244.	8047.	2782.	2959.							
12	8446.	10148.	3349.	563.							
13	13085.	5534.	5517.	191.							
14	7770.	9451.	2590.	2851.							
15	9383.	6621.	15397.	1094.							
TOTAL STOCK BIOMASS ON 1. JANUARY	166831.	138927.	151670.	147524.							
SPAWNING STOCK BIOMASS ON 1. JANUARY	120214.	92173.	48657.	23460.							

cont'd.

Table 2.8.1d cont'd.

PREDATION MORTALITY		MACKEREL								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
14	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
15	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
AGE	1984	1985	1986	1987						
0	.0000	.0000	.0000	.0000						
1	.0000	.0000	.0000	.0000						
2	.0000	.0000	.0000	.0000						
3	.0000	.0000	.0000	.0000						
4	.0000	.0000	.0000	.0000						
5	.0000	.0000	.0000	.0000						
6	.0000	.0000	.0000	.0000						
7	.0000	.0000	.0000	.0000						
8	.0000	.0000	.0000	.0000						
9	.0000	.0000	.0000	.0000						
10	.0000	.0000	.0000	.0000						
11	.0000	.0000	.0000	.0000						
12	.0000	.0000	.0000	.0000						
13	.0000	.0000	.0000	.0000						
14	.0000	.0000	.0000	.0000						
15	.0000	.0000	.0000	.0000						

Mortality of 0-group is for 3rd and 4th quarter only
 NORTH SEA DATA 1974 - 1987 (MULTISPECIES WORKING GROUP 1988)
 WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.8.1e Output from MSVPA key run for haddock. Last age group is a plus group.

FISHING MORTALITY		HADDOCK									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	.0160	.0159	.0246	.0202	.0289	.0460	.0487	.0586	.0329	.0328	
1	.3692	.3577	.3369	.3236	.5402	.1685	.2278	.1922	.2209	.2065	
2	.9227	1.0305	.8434	.9888	.8245	1.0083	.8047	.4627	.4548	.6569	
3	.9454	1.2967	1.4221	1.0448	1.0660	1.4380	1.2183	.9274	.8196	1.0516	
4	.9952	1.1345	.8063	1.2886	1.1224	1.0030	1.1066	1.0041	.8841	1.1391	
5	.7066	1.0292	1.3840	1.0605	1.1204	.9785	.7142	.6365	.6151	1.2445	
6	.9456	.6719	1.1574	1.0559	1.0425	1.0525	.9547	.3063	.4952	.8227	
7	1.1369	1.1393	.3565	.9248	1.1366	.5698	1.0123	.8919	.3858	.3685	
8	.7418	1.1622	.6443	.4003	.6845	1.0224	.6238	.6712	.9329	1.402	
9	.2758	.8873	1.2244	.4800	.6746	.5594	1.5070	.9143	.2543	.5377	
10	1.1548	2.5651	3.0570	1.0046	.2421	.3850	.8787	.9086	.5853	.9710	
11	.9000	.9000	.9000	.9000	1.0643	.9522	1.0033	.8952	.8874	.9354	
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.8596	.9127	.9812	1.0286	.9524	.9497	.7823	.5916	.7269	.8888	
AGE	1984	1985	1986	1987							
0	.0070	.0150	.0029	.0057							
1	.1680	.3429	.2135	.1952							
2	.6697	.6608	1.1514	.9409							
3	.9326	.9869	1.4045	1.1091							
4	1.0992	1.0939	1.4785	1.2935							
5	1.1256	1.0149	1.0124	1.2496							
6	1.0447	.9126	.7758	1.0443							
7	.7481	.8862	.8066	.9693							
8	.1700	.6399	.8954	.7802							
9	.0945	.1727	.8012	1.0653							
10	.6036	.0849	.4241	1.0652							
11	.9522	.9343	.9713	1.0653							
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.7180	.7256	1.2298	.9077							

Mortality of 0-group is for 3rd and 4th quarter only

STOCK NUMBERS		HADDOCK									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
1	11926866.	20086180.	2169080.	2495861.	4624390.	5356301.	8513012.	2964913.	4194609.	2706220.	
2	351092.	1282582.	2225882.	199947.	310491.	453534.	837422.	1407667.	298589.	606805.	
3	596502.	91031.	306779.	643165.	49624.	90739.	110195.	251104.	580695.	124330.	
4	92042.	176739.	19017.	56539.	171202.	13115.	16253.	24803.	75255.	192329.	
5	3933.	27519.	46091.	6886.	12636.	45233.	3904.	4360.	7370.	25165.	
6	2343.	1584.	8033.	9434.	1948.	3367.	13897.	1562.	1885.	3255.	
7	16911.	745.	662.	2067.	2687.	562.	962.	4380.	941.	940.	
8	491.	4442.	160.	380.	671.	706.	260.	286.	1470.	524.	
9	99.	192.	1138.	69.	208.	277.	208.	114.	120.	473.	
10	51.	62.	65.	274.	35.	87.	130.	38.	37.	76.	
11	15.	20.	6.	4.	114.	33.	69.	66.	19.	25.	
TOTAL STOCK BIOMASS ON 1. JANUARY	1018790.	1510144.	713204.	460551.	441975.	461531.	696296.	548547.	553076.	440841.	
SPAWNING STOCK BIOMASS ON 1. JANUARY	253580.	226552.	270257.	225942.	131896.	98678.	110965.	175624.	218456.	186793.	
AGE	1984	1985	1986	1987							
0	0.	0.	0.	0.							
1	10450908.	5185181.	5695497.	7337546.							
2	403977.	1508311.	363071.	471668.							
3	209696.	140510.	527439.	77673.							
4	33256.	63031.	40210.	98648.							
5	49924.	8998.	17147.	7452.							
6	5922.	13240.	2665.	5094.							
7	1170.	1706.	4352.	1004.							
8	533.	454.	576.	1591.							
9	373.	368.	196.	193.							
10	226.	278.	253.	72.							
11	34.	149.	303.	189.							
TOTAL STOCK BIOMASS ON 1. JANUARY	793908.	683291.	621280.	591229.							
SPAWNING STOCK BIOMASS ON 1. JANUARY	145818.	185274.	204359.	114864.							

cont'd.

Table 2.8.1e cont'd.

PREDATION MORTALITY		HADDOCK									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	.7801	.9072	1.0008	1.0430	1.0245	.9815	1.2421	1.3116	1.2350	.8411	
1	1.1410	1.1224	1.3273	1.0411	1.0619	.9674	.8520	1.3833	.9924	.9754	
2	.1172	.0900	.0881	.0948	.0956	.0965	.0898	.1128	.1113	.0956	
3	.0410	.0392	.0391	.0488	.0347	.0517	.0429	.0476	.0554	.0371	
4	.0121	.0095	.0095	.0098	.0086	.0087	.0091	.0095	.0113	.0096	
5	.0029	.0021	.0023	.0023	.0021	.0017	.0022	.0023	.0023	.0022	
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	

AGE	1984	1985	1986	1987							
0	.9746	1.1043	1.2450	2.3615							
1	1.0477	1.5960	1.5576	1.2906							
2	.0764	.0799	.0806	.0731							
3	.0394	.0343	.0420	.0221							
4	.0080	.0080	.0071	.0063							
5	.0016	.0020	.0013	.0018							
6	.0000	.0000	.0000	.0000							
7	.0000	.0000	.0000	.0000							
8	.0000	.0000	.0000	.0000							
9	.0000	.0000	.0000	.0000							
10	.0000	.0000	.0000	.0000							
11	.0000	.0000	.0000	.0000							

Mortality of 0-group is for 3rd and 4th quarter only

NORTH SEA DATA 1974 - 1987 (MULTISPECIES WORKING GROUP 1988)
WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.8.1f Output from MSVPA key run for herring- Last age group is a plus group.

FISHING MORTALITY		HERRING									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	.0770	.1000	.0959	.0755	.0358	.0611	.0581	.3527	.3198	.3999	
1	.4679	.5676	.2085	.1703	.1284	.1106	.0499	.1409	.1968	.1469	
2	.9688	1.2669	1.2433	.1429	.0181	.0786	.2718	.2813	.2097	.2698	
3	.9145	1.4289	1.5250	.9812	.0321	.0571	.3603	.2650	.4590	.3128	
4	.9549	1.3552	1.6067	.4783	.0676	.0744	.2517	.2628	.2347	.4121	
5	1.1217	1.7983	1.7359	.9339	.0219	.0343	.2098	.3512	.1289	.2690	
6	.9892	1.2094	1.0634	.8911	.0552	.0164	.0467	.3554	.1210	.2894	
7	.7642	2.0489	1.5734	.7310	.0913	.3154	.1520	.6210	.1822	.3238	
8	.7802	2.0003	2.3972	1.0526	.1731	.4175	.2301	1.2229	.1946	.3853	
9	1.0001	1.0003	.3602	.0010	.0003	.0120	.0100	.3000	.1000	.3302	
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	1.3574	1.3574	1.3168	.6094	.0316	.0689	.2771	.2960	.2822	.2980	
.9537											
AGE	1984	1985	1986	1987							
0	.1128	.0377	.0094	.1652							
1	.0719	.2162	.1586	.1835							
2	.2490	.3451	.4136	.4068							
3	.3731	.6060	.4575	.5339							
4	.4836	.6522	.5146	.5375							
5	.5496	.6098	.4625	.5459							
6	.3413	.6360	.6454	.5285							
7	.5300	.5587	.6790	.5502							
8	.4307	.5396	.8116	.4502							
9	.3401	.5403	.4702	.4002							
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.3174	.4915	.4575	.4639							
Mortality of 0-group is for 3rd and 4th quarter only											
STOCK NUMBERS		HERRING									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
1	4895070.	8228309.	1552470.	1458571.	2253522.	2388925.	6402609.	8326639.	11020120.	16198598.	
2	1583476.	931749.	1641862.	402331.	392232.	659987.	698063.	1785913.	1925337.	3160537.	
3	746372.	406773.	181561.	312145.	225004.	241478.	390560.	330513.	769360.	997043.	
4	22768.	20785.	7113.	2934.	85761.	160809.	164341.	198994.	173910.	347635.	
5	89401.	72592.	40891.	12013.	15359.	67485.	125705.	107768.	128087.	120039.	
6	39438.	25665.	10593.	6949.	4150.	13190.	57259.	69721.	66415.	90907.	
7	10024.	10928.	5861.	2924.	2321.	3216.	10681.	44038.	50152.	48897.	
8	3687.	4224.	1274.	1099.	1274.	1917.	2123.	8302.	21415.	37822.	
9	1076.	2291.	1402.	1092.	3639.	9150.	10969.	4629.	12197.	45626.	
TOTAL STOCK BIOMASS ON 1. JANUARY	320529.	264656.	183559.	92385.	99469.	144938.	232232.	343272.	439439.	658827.	
SPAWNING STOCK BIOMASS ON 1. JANUARY	217847.	140060.	119368.	63717.	61542.	97956.	136030.	193794.	253769.	376738.	
AGE	1984	1985	1986	1987							
0	0.	0.	0.	0.							
1	13863970.	12244494.	20978236.	37837320.							
2	5655684.	5716174.	4210772.	8220619.							
3	1573855.	2970768.	2648457.	1912382.							
4	544814.	823513.	1232250.	1254923.							
5	195297.	286419.	364121.	626104.							
6	81071.	99745.	137504.	203047.							
7	61925.	48782.	43113.	59499.							
8	32006.	32981.	25245.	19783.							
9	65383.	39812.	40033.	25775.							
TOTAL STOCK BIOMASS ON 1. JANUARY	927722.	1125406.	1153286.	1624747.							
SPAWNING STOCK BIOMASS ON 1. JANUARY	604409.	819848.	784698.	942577.							
PREDATION MORTALITY											
		HERRING									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	.4085	.4507	.4372	.3875	.4169	.4137	.5317	.4427	.3867	.2787	
1	.8714	.7245	.8219	.8234	.7798	.7998	.9070	1.0035	.7322	.5853	
2	.1805	.1826	.2069	.2284	.2570	.2361	.2659	.3508	.2363	.2175	
3	.2141	.1650	.1472	.1606	.1538	.1777	.1640	.1932	.1854	.1415	
4	.0551	.0476	.0418	.0395	.0423	.0419	.0403	.0478	.0399	.0345	
5	.0163	.0178	.0198	.0189	.0204	.0200	.0174	.0229	.0177	.0135	
6	.1946	.1677	.1238	.1056	.0998	.0946	.1159	.1263	.0852	.0806	
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
AGE	1984	1985	1986	1987							
0	.3106	.2478	.2935	.8140							
1	.4941	.5312	.4582	.7062							
2	.1848	.2142	.1657	.2462							
3	.1246	.1240	.1394	.1224							
4	.0294	.0339	.0325	.0380							
5	.0123	.0140	.0116	.0149							
6	.0667	.1028	.0923	.1150							
7	.0000	.0000	.0000	.0000							
8	.0000	.0000	.0000	.0000							
9	.0000	.0000	.0000	.0000							
Mortality of 0-group is for 3rd and 4th quarter only											
NORTH SEA DATA 1974 - 1987 (MULTISPECIES WORKING GROUP 1988)											
WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK											

Table 2.8.1g Output from MSVPA key run for sprat. Last age group is a plus group.

FISHING MORTALITY		SPRAT								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.0064	.0020	.0156	.0066	.0022	.0037	.0071	.0078	.0025	.0020
1	.1019	.2325	.2666	.1687	.5121	.3536	.4213	.4643	.6448	.7655
2	.4669	.6063	.5980	.5668	.5329	.7253	.6623	1.2847	1.0870	.9048
3	.8862	1.6196	3.1754	.5802	2.3069	1.8808	1.9059	1.7084	1.7864	1.6954
4	2.9220	1.9241	2.6032	4.4058	1.4285	1.7782	1.9340	.4375	.5214	2.0081
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.5103	.6805	1.0856	.5757	.8518	.8897	.7145	1.1903	1.1092	1.0111

AGE	1984	1985	1986	1987						
0	.0010	.0181	.0050	.0050						
1	.2187	.0619	.4562	.4947						
2	.7616	.1761	.2422	.8719						
3	1.2758	1.4537	.1342	.1479						
4	2.1428	1.144	.3790	.0148						
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.8686	.1962	.2300	.3513						

Mortality of 0-group is for 3rd and 4th quarter only										
STOCK NUMBERS		SPRAT								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	374799232.	221215584.	305934400.	162834464.	150167648.	265189216.	105838032.	66476192.	35173840.	18664572.
2	47720456.	108606352.	51950968.	72600704.	41695000.	27953344.	58556000.	20329224.	13504936.	6623606.
3	3091914.	7941625.	11672428.	5541386.	8677702.	4367776.	2354635.	3792935.	914848.	950540.
4	378132.	483795.	619101.	160930.	1165861.	299618.	208175.	118815.	545400.	53827.
TOTAL STOCK BIOMASS ON 1. JANUARY	1454352.	1609841.	1440077.	1116564.	902235.	1016228.	800866.	405154.	230338.	119857.
SPAWNING STOCK BIOMASS ON 1. JANUARY	442394.	1012559.	614055.	676911.	496782.	300217.	515103.	225668.	135368.	69463.

AGE	1984	1985	1986	1987						
0	0.	0.	0.	0.						
1	64528608.	81973232.	11668340.	74165232.						
2	3285741.	19393400.	29686824.	2659173.						
3	660552.	317683.	3849768.	4330036.						
4	64693.	105632.	34078.	1491677.						
TOTAL STOCK BIOMASS ON 1. JANUARY	212425.	385609.	331997.	321110.						
SPAWNING STOCK BIOMASS ON 1. JANUARY	38197.	164282.	300493.	120864.						

PREDATION MORTALITY		SPRAT								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	.2320	.2271	.2547	.2823	.2373	.2982	.2990	.2225	.2040	.1626
1	.5269	.6065	.5618	.5838	.5592	.5469	.6186	.5195	.4149	.3616
2	.7665	1.0644	1.0802	.9975	1.1634	1.1892	1.5148	1.2564	1.0068	.8405
3	.5255	.4576	.6126	.5562	.6070	.6971	.7513	.9054	.5952	.5314
4	.4120	.4746	.5791	.6252	.6680	.7866	.9604	.9155	.8105	.5399

AGE	1984	1985	1986	1987						
0	.1686	.2332	.2727	.4618						
1	.3735	.3438	.4127	.6927						
2	1.0147	.8808	1.1211	2.4762						
3	.4620	.5286	.4927	.7639						
4	.6111	.4857	.6299	1.2950						

Mortality of 0-group is for 3rd and 4th quarter only										
NORTH SEA DATA 1974 - 1987 (MULTISPECIES WORKING GROUP 1988)										
WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK										

Table 2.8.1h Output from MSVPA key run for Norway pout. Last age group is a plus group.

FISHING MORTALITY		NORWAY POUT									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	.0320	.0400	.0318	.0166	.0104	.0104	.0088	.1774	.0071	.0208	
1	.8341	.5634	.4812	.4524	.3434	.3944	.5090	.4105	.4337	.4370	
2	2.7966	1.2291	1.4911	.8495	1.3271	1.4445	1.9483	1.0942	1.5384	1.3786	
3	2.2440	.9938	.8790	.9397	1.9425	2.3001	.8118	2.8583	.8617	.9276	
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.8634	.5953	.5113	.4749	.4541	.4521	.6186	.5295	.4575	.5127	

AGE	1984	1985	1986	1987
0	.0171	.0042	.0302	.0204
1	.6158	.6189	.3130	.4632
2	1.9569	1.6377	1.7009	1.1954
3	2.9558	1.5482	.6665	.4340
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.7567	.6768	.3440	.4818

Mortality of 0-group is for 3rd and 4th quarter only

STOCK NUMBERS		NORWAY POUT									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
1	240296960.	165371136.	218796768.	161077568.	86414576.	116593840.	129255680.	63546952.	158026272.	139241504.	
2	3207401.	8284237.	6507516.	9271362.	9444928.	5802069.	10603268.	11736216.	3142014.	12093622.	
3	623297.	42753.	568712.	349921.	891059.	522788.	368835.	401499.	897117.	175439.	
TOTAL STOCK BIOMASS ON 1. JANUARY	1928772.	1455781.	1841620.	1459545.	918964.	1046160.	1250192.	779142.	1313459.	1353432.	
SPAWNING STOCK BIOMASS ON 1. JANUARY	1928772.	1455781.	1841620.	1459545.	918964.	1046160.	1250192.	779142.	1313459.	1353432.	

AGE	1984	1985	1986	1987
0	0.	0.	0.	0.
1	116169232.	109329360.	133994080.	148699520.
2	12222666.	6177665.	2989534.	3888660.
3	770927.	461724.	288156.	121175.
TOTAL STOCK BIOMASS ON 1. JANUARY	1206165.	997324.	1101608.	1227756.
SPAWNING STOCK BIOMASS ON 1. JANUARY	1206165.	997324.	1101608.	1227756.

PREDATION MORTALITY		NORWAY POUT									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	.2786	.3177	.3260	.3071	.2750	.2140	.2598	.2900	.2827	.2192	
1	1.7843	1.9225	1.9304	1.6350	1.6078	1.2536	1.1404	1.8464	1.3864	1.2459	
2	.9717	.9129	.8919	.8852	.9530	.8146	.6989	.9549	.8234	.7494	
3	.8539	.8188	.8067	.7751	.8835	.7284	.5618	.8327	.6953	.6407	
AGE	1984	1985	1986	1987							
0	.2935	.3278	.3919	.7613							
1	1.5683	2.2304	2.4767	3.0363							
2	.7281	.8989	.9907	1.4220							
3	.6030	.8535	.9430	1.0600							

Mortality of 0-group is for 3rd and 4th quarter only

NORTH SEA DATA 1974 - 1987 (MULTISPECIES WORKING GROUP 1988)
WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.8.1i Output from MSVPA key run for sandeel. Last age group is a plus group.

FISHING MORTALITY		SANDEEL									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	.0107	.0144	.0174	.0338	.0331	.0956	.0601	.1020	.1414	.0406	
1	.1693	.1227	.2015	.3107	.4320	.2267	.4380	.3430	.3397	.2114	
2	.1427	.2732	.4811	.4268	.6955	.8820	.7374	.8285	.8737	.8193	
3	.0505	.3882	.3205	.7636	.3780	.6870	.9534	.5355	1.1667	.7346	
4	.2695	.1447	.4082	.3924	.4872	.6018	.5164	.8092	1.2361	.3507	
5	.2695	.3595	.1346	.7792	.2375	.8674	.4608	.9511	.7942	.5472	
6	.5337	.3214	.4965	.8240	.8837	.9016	1.0662	.8243	.7993	.8337	
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.1401	.2821	.4453	.5195	.6324	.8389	.7573	.7766	.9782	.8079	

AGE	1984	1985	1986	1987
0	.0293	.0207	.0213	.0309
1	.5483	.1047	.3845	.5489
2	.2632	2.0999	1.0094	.8531
3	1.9778	1.1776	1.0911	.7438
4	.6217	1.1694	.0261	.7352
5	.4865	2.7827	.0637	.1030
6	1.1222	1.1491	.0002	.1456
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK	.9386	1.9585	.9422	.8410

Mortality of 0-group is for 3rd and 4th quarter only

STOCK NUMBERS		SANDEEL									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
1	498494592.	616195840.	382132224.	395231104.	414079872.	305439360.	321768384.	162033088.	413451776.	122338528.	
2	65162864.	54710384.	79836624.	41844192.	58201904.	63902552.	59003576.	49246816.	22922568.	97215680.	
3	24804260.	17775856.	14272738.	16167570.	10363202.	12277826.	11471282.	11640032.	8253682.	4352030.	
4	13223746.	11918516.	6214765.	5286466.	4067426.	4028759.	3565405.	2474580.	3677828.	1472885.	
5	1638483.	2864887.	2854767.	1202601.	1290525.	1054932.	1001140.	888401.	423196.	443203.	
6	348817.	468944.	752497.	967327.	268899.	582777.	258295.	360037.	176934.	112113.	
TOTAL STOCK BIOMASS ON 1. JANUARY	3273733.	3526562.	2698578.	2350490.	2463029.	2124298.	2110739.	1370849.	2050855.	1546751.	
SPANNING STOCK BIOMASS ON 1. JANUARY	1329604.	1123399.	1208263.	809088.	848118.	933085.	855843.	738920.	438392.	1069631.	

AGE	1984	1985	1986	1987
0	0.	0.	0.	0.
1	352856832.	107728416.	480827712.	221827936.
2	29546540.	71693440.	22007440.	96228656.
3	19763264.	11457724.	3738559.	3811379.
4	1226111.	1665695.	1993952.	729951.
5	487041.	350297.	219361.	824909.
6	158483.	197385.	15994.	158152.
TOTAL STOCK BIOMASS ON 1. JANUARY	2003810.	1347145.	2195001.	1911010.
SPANNING STOCK BIOMASS ON 1. JANUARY	627668.	927004.	319772.	1045882.

PREDATION MORTALITY		SANDEEL									
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
0	.5328	.5158	.4597	.3935	.3768	.3850	.4382	.3373	.3239	.3002	
1	1.5503	1.4310	1.5205	1.1150	.9468	.9279	.9491	1.1227	.6179	.7194	
2	.7085	.6206	.6660	.5190	.4107	.3857	.4358	.5077	.3378	.3238	
3	.2925	.2728	.2828	.2264	1.768	.1596	1.904	.2266	.1668	.1422	
4	.9004	.9250	.8744	.6579	.5024	.4307	.5133	.5968	.5200	.3959	
5	.8015	.7950	.7617	.5625	.4216	.3560	.4095	.5087	.4145	.3371	
6	1.1342	1.2512	1.0914	.7828	.5612	.4479	.5279	.6016	.6349	.4466	

AGE	1984	1985	1986	1987
0	.3290	.3301	.4022	.6027
1	.5554	.9936	.7343	.9852
2	.2341	.4038	.2940	.4286
3	.1058	.1809	.1524	.1866
4	.2712	.4979	.4965	.5297
5	.2317	.4382	.4016	.3812
6	.2639	.5660	.6336	.4819

Mortality of 0-group is for 3rd and 4th quarter only

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
		<u>Cod</u>			<u>Whiting</u>	
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	-	-	-
		<u>Haddock</u>			<u>Herring</u>	
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 1980-1985. 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
		<u>Saithe</u>			<u>Mackerel</u>	
0	0.00	0.100	356,961	0.00	0.075	199,768
1	0.01	0.200	314,563	0.01	0.150	191,742
2	0.12	0.200	271,050	0.11	0.150	104,928
3	0.35	0.200	158,412	0.32	0.150	86,051
4	0.53	0.200	69,868	0.36	0.150	68,239
5	0.56	0.200	32,250	0.37	0.150	51,689
6	0.61	0.200	15,526	0.46	0.150	43,680
7	0.58	0.200	7,774	0.44	0.150	36,941
8	0.58	0.200	3,387	0.37	0.150	29,123
9	0.51	0.200	1,618	0.36	0.150	28,244
10	0.37	0.200	934	0.37	0.150	21,092
11	0.36	0.200	683	0.29	0.150	27,229
12	0.37	0.200	531	0.35	0.150	19,610
13	0.35	0.200	414	0.32	0.150	11,645
14	0.43	0.200	317	0.54	0.150	7,521
15	0.42	0.200	364	0.94	0.150	5,986

Table 2.8.2c Mean values of fishing mortality, natural mortality (total), and stock size ('000 t) at age from the "Key run" for 1980-1985. 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
<u>Sprat</u>						
0	0.01 ¹	0.530 ¹	79,355,968	0.04 ¹	0.680 ¹	249,860,928
1	0.43	1.050	62,109,072	0.50	2.320	119,261,504
2	0.81	1.650	20,282,148	1.59	1.450	9,329,240
3	1.47	1.130	1,498,532	1.66	1.240	512,590
4	1.19	1.180	182,757	-	-	-
<u>Sandeel</u>						
0	0.07 ¹	0.600 ¹	526,614,016			
1	0.33	1.320	246,696,192			
2	0.94	0.820	54,938,096			
3	1.09	0.560	11,156,336			
4	0.78	0.830	2,347,084			
5	1.00	0.730	598,880			
6	0.97	0.820	210,541			

¹Only half-year mortality rate.

Table 2.8.3 The mean of the ratio between numbers in the MSVPA and the single-species VPAs for the years 1980-1985 for cod, haddock, whiting, and herring.

Age	Cod	Haddock	Whiting	Herring
1	1.17	1.30	1.13	1.20
2	1.06	1.07	1.02	1.27
3	1.04	1.00	1.02	1.14
4	1.01	0.97	1.00	1.10
5	1.00	1.01	0.96	1.05
6	1.00	1.05	1.03	1.05
7	1.00	1.12	1.00	0.90
8	1.00	1.41	0.99	0.89

Table 2.8.4 Natural mortalities used by the single-species working groups in 1988 compared to the Ms from the MSVPA key run. Ms averaged over the period 1980-1985.

Age	Cod		Whiting		Haddock	
	SSVPA	MSVPA	SSVPA	MSVPA	SSVPA	MSVPA
0	2.70	1.74	2.55	2.54	2.05	3.48
1	0.80	0.83	0.95	1.00	1.65	1.86
2	0.35	0.37	0.45	0.48	0.40	0.40
3	0.25	0.28	0.35	0.35	0.25	0.27
4	0.20	0.20	0.30	0.27	0.25	0.21
5	0.20	0.20	0.25	0.23	0.20	0.20
6	0.20	0.20	0.25	0.22	0.20	0.20
7	0.20	0.20	0.20	0.20	0.20	0.20
8	0.20	0.20	0.20	0.20	0.20	0.20
9	0.20	0.20	0.20	0.20	0.20	0.20
10	0.20	0.20	0.20	0.20	0.20	0.20
11	0.20	0.20	-	-	0.20	0.20

Age	Herring		Sprat		Norway pout		Sandeel	
	SSVPA	MSVPA	SSVPA	MSVPA	SSVPA	MSVPA	SSVPA	MSVPA
0	1.00	1.14	-	1.06	0.80	1.36	0.80	1.20
1	1.00	1.03	-	1.05	1.60	2.32	1.20	1.32
2	0.30	0.46	-	1.65	1.60	1.45	0.60	0.82
3	0.20	0.31	-	1.13	1.60	1.24	0.60	0.56
4	0.10	0.17	-	1.18	-	-	0.60	0.83
5	0.10	0.12	-	-	-	-	0.60	0.73
6	0.10	0.20	-	-	-	-	0.60	0.82
7	0.10	0.10	-	-	-	-	-	-
8	0.10	0.10	-	-	-	-	-	-
9	0.10	0.10	-	-	-	-	-	-

Table 3.1 North Sea cod. Recruitment estimates from programme RCRTINX using MSVPA 1-group estimates as input. To be compared with Table 10.10 in Anon. (1988c). Figures in brackets are estimates based on single-species VPA.

Yearclass = 1985

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
IYFS1	2.8904	.931	3.733	.4631	15	6.4248	.69672	.73315	.02185
EGFS1	3.5667	.822	3.454	.8652	9	6.3850	.26928	.28761	.14195
DGFS1	4.7203	.571	3.832	.9673	6	6.5282	.15346	.17274	.29355
SGFS1	2.1972	.000	.000	.0000	0	.0000	.00000	.00000	.00000
EGFS0	2.2300	.547	4.592	.6639	8	5.8124	.49484	.52877	.04200
DGFS0	4.9740	.402	4.395	.9987	5	6.3968	.02832	.03311	.29355
IYFS2	3.3945	1.083	3.271	.7774	15	6.9474	.34623	.38891	.07763
FRGSF	2.3514	.634	4.313	.7933	15	5.8032	.33028	.34519	.54
MEAN						5.9891	.61600	.61600	.03094

Yearclass = 1986

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
IYFS1	2.2824	.918	3.790	.4910	16	5.8859	.63774	.66471	.02149
EGFS1	2.7213	.818	3.453	.8649	10	5.6792	.25467	.27433	.12617
DGFS1	3.7495	.558	3.845	.9518	7	5.9379	.17010	.18238	.23738
SGFS1	1.1632	1.033	4.184	.9507	5	5.3861	.18904	.21783	.20011
EGFS0	.7885	.564	4.600	.6266	9	5.0442	.50404	.58553	.02770
DGFS0	3.6376	.394	4.407	.9931	6	5.8391	.06003	.06497	.23738
IYFS2	2.0412	1.036	3.345	.7478	16	5.4589	.36379	.38911	.06271
FRGSF	1.1939	.664	4.266	.7593	16	5.0584	.35266	.39647	.06041
MEAN						6.0158	.59685	.59685	.02665

Yearclass = 1987

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
IYFS1	1.8083	.909	3.852	.5197	16	5.4964	.60921	.64772	.07273
EGFS1									
DGFS1									
SGFS1									
EGFS0	.3365	.561	4.604	.6297	9	4.7932	.50677	.61775	.96
DGFS0	3.6163	.394	4.407	.9931	6	5.8305	.06053	.06559	.87
IYFS2									
FRGSF									
MEAN						6.0200	.60116	.60116	.08444

Yearclass	Weighted Average Prediction	Internal Standard Error	External Standard Error	Virtual Population Analysis	Ext.SE/ Int.SE
1981	6.34	569.54 (499.48)	.16	.08	6.45 631.67 .54
1982	5.87	354.90 (307.29)	.15	.12	5.73 308.14 .76
1983	6.72	826.45 (715.74)	.15	.13	6.37 582.31 .86
1984	4.99	147.24 (136.41)	.17	.19	4.73 113.38 1.11
1985	6.38	590.75 (524.30)	.11	.11	6.27 528.40 1.00
1986	5.66	288.42 (254.43)	.10	.10	
1987	5.74	310.84 (277.23)	.17	.17	

Table 3.2 North Sea whiting. Recruitment estimates from programme RCRTINX2 using MSVPA 1-group estimates as input. To be compared with Table 18.10 in Anon. (1988c). Figures in brackets are estimates based on single-species VPA.

Yearclass = 1985

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
IYFS	6.1247	.839	3.130	.7490	15	8.2677	.27102	.28347	.45588
EGFS	5.0291	3.396	-10.558	.0745	9	6.5204	1.58385	1.76272	.01179
DGFS	5.9532	-2.441	23.071	.0430	6	8.5384	1.77369	1.95317	.00960
JGFS	4.7185	.000	.000	.0000	0	.0000	.00000	.00000	.00000
EGFSO	5.3033	2.050	-3.165	.0706	8	7.7065	1.66014	1.76714	.01173
DGFSO	6.7551	.235	6.236	.1202	5	7.8225	.35339	.39720	.23219
IYFS2	6.3008	1.404	.232	.4176	15	9.0794	.55288	.62282	.09444
MEAN						8.1140	.44574	.44574	.18437

Yearclass = 1986

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
IYFS	6.5073	.838	3.130	.7509	16	8.5832	.25900	.28005	.52793
EGFS	5.4350	4.928	-18.673	.0328	10	8.1114	2.33322	2.45594	.00686
DGFS	7.6034	-2.118	21.027	.0736	7	4.9265	1.37885	1.95517	.01083
JGFS	4.9523	1.422	1.308	.2609	5	8.3506	.57532	.69323	.08616
EGFSO	5.1017	2.303	-4.472	.0586	9	7.2773	1.75042	1.86916	.01185
DGFSO	7.4847	.628	3.877	.1115	6	8.5787	.84388	.99170	.04210
IYFS2	6.7405	1.354	.444	.3949	16	9.5686	.55662	.68312	.08873
MEAN						8.1080	.42846	.42846	.22554

Yearclass = 1987

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
IYFS	6.0753	.837	3.129	.7492	16	8.2161	.26086	.27332	.66910
EGFS									
DGFS									
JGFS									
EGFSO	4.7230	2.270	-4.296	.0588	9	6.4250	1.74589	1.94271	.01324
DGFSO	7.9571	.628	3.878	.1125	6	8.8748	.84625	1.06015	.04447
IYFS2									
MEAN						8.0870	.42775	.42775	.27318

Yearclass	Weighted Average Prediction	Internal Standard Error	External Standard Error	Virtual Population Analysis	Ext.SE/ Int.SE
1981	7.87	2624.54 (2417.26)	.18	.27	7.60 1995.49
1982	7.57	2141.68 (1895.62)	.18	.27	7.50 1809.23
1983	8.37	4323.77 (4191.46)	.17	.16	7.79 2415.41
1984	8.06	3156.21 (2992.65)	.20	.11	7.71 2237.48
1985	8.19	3597.80 (3172.32)	.19	.16	8.26 3874.18
1986	8.48	4841.23 (5133.16)	.20	.21	
1987	8.19	3591.86 (3499.56)	.22	.15	

Table 3.3 North Sea haddock. Recruitment estimates from programme RCRTINX2 using MSVPA 1-group estimates as input. To be compared with Table 14.10 in Anon. (1988c). Figures in brackets are estimates based on single-species VPA.

Yearclass = 1985

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
IYFS	6.3630	1.041	2.220	.8275	15	8.8426	.31720	.33288	.38357
EGFS	5.0160	.872	3.651	.7008	9	8.0230	.34775	.37866	.29642
SGFS	5.4549	.000	.000	.0000	0	.0000	.00000	.00000	.00000
EGFS0	5.5090	1.645	-1.751	.1857	8	7.3105	1.07159	1.22630	.02826
IYFS2	5.7900	1.094	2.272	.7058	15	8.6055	.44847	.46739	.19456
MEAN						8.5447	.66131	.66131	.09719

Yearclass = 1986

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
IYFS	6.7867	1.035	2.232	.8121	16	9.2598	.31361	.34121	.28164
EGFS	5.6451	.939	3.345	.5888	10	8.6471	.41962	.44356	.16665
SGFS	5.4819	1.633	-.459	.7776	5	8.4905	.30440	.33396	.29399
EGFS0	5.5872	1.838	-2.782	.1294	9	7.4874	1.23909	1.36387	.01763
IYFS2	6.5568	1.088	2.295	.7098	16	9.4269	.41684	.45975	.15513
MEAN						8.5427	.62125	.62125	.08496

Yearclass = 1987

Survey/ Series	Index Value	Slope	Inter- cept	Rsquare	No. Pts	Predicted Value	Sigma	Standard Error	Weight
IYFS	4.5747	1.034	2.239	.7976	16	6.9668	.32233	.41055	.67313
EGFS									
SGFS									
EGFS0	3.1527	1.841	-2.795	.1287	9	3.0101	1.25413	2.44705	.01895
IYFS2									
MEAN						8.5328	.60700	.60700	.30793

Yearclass	Weighted Average Prediction	Internal Standard Error	External Standard Error	Virtual Population Analysis	Ext.SE/ Int.SE	
1981	8.74	6270.36 (5208.35)	.14	.05	8.34 4195.60	.35
1982	8.28	3926.64 (2974.35)	.16	.08	7.90 2707.20	.52
1983	9.31	11060.15 (9796.40)	.20	.16	9.2510451.90	.80
1984	8.01	2999.26 (2327.44)	.18	.14	8.55 5186.20	.77
1985	8.48	4823.55 (3636.06)	.21	.20	8.65 5696.50	.95
1986	8.87	7081.76 (4254.82)	.18	.19		1.06
1987	7.37	1594.10 (824.62)	.34	.67		1.98

Table 4.4.1 Status quo baseline yield ('000 t) forecasts for the MSFOR and Shepherd models.

Fleet	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
MSFOR									
1	249.83	153.63	26.20	-	202.92	-	-	-	-
2	12.57	41.91	2.93	-	43.22	-	-	434.88	973.13
3	-	7.62	-	-	-	159.37	319.52	-	-
4	-	-	-	-	-	140.97	-	-	-
5	-	-	148.76	-	-	-	-	-	-
6	-	-	-	44.30	-	-	-	-	-
Total	262.40	203.21	177.86	44.30	246.14	300.40	319.52	434.88	973.13
Shepherd									
1	239.13	143.96	24.91	-	168.45	-	-	-	-
2	14.98	41.56	2.81	-	51.42	-	-	396.89	984.82
3	-	7.73	-	-	-	135.89	250.68	-	-
4	-	-	-	-	-	109.22	-	-	-
5	-	-	141.68	-	-	-	-	-	-
6	-	-	-	42.13	-	-	-	-	-
Total	254.11	193.25	169.40	42.13	219.87	245.12	250.68	396.89	984.82

Fleets: 1 = roundfish human consumption, 2 = industrial demersal 3 = industrial pelagic,
4 = herring, 5 = saithe, 6 = mackerel.

Table 4.4.2 Percentage changes in yield for each species in each fleet consequent upon a 10% increase in the roundfish human consumption fishery.

Fleet	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
MSFOR									
1	1.76	5.91	7.95	-	7.95	-	-	-	-
2	2.50	-0.34	-0.75	-	2.89	-	-	4.15	0.11
3	-	0.34	-	-	-	2.47	0.18	-	-
4	-	-	-	-	-	3.42	-	-	-
5	-	-	-1.76	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
Total	1.80	4.41	-0.32	-	7.07	2.92	0.18	4.15	0.11
Shepherd									
1	2.40	5.94	7.98	-	6.06	-	-	-	-
2	0.87	-0.74	-0.73	-	0.70	-	-	1.30	0.10
3	-	-0.09	-	-	-	1.61	0.08	-	-
4	-	-	-	-	-	2.46	-	-	-
5	-	-	-1.74	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
Total	2.31	4.26	-0.29	-	4.80	1.99	0.08	1.30	0.10

Fleets: 1 = roundfish human consumption, 2 = industrial demersal 3 = industrial pelagic, 4 = herring, 5 = saithe, 6 = mackerel.

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

Fleet	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
MSFOR									
1	-0.82	-1.92	-0.23	-	-2.60	-	-	-	-
2	9.51	8.89	9.84	-	8.58	-	-	3.61	2.31
3	-	-0.54	-	-	-	0.27	0.09	-	-
4	-	-	-	-	-	0.32	-	-	-
5	-	-	-0.23	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
Total	-0.32	0.37	-0.06	-	-0.64	0.30	0.09	3.61	2.31
Shepherd									
1	-0.35	-1.24	-0.23	-	-0.77	-	-	-	-
2	9.89	9.35	9.84	-	9.34	-	-	7.15	5.14
3	-	-0.32	-	-	-	0.60	0.20	-	-
4	-	-	-	-	-	0.82	-	-	0
5	-	-	-0.23	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
Total	0.25	1.08	-0.06	-	1.71	0.69	0.20	7.15	5.14

Fleets: 1 = roundfish human consumption, 2 = industrial demersal 3 = industrial pelagic, 4 = herring, 5 = saithe, 6 = mackerel.

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

Fleet	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
MSFOR									
1	-0.29	-0.67	-	-	-0.66	-	-	-	-
2	-0.24	-0.46	-	-	-0.45	-	-	-0.25	-0.06
3	-	9.66	-	-	-	4.06	4.02	-	-
4	-	-	-	-	-	-7.27	-	-	-
5	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
Total	-0.28	-0.24	-	-	-0.63	-1.26	4.02	-0.25	-0.06
Shepherd									
1	0.01	-0.23	-	-	0.10	-	-	-	-
2	0.01	-0.14	-	-	0.07	-	-	0.01	0.06
3	-	9.90	-	-	-	5.40	6.57	-	-
4	-	-	-	-	-	-5.85	-	-	-
5	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
Total	0.02	0.15	-	-	0.01	0.04	6.57	0.01	0.06
Fleets: 1 = roundfish human consumption, 2 = industrial demersal 3 = industrial pelagic, 4 = herring, 5 = saithe, 6 = mackerel.									

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

Fleet	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
<u>MSFOR</u>									
1	-0.05	-0.02	-	-	-0.06	-	-	-	-
2	-0.02	-0.01	-	-	-0.04	-	-	-0.03	0.01
3	-	-	-	-	-	-3.08	-	-	-
4	-	-	-	-	-	4.65	-	-	-
5	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
Total	-0.04	-0.01	-	-	-0.06	0.55	-	-0.03	0.01
<u>Shepherd</u>									
1	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-2.44	-	-	-
4	-	-	-	-	-	5.48	-	-	-
5	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	1.09	-	-	-

Fleets: 1 = roundfish human consumption, 2 = industrial demersal 3 = industrial pelagic,
4 = herring, 5 = saithe, 6 = mackerel.

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

Fleet	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
MSFOR									
1	1.67	0.59	-9.85	-	10.90	-	-	-	-
2	1.60	0.37	-4.10	-	7.47	-	-	12.32	-0.25
3	-	0.21	-	-	-	1.06	0.18	-	-
4	-	-	-	-	-	1.53	-	-	-
5	-	-	-0.37	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
Total	1.67	0.53	-1.83	-	10.30	1.28	0.18	12.32	-0.25
Shepherd									
1	0.70	0.01	-9.69	-	6.42	-	-	-	-
2	0.93	0.01	-4.00	-	3.36	-	-	4.84	-0.18
3	-	0.02	-	-	-	0.41	-0.03	-	-
4	-	-	-	-	-	0.68	-	-	-
5	-	-	-0.22	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
Total	0.72	0.01	-1.67	-	5.70	0.63	-0.03	4.84	-0.18

Fleets: 1 = roundfish human consumption, 2 = industrial demersal 3 = industrial pelagic, 4 = herring, 5 = saithe, 6 = mackerel.

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

Fleet	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
MSFOR									
1	0.43	0.06	-	-	0.18	-	-	-	-
2	0.45	0.06	-	-	0.14	-	-	0.31	1.02
3	-	0.05	-	-	-	0.62	0.48	-	-
4	-	-	-	-	-	0.78	-	-	-
5	-	-	-	-	-	-	-	-	-
6	-	-	-	1.48	-	-	-	-	-
Total	0.43	0.06	-	1.48	0.17	0.69	0.48	0.31	1.02
Shepherd									
1	0.19	-0.06	-	-	-0.07	-	-	-	-
2	0.26	-0.04	-	-	-0.03	-	-	0.10	0.61
3	-	-0.02	-	-	-	0.38	0.26	-	-
4	-	-	-	-	-	0.50	-	-	-
5	-	-	-	-	-	-	-	-	-
6	-	-	-	1.68	-	-	-	-	-
Total	0.20	-0.06	-	1.68	-0.06	0.43	0.26	0.10	0.61

Fleets: 1 = roundfish human consumption, 2 = industrial demersal 3 = industrial pelagic, 4 = herring, 5 = saithe, 6 = mackerel.

Table 4.6.1

		Long term effects of mesh size changes		
		COD		
		Mesh	Mesh	Mesh
SS=single species		70mm	85mm	120mm
MS=multispecies				
SH=Shepherd				
Number caught	SS	176.3	175.6	150.2
(millions)	MS	210.5	196.1	114.8
	SH			
Total catch	SS	233.3	234.1	287.9
(thous.tons)	MS	279.7	262.4	215.7
	SH	262.1	254.1	217.4
Mean weight	SS	1323.0	1333.3	1916.4
(g)	MS	1328.7	1337.8	1878.2
	SH			
Spawning stock	SS	97.6	99.1	191.6
(thous.tons)	MS	118.4	112.1	141.8
	SH	120.3	118.3	169.1

Table 4.6.2

		Long term effects of mesh size changes		
		WHITING		
SS=single species		Mesh	Mesh	Mesh
MS=multispecies				
SH=Shepherd		70mm	85mm	120mm
Number caught (millions)	SS	2361.8	1613.5	1044.0
	MS	2733.0	1511.4	738.4
	SH	/	/	/
Total catch (thous.tons)	SS	221.0	213.9	169.3
	MS	270.6	203.2	96.9
	SH	304.1	193.2	73.8
Mean weight in catch (g)	SS	93.6	132.6	162.2
	MS	99.0	134.4	131.3
	SH	/	/	/
Human cons. (thous.tons)	SS	56.9	102.5	91.7
	MS	101.1	98.0	50.2
	SH	34.7	72.4	50.2
Mean weight human cons. (g)	SS	252.0	315.3	556.9
	MS	298.9	315.8	572.5
	SH	/	/	/
Discards (thous.tons)	SS	144.3	73.5	8.7
	MS	84.2	69.4	5.1
	SH	175.5	71.5	7.3
Mean weight in discards (g)	SS	96.5	134.0	180.4
	MS	109.2	134.6	180.4
	SH	/	/	/
Industr.land. (thous.tons)	SS	19.7	37.9	68.9
	MS	17.9	35.8	41.6
	SH	93.9	49.3	16.3
Mean weight ind. land. (g)	SS	30.8	51.3	82.9
	MS	44.5	52.2	66.9
	SH	/	/	/
Total landings	SS	76.7	140.4	160.6
	MS	186.4	133.7	91.8
	SH	128.6	121.7	66.5
Spawning stock (thous.tons)	SS	141.9	326.6	876.2
	MS	176.3	308.4	474.5
	SH	122.2	336.4	584.8

Table 4.6.3

		Long term effects of mesh size changes		
		SAITHE		
		Mesh	Mesh	Mesh
SS=	single species			
MS=	multispecies			
SH=	Shepherd	70mm	85mm	120mm
Number caught	SS	123.1	120.9	105.0
(millions)	MS	123.1	120.9	105.0
	SH			
Total catch	SS	175.2	177.9	202.1
(thous.tons)	MS	175.2	177.9	202.1
	SH	166.8	169.4	193.2
Mean weight	SS	1423.3	1471.8	1924.5
(g)	MS	1423.3	1471.8	1924.5
	SH			
Spawning stock	SS	182.4	188.0	271.7
(thous.tons)	MS	182.4	188.0	271.7
	SH	190.3	196.0	286.3

Table 4.6.4

		Long term effects of mesh size changes		
		MACKEREL		
		Mesh	Mesh	Mesh
SS=	single species			
MS=	multispecies			
SH=	Shepherd	70mm	85mm	120mm
Number caught	SS	108.2	108.2	108.2
(millions)	MS	108.2	108.2	108.2
	SH			
Total catch	SS	44.3	44.3	44.3
(thous.tons)	MS	44.3	44.3	44.3
	SH	42.1	42.1	42.1
Mean weight	SS	409.3	409.3	409.3
(g)	MS	409.3	409.3	409.3
	SH			
Spawning stock	SS	74.1	74.1	74.1
(thous.tons)	MS	74.1	74.1	74.1
	SH	85.2	85.2	85.2

Table 4.6.5

		Long term effects of mesh size changes		
		HADDOCK		
SS=single species	Mesh	Mesh	Mesh	
MS=multispecies				
SH=Shepherd	70mm	85mm	120mm	
Number caught (millions)	SS	1710.2	1344.9	992.8
	MS	2168.6	1249.9	392.8
	SH	/	/	/
Total catch (thous.tons)	SS	251.0	251.0	282.5
	MS	359.0	246.1	65.7
	SH	375.5	219.9	85.6
Mean weight in catch (g)	SS	146.8	186.6	284.6
	MS	165.6	196.9	167.4
	SH	/	/	/
Human cons. (thous.tons)	SS	114.0	156.6	237.9
	MS	149.2	154.9	53.2
	SH	79.6	92.7	65.5
Mean weight human cons. (g)	SS	437.7	501.9	770.1
	MS	469.5	498.3	836.1
	SH	/	/	/
Discards (thous.tons)	SS	121.5	74.0	9.2
	MS	83.8	71.9	2.2
	SH	168.0	75.7	6.4
Mean weight in discards (g)	SS	139.5	173.4	246.6
	MS	148.4	175.7	239.7
	SH	/	/	/
Industr.land. (thous.tons)	SS	15.6	20.4	35.4
	MS	13.2	19.3	10.3
	SH	127.9	51.4	13.3
Mean weight ind. land. (g)	SS	27.0	33.6	54.7
	MS	35.8	36.5	32.2
	SH	/	/	/
Total landings	SS	129.5	177.0	273.3
	MS	275.3	174.2	63.5
	SH	207.5	144.2	79.2
Spawning stock (thous.tons)	SS	128.9	191.7	547.8
	MS	193.5	191.2	114.0
	SH	124.5	162.1	199.8

Table 4.6.6

		Long term effects of mesh size changes		
		HERRING		
SS=single species		Mesh	Mesh	Mesh
MS=multispecies				
SH=Shepherd		70mm	85mm	120mm
Number caught (millions)	SS	5228.3	5288.3	5288.3
	MS	6074.0	5157.1	4247.6
	SH	/	/	/
Total catch (thous.tons)	SS	318.5	318.5	318.5
	MS	422.8	300.3	174.0
	SH	368.2	245.1	160.9
Mean weight (g)	SS	60.9	60.2	60.2
	MS	69.6	58.2	41.0
	SH	/	/	/
Spawning stock (thous.tons)	SS	565.5	565.5	565.5
	MS	866.4	596.0	318.4
	SH	1,022.0	627.8	367.6

Table 4.6.7

		Long term effects of mesh size changes		
		SPRAT		
SS=single species		Mesh	Mesh	Mesh
MS=multispecies				
SH=Shepherd		70mm	85mm	120mm
Number caught (millions)	SS	26284.1	26284.1	26284.1
	MS	38554.2	35140.0	34075.5
	SH	/	/	/
Total catch (thous.tons)	SS	238.1	238.1	238.1
	MS	361.5	319.5	305.2
	SH	267.6	250.7	249.5
Mean weight (g)	SS	9.1	9.1	9.1
	MS	9.4	9.1	9.0
	SH	/	/	/
Spawning stock (thous.tons)	SS	133.7	133.7	133.7
	MS	331.3	290.8	281.4
	SH	315.1	288.9	288.6

Table 4.6.8

		Long term effects of mesh size changes		
		NORWAY POUT		
		Mesh	Mesh	Mesh
SS=single species				
MS=multispecies				
SH=Shepherd		70mm	85mm	120mm
Number caught (millions)	SS	22398.9	22398.9	22398.9
	MS	28721.2	25001.1	14246.2
	SH	/	/	/
Total catch (thous.tons)	SS	381.6	381.6	381.6
	MS	529.3	434.9	182.4
	SH	429.7	396.9	298.7
Mean weight (g)	SS	17.0	17.0	17.0
	MS	18.4	17.4	12.8
	SH	/	/	/
Spawning stock (thous.tons)	SS	721.8	721.8	721.8
	MS	1377.8	1269.6	938.9
	SH	2329.0	2258.0	2084.0

Table 4.6.9

		Long term effects of mesh size changes		
		SANDEEL		
		Mesh	Mesh	Mesh
SS=single species				
MS=multispecies				
SH=Shepherd		70mm	85mm	120mm
Number caught (millions)	SS	99045.3	99045.3	99045.3
	MS	136987	129204	128190
	SH	/	/	/
Total catch (thous.tons)	SS	740.2	740.2	740.2
	MS	1060.5	973.1	952.4
	SH	1064.0	984.8	964.5
Mean weight (g)	SS	7.5	7.5	7.5
	MS	7.7	7.5	7.4
	SH	/	/	/
Spawning stock (thous.tons)	SS	657.8	657.8	657.8
	MS	1086.3	972.5	945.2
	SH	1084.0	917.1	883.5

Table 4.6.10a		Average prices of roundfish in 5 European ports in August 1987								
		ECU's per ton								
Size cat.	Cod	Whiting		Saithe		Haddock				
	Weight	Price	Weight	Price	Weight	Price	Weight	Price		
	(kg)	(ECU/t)	(kg)	(ECU/t)	(kg)	(ECU/t)	(kg)	(ECU/t)		
1	8.00	2720			6.00	1756	1.00	1689		
2	5.50	2419	0.42	1332	4.00	1868	0.78	1698		
3	3.00	1975	0.30	1190	2.25	1299	0.44	1341		
4	1.50	1512	0.17	867			0.24	1481		
5	0.65	1285								
Regression										
Const.	1251		575		1161		1304			
Slope	196		1869		118		404			
Table 4.6.10b		Average prices of other fish in some European ports in spring 1988								
		ECU's per ton								
	Mackerel		800							
	Herring		240							
	Industrial fish		75							

Table 4.6.11 Changes in value of annual landings due to mesh size changes using multispecies (MSFOR) and Shepherd (SH) models.

Species	Mesh	Landings ('000 t)		Value (millions of ECUs)		Average value (ECU/kg)	
		MSFOR	SH	MSFOR	SH	MSFOR	SH
Cod	70	279.7	262.1	483.6	432.3	1.73	1.65
	85	262.4	254.1	454.5	421.5	1.73	1.66
	120	215.7	217.4	409.6	419.2	1.90	1.93
Whiting	70	186.4	128.6	77.5	32.0	0.42	0.25
	85	133.7	121.7	111.7	86.6	0.84	0.71
	120	91.8	66.5	79.7	85.9	0.87	1.29
Saithe	70	175.2	166.8	248.0	234.8	1.42	1.41
	85	177.9	169.4	252.3	238.9	1.42	1.41
	120	202.1	193.2	295.0	282.1	1.46	1.46
Mackerel	70	44.3	42.1	35.4	33.7	0.80	0.80
	85	44.3	42.1	35.4	33.7	0.80	0.80
	120	44.3	42.1	35.4	33.7	0.80	0.80
Haddock	70	275.3	207.5	231.4	128.3	0.84	0.62
	85	174.2	144.2	209.3	144.1	1.20	1.00
	120	63.5	79.2	77.7	108.2	1.22	1.37
Herring	70	422.8	368.2	101.5	56.3	0.24	0.15
	85	300.3	265.1	72.1	36.4	0.24	0.14
	120	174.0	160.9	41.8	22.8	0.24	0.14
Sprat	70	361.5	267.6	27.1	20.1	0.07	0.08
	85	319.5	250.7	24.0	18.8	0.08	0.07
	120	305.2	249.5	22.9	18.7	0.08	0.07
Norway pout	70	529.3	429.7	39.7	32.2	0.08	0.07
	85	319.5	396.9	32.6	29.8	0.10	0.08
	120	182.4	298.7	13.7	22.4	0.08	0.07
Sandeel	70	1,060.5	1,076.9	79.5	80.8	0.07	0.08
	85	973.1	984.8	73.0	73.9	0.08	0.08
	120	952.4	964.5	71.4	72.3	0.07	0.07
Grand Total	70	3,335.0	2,949.5	1,323.7	1,050.5	0.40	0.36
	85	2,704.9	2,609.0	1,264.9	1,083.7	0.47	0.42
	120	2,231.4	2,272.0	1,047.2	1,065.3	0.47	0.47

Table 4.6.12 Yield and SSB for various effort and mesh sizes using Shepherd's method ('000 t).

Species	Mesh	Effort					
		0.9		1.0		1.1	
		Yield	SSB	Yield	SSB	Yield	SSB
Cod	70	251	143	262	120	272	102
	85	244	141	254	118	264	100
	120	209	191	217	169	225	151
Whiting	70	293	136	304	122	314	112
	85	182	346	193	336	204	327
	120	68	585	74	585	79	504
Saithe	70	170	229	167	190	163	160
	85	173	235	169	196	166	165
	120	195	331	193	286	191	250
Haddock	70	331	128	376	125	417	120
	85	192	158	220	162	247	164
	120	75	187	87	200	96	211
Herring	70	345	1,066	368	1,022	388	977
	85	232	665	245	628	258	599
	120	153	395	161	368	168	343
Sprat	70	247	327	268	315	287	304
	85	233	302	251	289	269	279
	120	231	301	250	289	267	276
Norway pout	70	369	2,297	430	2,329	489	2,356
	85	343	2,232	397	2,258	451	2,281
	120	261	2,067	299	2,084	336	2,095
Sandeel	70	1,008	1,111	1,064	1,084	1,141	1,020
	85	930	973	985	917	1,048	882
	120	906	931	965	884	1,019	840

Table 4.7.1 Catch weights and SSB ('000 t) for 70 mm and 120 mm meshes when all, half, or no M2(O) is admitted [the remainder, calculated at status quo, is put into M1(O)].

Species	No M2		Half M2		Full M2	
	Catch	SSB	Catch	SSB	Catch	SSB
<u>70 mm mesh</u>						
Cod	257	118	260	119	262	120
Whiting	271	109	291	117	304	122
Saithe	167	190	167	190	167	190
Mackerel	42	85	42	85	42	85
Haddock	304	101	339	113	375	125
Herring	357	989	363	1,003	368	1,017
Sprat	281	335	273	322	268	314
Norway pout	425	2,281	428	2,307	430	2,328
Sandeel	1,141	1,152	1,108	1,098	1,077	1,054
<u>120 mm mesh</u>						
Cod	227	176	220	172	217	169
Whiting	78	624	75	598	74	585
Saithe	193	286	193	286	193	286
Mackerel	42	85	42	85	42	85
Haddock	113	271	98	232	86	200
Herring	157	350	160	361	161	368
Sprat	238	269	245	281	249	289
Norway pout	308	2,189	303	2,132	299	2,084
Sandeel	897	787	933	840	964	883

Table 6.2.1 MANOVA tables for fits of the kernel model to restricted data sets NS81, NS85, NS86, and NS87.

Source	NS81		NS85		NS86		NS87	
	SS	df	SS	df	SS	df	SS	df
PD	179.1	4	267.1	4	50.1	4	101.0	4
PY	369.0	6	419.1	6	461.9	6	316.2	6
PD x PY	804.2	21	825.2	21	715.4	21	766.9	21
Q x PD	229.1	4	379.6	4	139.5	4	188.4	4
Q x PY	319.5	6	720.9	6	447.1	6	304.1	6
LWTR, within PD	317.3	5	245.4	5	463.7	5	213.1	5
LWTR	144.7	1	171.4	1	287.2	1	59.8	1
Residual	3560.2	1561	3388.6	1567	4363.7	1562	3518.1	1518
MS error	2.28		2.16		2.79		2.32	

Table 6.2.2 Parameter estimates from fits of kernel models to restricted data sets. Interaction terms not listed, to save space.

Parameter	NS81	NS85	NS86	NS87
PRED-Cod	1.123	0.707	0.783	0.489
Whiting	-0.339	1.941	-0.360	-1.292
Saithe	-2.409	-3.260	-0.800	-0.741
Mackerel	1.906	2.788	1.176	1.690
Haddock	0.281	2.176	0.798	0.944
PREY-Cod	0.231	-2.392	-0.107	0.765
Whiting	-0.320	0.509	-0.122	-0.313
Norway pout	0.520	1.207	0.684	0.611
Sandeel	-0.890	-0.457	-0.840	-0.749
Haddock	0.582	0.980	0.497	0.391
Herring	0.492	0.555	0.723	0.211
Sprat	0.616	0.400	0.834	0.917
Log weight ratio within Predator				
Cod	0.908	1.089	1.713	0.688
Whiting	1.457	0.911	2.188	1.337
Saithe	1.682	1.949	2.096	1.018
Mackerel	1.335	1.554	2.262	1.084
Haddock	1.387	1.513	2.205	1.114
Wt ratio ²	-0.140	-0.166	-0.235	-0.114

Table 6.2.3 MANOVA tables from fits to the four restricted data sets combined for the kernel model with the year effects included.

Source	All data			
	No year effect		With year effect	
	SS	df	SS	df
PD	443.5	4	1373.2	4
PY	1489.1	6	1777.4	6
PD x PY	2622.5	21	3372.0	21
YR x PD	-	-	210.4	12
YR x PY	-	-	188.4	18
Q x PD	816.7	4	825.7	4
Q x PY	1255.6	6	1283.2	6
LWTR x PD x YR	-	-	236.9	12
LWTR W. PD	953.9	5	-	-
Regression	537.7	1	169.0	1
Residual	16726.3	6353	17140.5	6316
MS error	2.63		2.71	

Table 6.3.1 MANOVA tables from fits to combined data sets for the kernel model, and the kernel model with the log prey biomass nested under prey species and prey age. Some older age groups are absent compared with Table 6.2.3.

Source	All data			
	Without biomass		With biomass	
	SS	df	SS	df
PD	535.1	4	196.1	4
PY	1917.8	6	114.0	6
PD x PY	2692.2	21	2243.0	21
Q x PD	702.2	4	359.4	4
Q x PY	1257.4	6	369.5	6
LWTR within PD	1201.1	5	1159.7	5
LBPY within AY within PY	-	-	1922.3	35
Regression	529.9	1	321.9	1
Residual	14829.0	5755	12906.7	5720
MS error	2.58		2.26	

Table 6.3.2a Parameter estimates from MANOVA fit of kernel model and model with prey biomass slopes nested under prey species and prey age.

Parameter	With nested biomass term	Without nested biomass term
Pred: Cod	2.228	-1.672
Whiting	0.377	0.326
Saithe	-0.921	-1.611
Mackerel	1.110	1.845
Haddock	-2.794	-1.112
Prey: Cod	-4.730	-2.462
Whiting	4.547	0.477
Norway pout	-0.738	1.053
Sandeel	2.405	-0.689
Haddock	-0.579	1.028
Herring	-5.486	0.920
Sprat	0.229	-0.327
Wt ratio within predator		
Cod	0.752	0.994
Whiting	1.397	1.484
Saithe	1.469	1.697
Mackerel	1.898	1.709
Haddock	1.462	1.538
Wt ratio ²	-0.131	-0.155

Table 6.3.2b Parameter estimates for the nested prey biomass.

Prey species	Age	Estimate
Cod	1	-0.494
	2	-0.296
	3	-0.211
	4	-0.348
	5	0.000
Whiting	1	-0.835
	2	-0.789
	3	-0.803
	4	-0.828
	5	-0.918
Norway pout	1	-0.299
	2	-0.258
	3	-0.262
	4	0.291
	5	0.000
Sandeel	1	-0.579
	2	-0.651
	3	-0.665
	4	-0.771
	5	-0.739
Haddock	1	-0.232
	2	-0.264
	3	-0.372
	4	-0.403
	5	-0.512
Herring	1	0.025
	2	0.123
	3	0.122
	4	0.134
	5	0.100
Sprat	1	-1.176
	2	-0.831
	3	-0.828
	4	-1.006
	5	-1.289

Table 6.3.3 MANOVA table for fit to combined data set (NS81 to NS87), restricted to cod and whiting and ages up to 5, for model of predator and prey ages, and with overlap as covariate.

Factor	SS	df
Predator age	2.74	3
Prey species	11.89	5
Prey age	9.06	3
Pred age x prey spec	47.63	14
Pred age x prey age	50.02	9
Pred x prey age	132.14	13
Pred age x prey spec x prey age	70.19	24
Overlap covariate	0.11	1
Residual	449.04	
MS error	2.41	

Table 6.3.4 Statistics of regressions of log suitability on log overlaps, and residuals on log biomass estimates, for cod and whiting, across the combined data set.

Species	Model term	r^2	Prob. level	Parameter estimate	Prob. level
Cod	log overlap	0.014	0.055	0.230	0.055
	log pred biomass			-0.138	0.107
	log prey biomass	0.010	0.272	-0.025	0.865
Whiting	log overlap	0.097	<0.001	-0.524	<0.001
	log pred biomass			-0.204	0.017
	log prey biomass	0.031	0.048	0.082	0.512

Table 6.3.5 Statistics of regression of log changes in suitability on changes in biomass. Species are combined but quarters separate.

Year pair	r ²	Prob.	Pred slope ¹	Prob.	Prey slope ¹	Prob.
<u>Net differences</u>						
<u>Quarter 1</u>						
81-85	0.0014	0.591	4.558	0.702	-2.945	0.357
81-86	0.0003	0.898	-1.408	0.820	0.444	0.700
81-87	0.0031	0.316	-8.507	0.318	-1.637	0.191
85-86	0.0050	0.152	-3.334	0.750	-3.187	0.054
85-87	0.0040	0.243	-2.932	0.838	-5.663	0.093
86-87	0.0082	0.045	-17.466	0.028	1.895	0.228
<u>Quarter 3</u>						
81-85	0.0511	<0.001	45.784	0.015	-17.574	<0.001
81-86	0.0073	0.086	12.101	0.235	-2.727	<0.001
81-87	0.0157	0.005	-7.347	0.552	-3.330	<0.001
85-86	0.0149	0.007	13.907	0.166	-4.013	0.004
85-87	0.0200	<0.001	0.251	0.982	-4.162	<0.001
86-87	0.0200	<0.001	1.746	0.808	-2.596	<0.001
<u>Differences of log terms</u>						
<u>Quarter 1</u>						
81-85	0.0127	0.009	0.194	0.076	-0.223	0.011
81-86	0.0358	<0.001	0.306	0.005	-0.313	<0.001
81-87	0.1274	<0.001	0.280	0.001	-0.563	<0.001
85-86	0.1144	<0.001	0.040	0.673	-0.701	<0.001
85-87	0.0395	<0.001	0.085	0.509	-0.490	<0.001
86-87	0.0531	<0.001	-0.197	0.004	-0.347	<0.001
<u>Quarter 3</u>						
81-85	0.1840	<0.001	0.024	0.853	-1.536	<0.001
81-86	0.0356	<0.001	0.420	0.001	-0.293	<0.001
81-87	0.0372	<0.001	-0.257	0.015	-0.270	<0.001
85-86	0.0777	<0.001	0.273	0.027	-0.797	<0.001
85-87	0.0764	<0.001	-0.422	0.002	-0.537	<0.001
86-87	0.0632	<0.001	0.144	0.167	-1.696	<0.001

¹Values time 10⁻⁸.

Table 6.3.6 Statistics of regressions of change in log suitabilities on change in log overlap, and of residuals on changes in log abundance. Data used were for first quarter for cod and whiting younger than age 7.

Species	Year	Parameter	r ²	Prob.	Estimate	Prob.
Cod	81-85	Overlap	0.0331	0.345	0.237	0.345
		Pred biomass			-0.2924	0.002
		Prey biomass	0.3245	0.006	0.063	0.872
	81-86	Overlap	0.0215	0.465	0.304	0.465
		Pred biomass			0.080	0.759
		Prey biomass	0.0332	0.667	0.212	0.419
	81-87	Overlap	0.0061	0.717	-0.202	0.717
		Pred biomass			0.220	0.710
		Prey biomass	0.0154	0.850	0.149	0.667
	85-86	Overlap	0.0039	0.749	-0.100	0.749
		Pred biomass			-0.062	0.822
		Prey biomass	0.0153	0.818	-0.171	0.562
	85-87	Overlap	0.0050	0.731	0.101	0.731
		Pred biomass			-0.048	0.958
		Prey biomass	0.0142	0.848	0.303	0.570
	86-87	Overlap	0.0132	0.568	0.281	0.568
		Pred biomass			-0.461	0.124
		Prey biomass	0.1029	0.272	0.224	0.595
Whiting	81-85	Overlap	0.0024	0.857	-0.157	0.857
		Pred biomass			0.259	0.846
		Prey biomass	0.1628	0.315	-0.882	0.179
	81-86	Overlap	0.0112	0.631	-0.069	0.631
		Pred biomass			0.165	0.780
		Prey biomass	0.9843	<0.001	-0.993	<0.001
	81-87	Overlap	0.2190	0.024	-0.096	0.024
		Pred biomass			-0.461	0.261
		Prey biomass	0.7780	<0.001	-0.770	<0.001
	85-86	Overlap	0.2678	0.040	-0.977	0.040
		Pred biomass			0.927	0.475
		Prey biomass	0.1730	0.291	-0.556	0.256
	85-87	Overlap	0.0236	0.570	-0.330	0.570
		Pred biomass			0.339	0.810
		Prey biomass	0.1376	0.382	-0.792	0.226
	86-87	Overlap	0.0009	0.892	0.037	0.892
		Pred biomass			0.138	0.157
		Prey biomass	0.9999	<0.001	-1.002	<0.001

Table 7.1.1 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	Ave.pred. biomass	<u>Yield</u> Ave.biom.	<u>Tot.eaten</u> Ave.biom.	<u>Tot.eaten</u> Ave.pred.biom.
1974	10,601,348	10,224,452	3,029,667	6,281,296	3,624,000	0.30	0.61	1.73
1975	10,800,866	9,682,734	3,159,467	5,821,550	3,943,000	0.33	0.60	1.48
1976	9,157,944	7,973,906	3,157,725	4,770,433	2,994,000	0.40	0.60	1.59
1977	7,328,124	6,655,876	2,505,529	3,731,329	2,210,000	0.38	0.56	1.62
978	6,516,052	6,190,162	2,417,276	3,169,102	2,032,000	0.39	0.51	1.56
979	6,383,112	6,362,210	2,419,446	2,981,811	2,264,000	0.38	0.47	1.32
1980	6,657,705	5,766,783	2,600,846	2,683,281	2,100,000	0.45	0.47	1.28
1981	4,997,553	5,242,936	2,419,029	2,420,915	2,099,000	0.46	0.46	1.15
1982	5,970,034	5,788,002	2,377,845	2,410,384	1,935,000	0.41	0.42	1.25
1983	5,403,454	5,759,248	2,348,782	2,196,278	1,724,000	0.41	0.38	1.27
1984	6,378,788	6,148,435	2,586,337	2,075,918	2,029,000	0.42	0.34	1.02
1985	5,835,113	5,981,011	2,445,790	2,397,899	1,980,000	0.41	0.40	1.21
1986	6,779,950	6,951,582	2,342,993	3,086,521	1,999,000	0.34	0.44	1.54
1987	7,134,178	6,043,769	2,530,308	2,647,596	2,050,000	0.42	0.44	1.29

Table 8.3.1 Sums of squares of deviations obtained from fitting two models of suitability.

Source of variation	SS	df	MS	F	Signif.
A: Linearized Andersen and Ursin model using weight at ingestion (INDEX: pred-prey-quarter main effect)					
Within + Residual	3,432.74	1,764	1.95	-	-
INDEX	3,093.12	56	55.23	28.38	0.000
LWTR within PD	182.64	5	36.53	18.77	0.000
LWTR2 within PD	247.29	5	49.46	25.42	0.000
B: ANOVA model using weight at ingestion					
Within + Residual	3,730.73	1,783	2.09	-	-
Regression	189.01	1	189.01	90.33	0.000
PD	162.83	4	40.71	19.46	0.000
PY	448.90	6	74.82	35.76	0.000
PD x PY	906.47	21	43.17	20.63	0.000
Q x PD	229.89	4	57.47	27.47	0.000
Q x PY	407.50	6	67.92	32.46	0.000
LWTR within PD	266.68	5	53.34	25.49	0.000
C: ANOVA model using weights in the stock					
Within + Residual	3,919.12	1,859	2.11	-	-
Regression	278.61	1	278.61	132.15	0.000
PD	113.59	4	28.40	13.47	0.000
PY	460.92	6	76.82	35.44	0.000
PD x PY	1,011.33	21	48.16	22.84	0.000
Q x PD	203.94	4	50.98	24.18	0.000
Q x PY	401.95	6	66.99	31.78	0.000
LWTR within PD	307.27	5	61.45	29.15	0.000

Table 8.3.2 Size preference parameters of the Andersen and Ursin model estimated from log(SUIT) regression.

Species	μ	σ^2	e^{μ}	Average prey weight ratio	
				From smoothing	From key run
Cod	3.46	2.71	31.8	123.3	29
Whiting	3.64	1.99	38.0	103.0	50
Saithe	6.14	7.85	465.6	23,505.7	155
Mackerel	4.80	5.10	122.1	1,556.2	126
Haddock				Not estimable	134

Table 8.4.1 Parameter estimates from the model fitted to $\ln(M_2)$ per unit biomass).

Prey	Predator				
	Cod	Whiting	Saithe	Mackerel	Haddock
<u>Relative values for preference</u>					
Cod	0.302	0.535	1.979	2.613	0.090
Whiting	0.212	1.000	0.060	1.832	0.087
Haddock	0.182	0.807	0.326	1.576	0.051
Herring	0.108	0.542	0.071	0.213	0.019
Sprat	0.115	0.446	0.022	0.289	0.004
Norway pout	0.140	0.385	1.724	0.279	0.048
Sandeel	0.105	0.163	0.025	0.521	0.031

Overall predation mortality (uncorrected) = 1.1 per megatonne

Weight ratio estimate¹

Multiplicative model parameters: (LWTR)²

=	0.1434
LWTR(Cod)	= 0.9345
LWTR(Whiting)	= 1.0540
LWTR(Saithe)	= 1.4550
LWTR(Mackerel)	= 0.9900
LWTR(Haddock)	= 1.4050

Prey/predator weight ratio

Conversions to size preference:

M(Cod)	= -26.01
M(Whiting)	= -39.45
M(Saithe)	= -159.69
M(Mackerel)	= -31.64
M(Haddock)	= -134.14
SD	= 1.8673

¹ LWTR indicates $\ln(W_{pred}/W_{prey})$.

Table 9.1.1 Percentage changes in yield for a 25% increase in the industrial demersal fishery based on the MSFOR and Shepherd models.

Fleet/Species	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
MSFOR									
Roundfish-HC	-1.94	-4.60	-0.57	-	-6.09	-	-	-	-
Industrial-Dem	23.75	21.99	24.52	-	21.28	-	-	8.56	5.31
Industrial-Pel	-	-1.29	-	-	-	0.77	0.25	-	-
Herring	-	-	-	-	-	0.91	-	-	-
Saithe	-	-	-0.57	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	-0.71	1.01	-0.16	-	-1.29	0.84	0.25	8.56	5.31
Shepherd									
Roundfish-HC	-0.88	-3.06	-0.57	-	-1.91	-	-	-	-
Industrial-Dem	24.68	23.16	24.54	-	24.55	-	-	17.33	12.20
Industrial-Pel	-	-0.80	-	-	-	1.50	0.49	-	-
Herring-HC	-	-	-	-	-	2.05	-	-	-
Saithe	-	-	-0.57	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	0.63	0.08	-0.15	-	4.28	1.75	0.49	17.33	12.20

Table 9.2.1 Percentage changes in yield for a 25% increase in the HC-roundfish fishery based on the MSFOR and Shepherd models.

Fleet/Species	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
<u>MSFOR</u>									
Roundfish-HC	3.61	13.88	19.31	-	19.63	-	-	-	-
Industrial-Dem	5.58	-1.07	-1.84	-	7.13	-	-	10.41	0.38
Industrial-Pel	-	0.71	-	-	-	6.17	0.52	-	-
Herring	-	-	-	-	-	8.49	-	-	-
Saithe	-	-	-4.31	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	3.71	10.30	-0.79	-	17.44	7.26	0.52	10.41	0.38
<u>Shepherd</u>									
Roundfish-HC	5.30	14.00	19.41	-	14.80	-	-	-	-
Industrial-Dem	1.87	-1.99	-1.80	-	1.71	-	-	3.24	0.26
Industrial-Pel	-	-0.33	-	-	-	4.00	0.20	-	-
Herring-HC	-	-	-	-	-	6.11	-	-	-
Saithe	-	-	-4.24	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	5.10	9.99	-0.73	-	11.74	4.94	0.20	3.24	0.26

Table 9.2.2 Percentage changes in yield for a 50% increase in the HC-roundfish fishery based on the MSFOR and Shepherd models.

Fleet/Species	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
<u>MSFOR</u>									
Roundfish-HC	5.27	25.20	36.89	-	38.28	-	-	-	-
Industrial-Dem	9.13	-2.72	-3.65	-	13.80	-	-	20.78	1.07
Industrial-Pel	-	0.97	-	-	-	12.22	1.25	-	-
Herring	-	-	-	-	-	16.71	-	-	-
Saithe	-	-	-8.32	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	5.45	18.53	-1.58	-	33.98	14.33	1.25	20.78	1.07
<u>Shepherd</u>									
Roundfish-HC	8.78	25.62	37.10	-	28.62	-	-	-	-
Industrial-Dem	2.85	-4.28	-3.56	-	3.30	-	-	6.45	0.57
Industrial-Pel	-	-0.95	-	-	-	7.91	0.45	-	-
Herring-HC	-	-	-	-	-	12.02	-	-	-
Saithe	-	-	-8.19	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	8.43	18.13	-1.45	-	22.70	9.75	0.45	6.45	0.57

Table 9.2.3 Percentage changes in yield for a 75% increase in the HC-roundfish fishery based on the MSFOR and Shepherd models.

Fleet/Species	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
<u>MSFOR</u>									
Roundfish-HC	5.99	34.63	52.93	-	55.74	-	-	-	-
Industrial-Dem	11.14	-4.69	-5.43	-	19.84	-	-	30.87	1.98
Industrial-Pel	-	0.91	-	-	-	18.08	2.13	-	-
Herring	-	-	-	-	-	24.58	-	-	-
Saithe	-	-	-12.04	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	6.24	25.25	-2.36	-	49.44	21.13	2.13	30.87	1.98
<u>Shepherd</u>									
Roundfish-HC	11.13	35.51	53.28	-	41.68	-	-	-	-
Industrial-Dem	3.12	-6.69	-5.28	-	4.77	-	-	9.60	0.94
Industrial-Pel	-	-1.77	-	-	-	11.71	0.72	-	-
Herring-HC	-	-	-	-	-	17.72	-	-	-
Saithe	-	-	-11.86	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	10.66	24.95	-2.17	-	33.04	14.39	0.72	9.60	0.94

Table 9.2.4 Percentage changes in yield for a 100% increase in both industrial whiting fisheries based on MSFOR model only.

Fleet/Species	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	1.75	-14.55	-	-	12.29	-	-	-	-
Industrial-Dem	1.70	86.19	-	-	9.43	-	-	3.52	2.50
Industrial-Pel	-	93.75	-	-	-	8.73	3.92	-	-
Herring	-	-	-	-	-	10.90	-	-	-
Saithe	-	-	-	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	1.75	10.29	-	-	11.79	9.75	3.92	3.52	2.50

Table 9.3.1 Percentage changes in yield for a complete stoppage of the mackerel fishery based on the MSFOR and Shepherd models.

Fleet/Species	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
MSFOR									
Roundfish-HC	-9.48	-3.72	-	-	-10.15	-	-	-	-
Industrial-Dem	-9.58	-3.00	-	-	-7.41	-	-	-16.72	-23.68
Industrial-Pel	-	-2.36	-	-	-	-24.51	-26.20	-	-
Herring	-	-	-	-	-	-31.45	-	-	-
Saithe	-	-	-	-	-	-	-	-	-
Mackerel	-	-	-	-100.0	-	-	-	-	-
Total	-9.48	-3.52	-	-100.0	-9.67	-27.77	-26.20	-16.72	-23.68
SHEPHERD									
Roundfish-HC	-3.66	1.23	-	-	1.35	-	-	-	-
Industrial-Dem	-4.81	0.70	-	-	0.43	-	-	-6.06	-13.73
Industrial-Pel	-	0.37	-	-	-	-14.86	-13.06	-	-
Herring-HC	-	-	-	-	-	-20.04	-	-	-
Saithe	-	-	-	-	-	-	-	-	-
Mackerel	-	-	-	-100.0	-	-	-	-	-
Total	-3.73	1.08	-	-100.0	1.15	-17.16	-13.06	-6.06	-13.73

Table 9.4.1 Percentage changes in yield for a 100% increase in the HC-herring fishery based on the MSFOR and Shepherd models.

Fleet/Species	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
MSFOR									
Roundfish-HC	-0.39	-0.14	-	-	-0.49	-	-	-	-
Industrial-Dem	-0.21	-0.07	-	-	-0.30	-	-	-0.26	0.05
Industrial-Pel	-	-0.04	-	-	-	-22.17	0.01	-	-
Herring	-	-	-	-	-	31.90	-	-	-
Saithe	-	-	-	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	-0.38	-0.13	-	-	-0.46	3.21	0.01	-0.26	0.05
Shepherd									
Roundfish-HC	-	-	-	-	-	-	-	-	-
Industrial-Dem	-	-	-	-	-	-	-	-	-
Industrial-Pel	-	-	-	-	-	-17.98	-	-	-
Herring-HC	-	-	-	-	-	41.34	-	-	-
Saithe	-	-	-	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	8.45	-	-	-

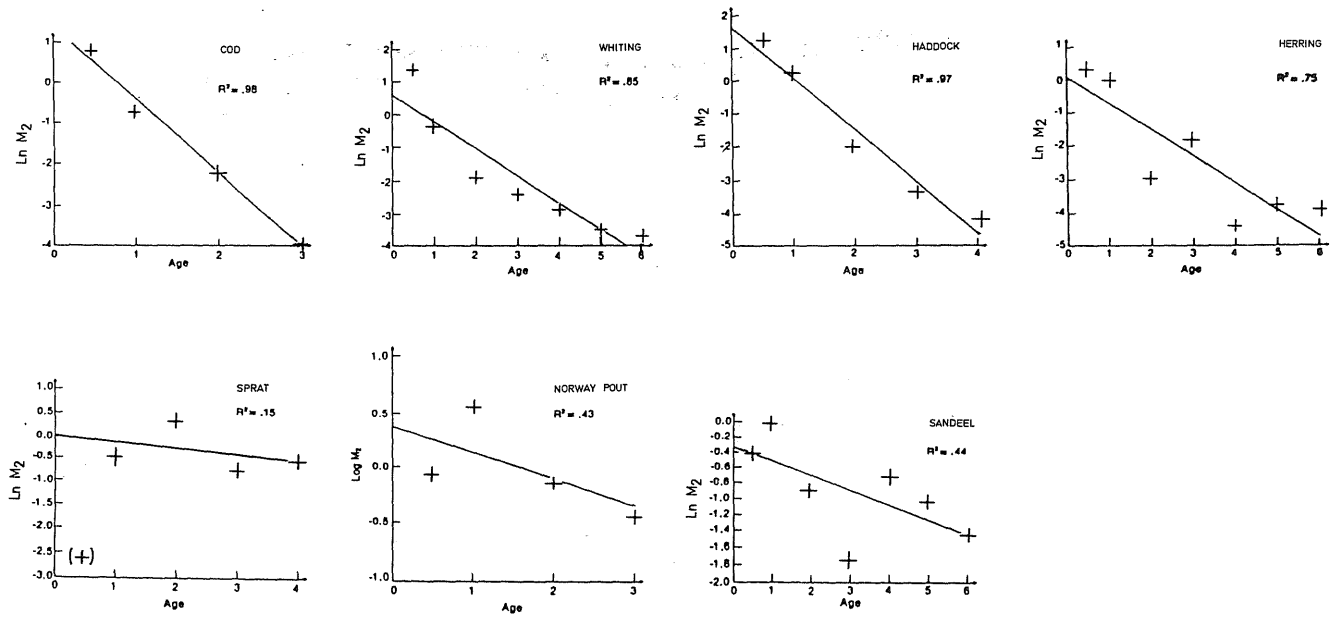


Figure 2.5.1 $\ln M_2$ plotted against age.

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

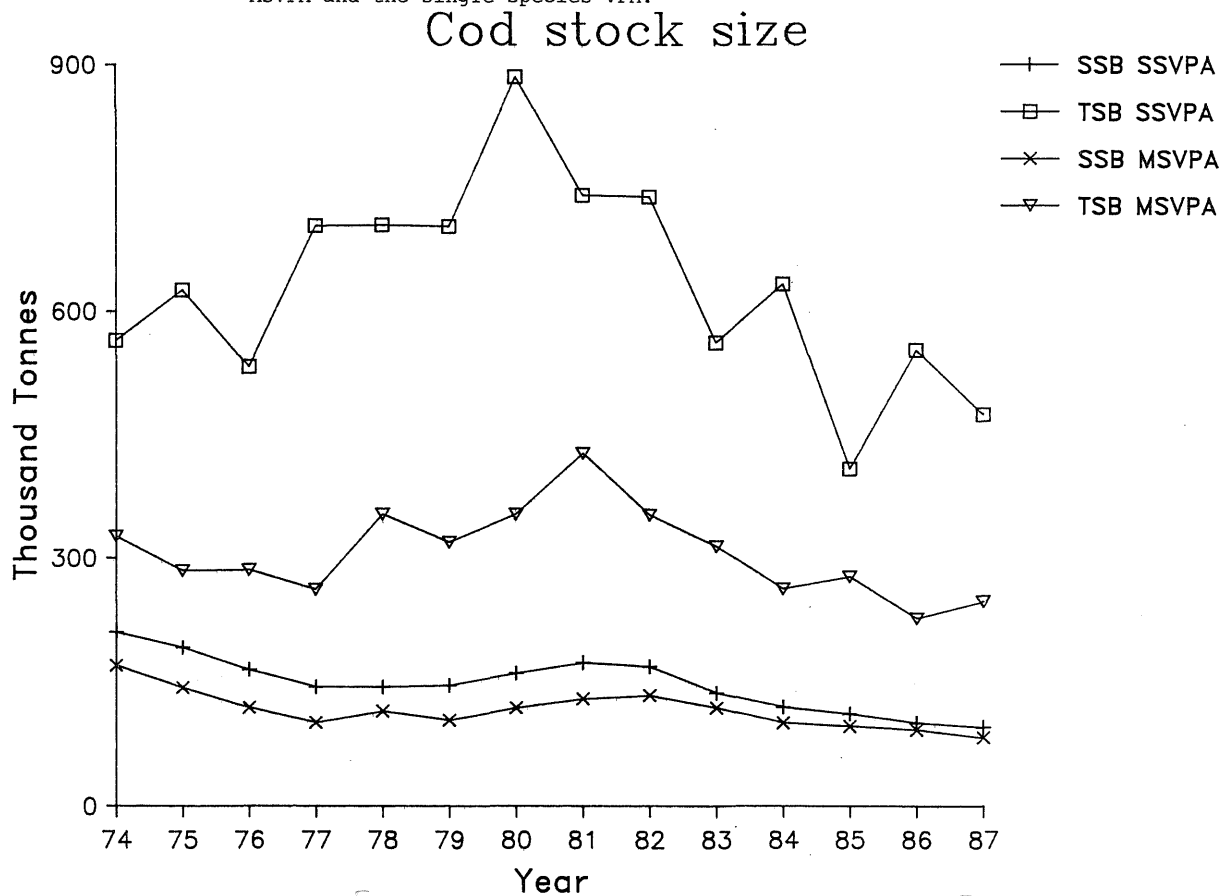


Figure 2.8.1b The total stock biomass (TSB) and spawning stock biomass (SSB) of whiting from the MSVPA and the single-species VPA.

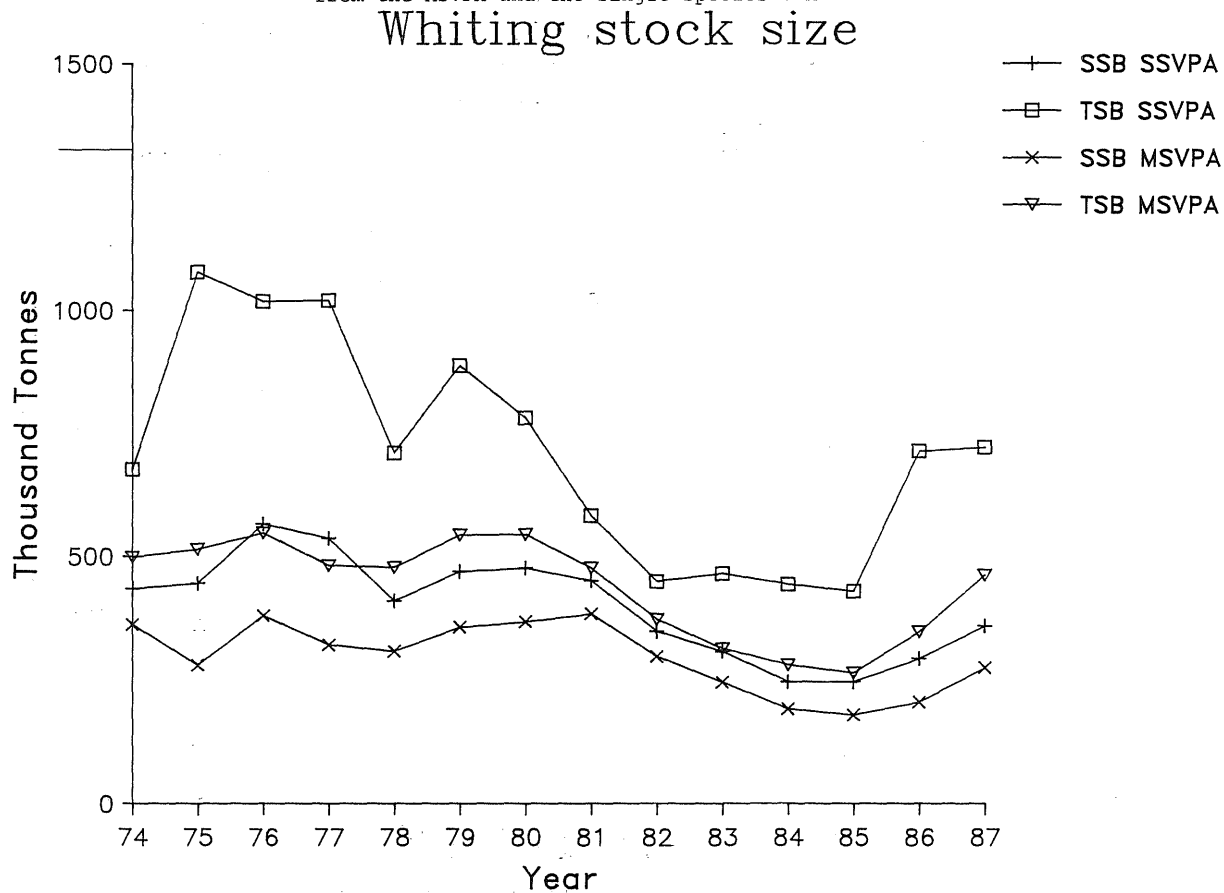


Figure 2.8.1c The total stock biomass (TSB) and spawning stock biomass (SSB) of haddock from the MSVPA and the single-species VPA.

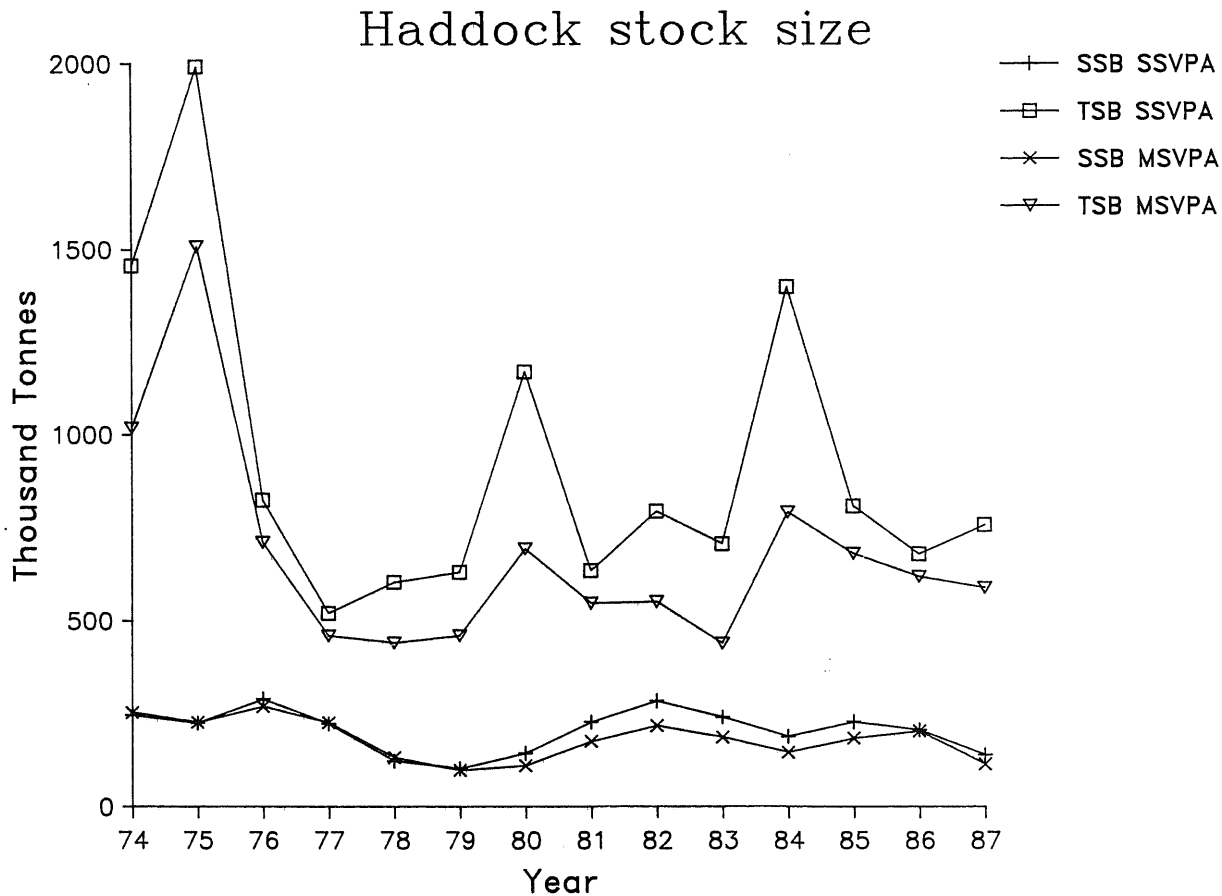


Figure 2.8.1d The total stock biomass (TSB) and spawning stock biomass (SSB) of herring from the MSVPA and the single-species VPA.

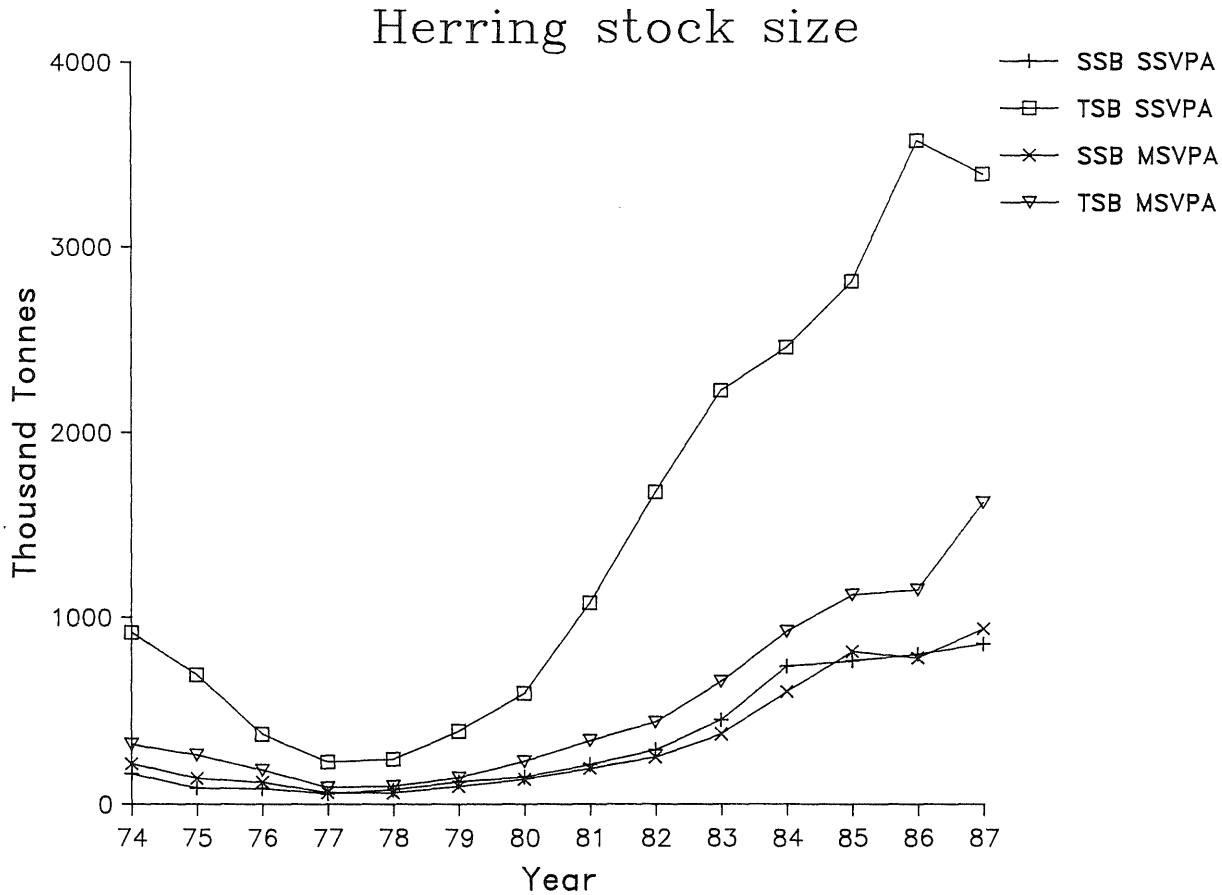


Figure 2.8.1e The total stock biomass (TSB) and spawning stock biomass (SSB) of Norway pout from the MSVPA and the single-species VPA.

Norway Pout stock size

SSVPA stocks in 2 quarter

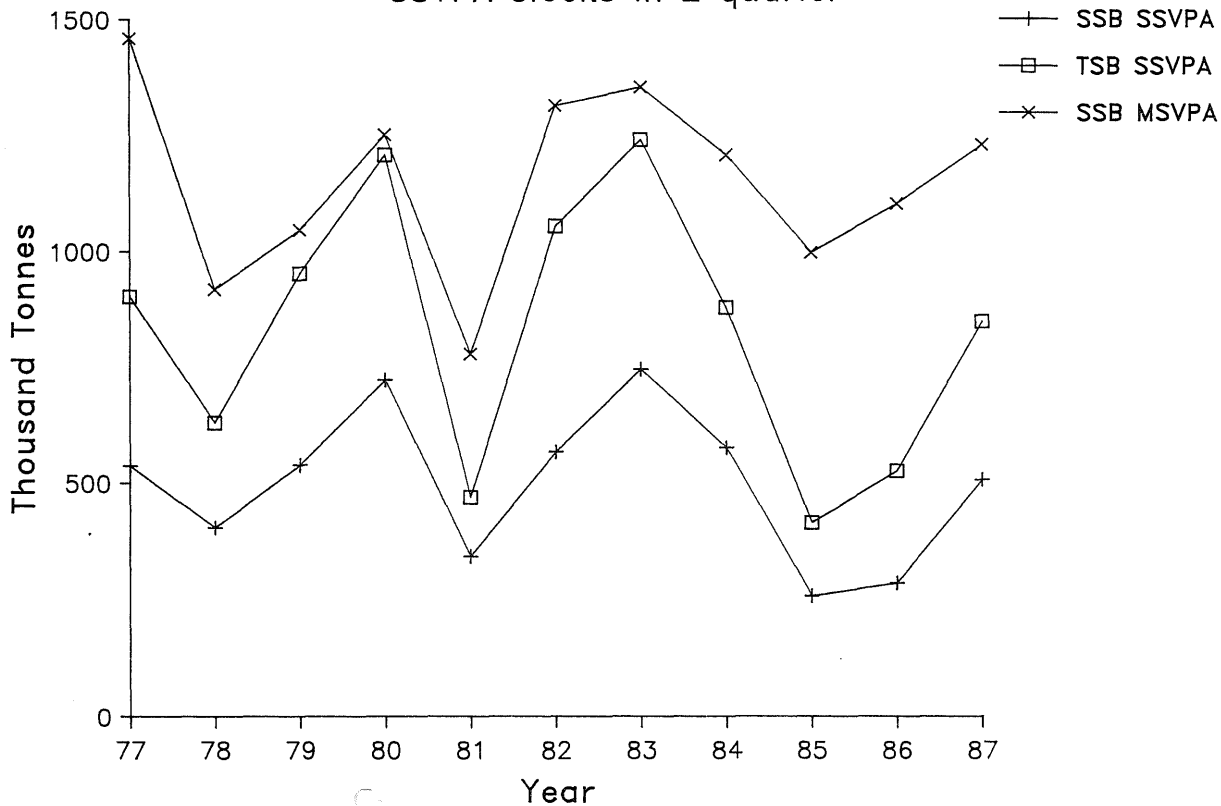


Figure 3.1a Relationship between recruitment estimated by MSVPA and by single-species working group for 1.

Recr. Cod
No *10⁻³, 1WR

120

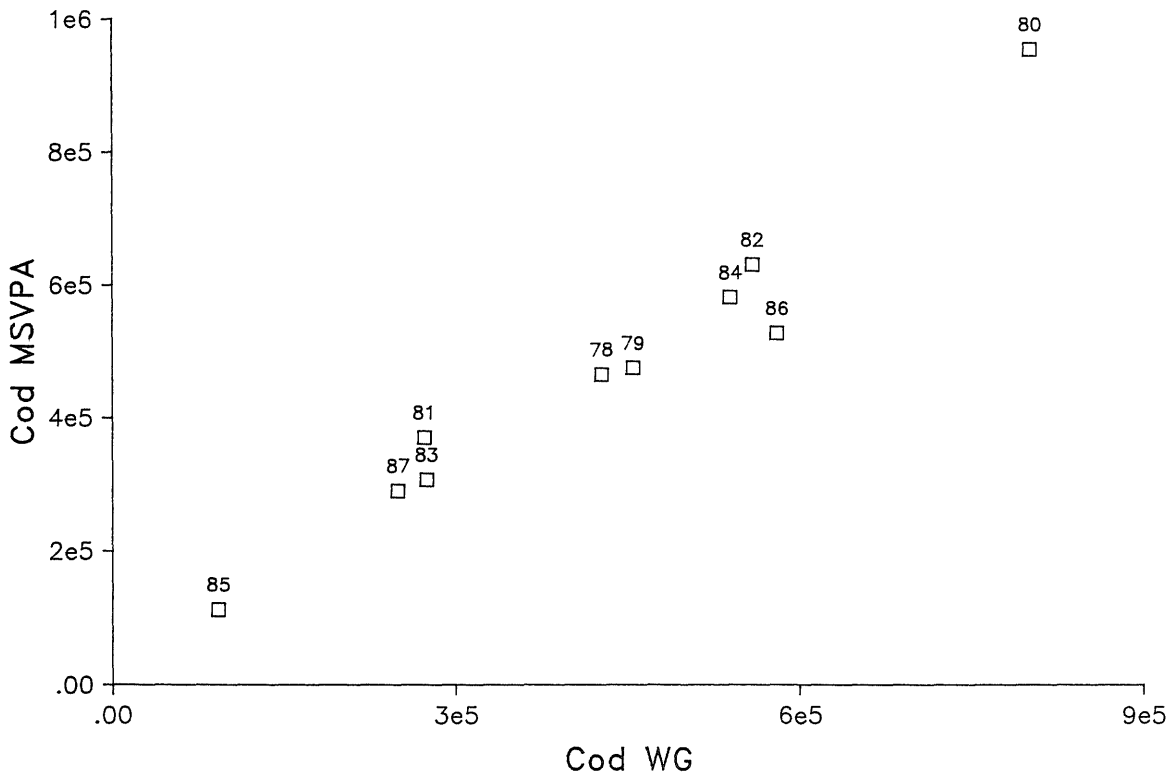


Figure 2.8.1f The total stock biomass (TSB) and spawning stock biomass (SSB) of sandeel from the MSVPA and the single-species VPA.

Sandeel stock size

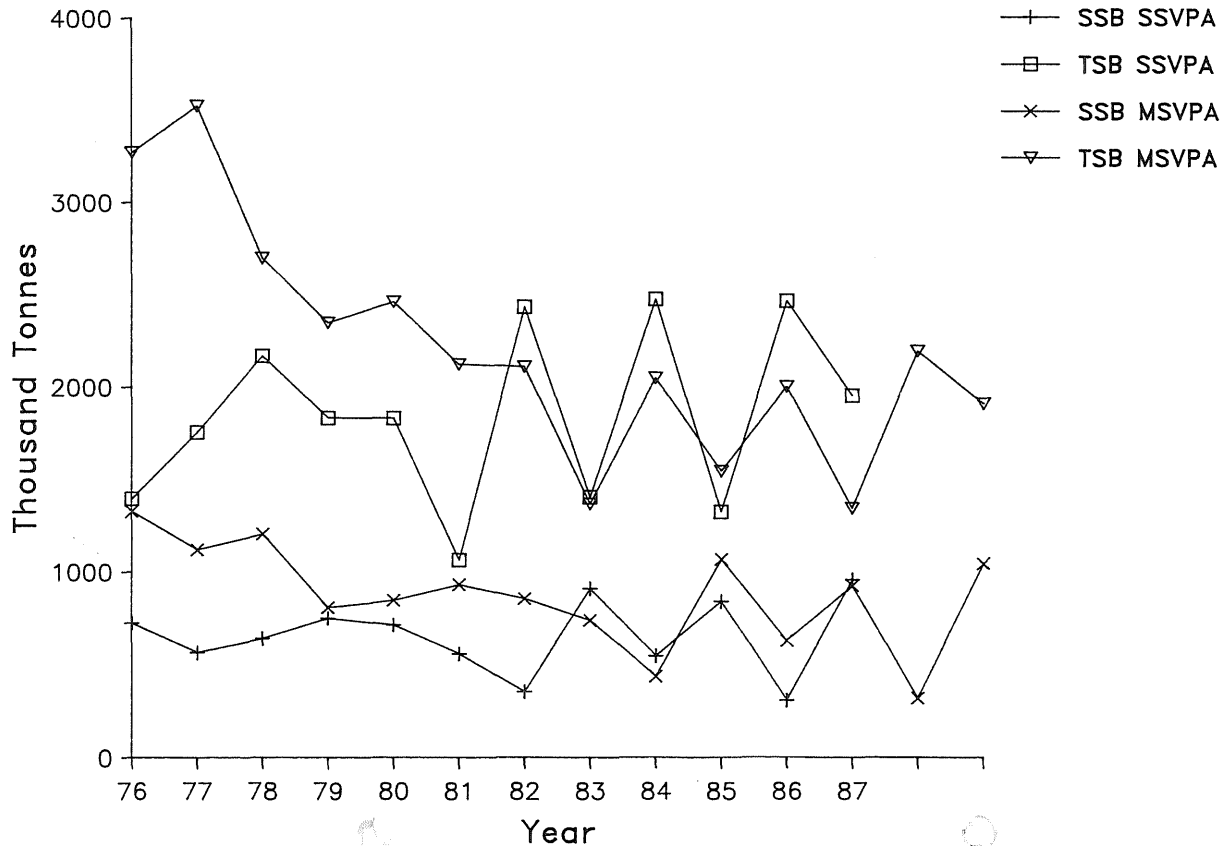


Figure 3.1b Relationship between recruitment estimated by MSVPA and by single-species working group for whiting.

Recr. Whiting

No *10-3, 1WR

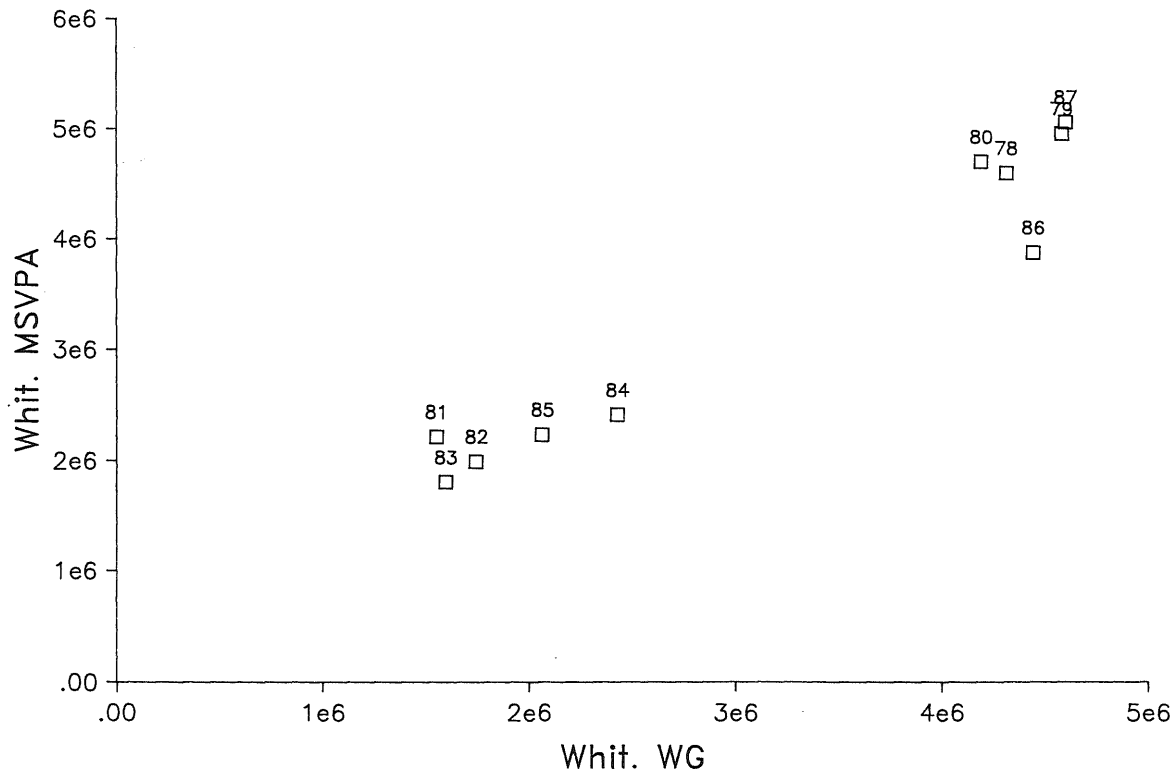


Figure 3.1c Relationship between recruitment estimated by MSVPA and by single-species working group for haddock.

Recr. Haddock

No *10⁻³, 1WR

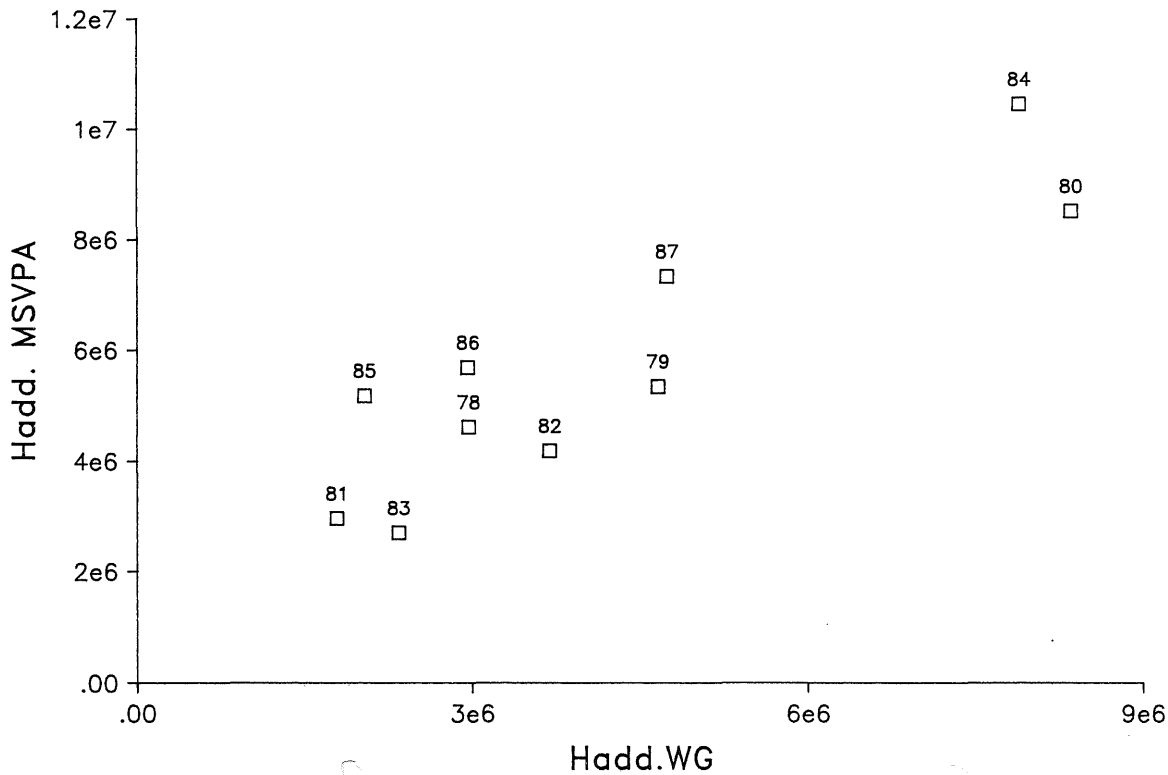


Figure 3.1d Relationship between recruitment estimated by MSVPA and by single-species working group for herring.

Recr. Herring

No *10⁻³, 1WR

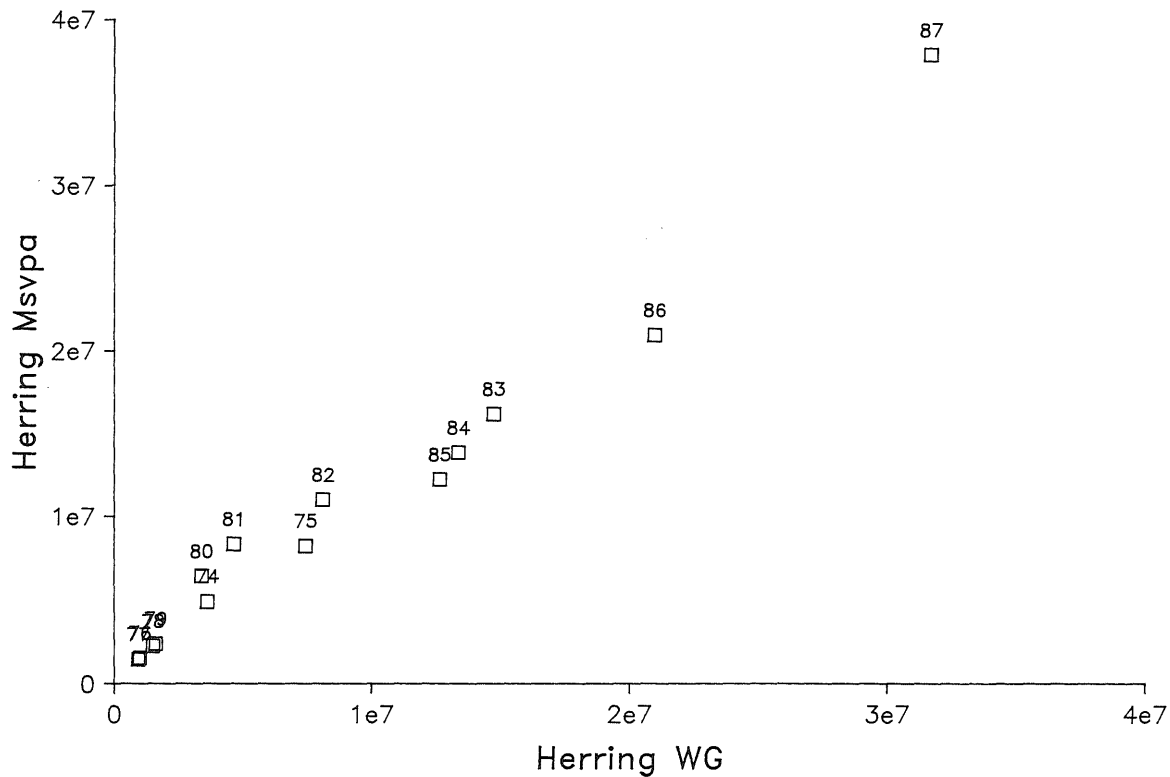


Figure 3.1e Relationship between recruitment estimated by MSVPA and by single-species working group for sandeel.

Recr. Sandeel

No *10⁻³, 1WR

124

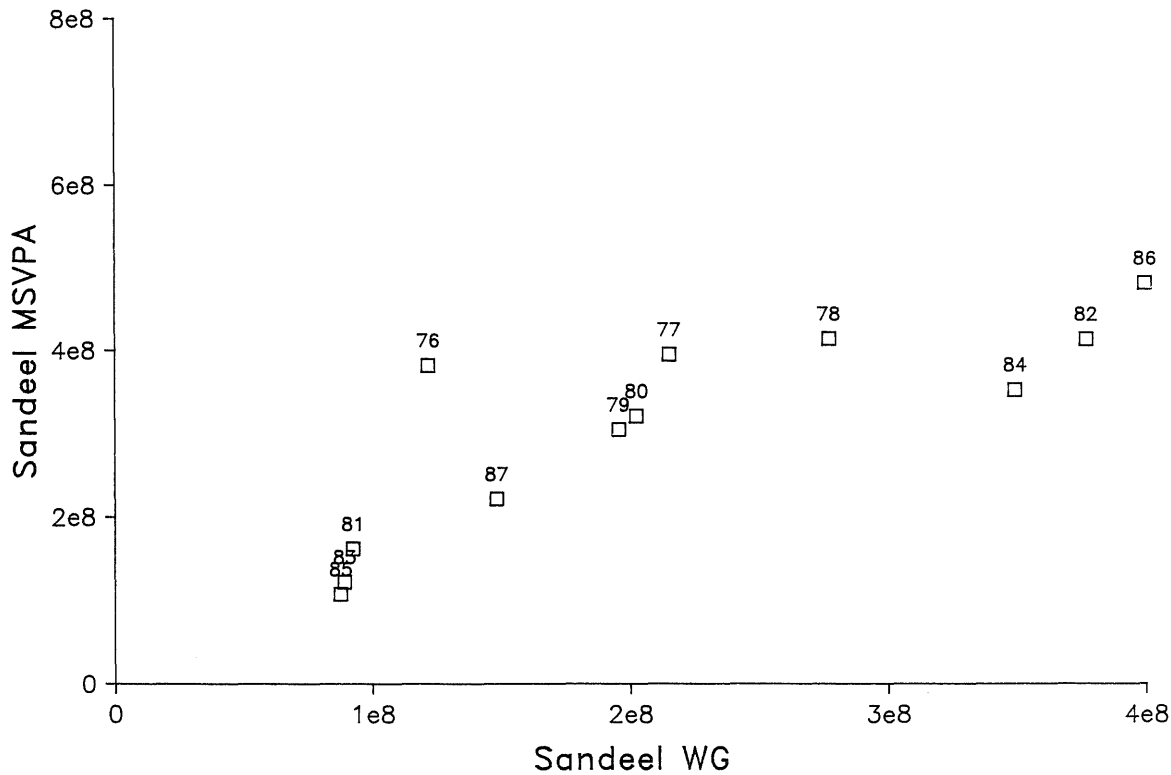


Figure 4.6.1 Total landings ('000 t) for different mesh sizes based on single-species model.

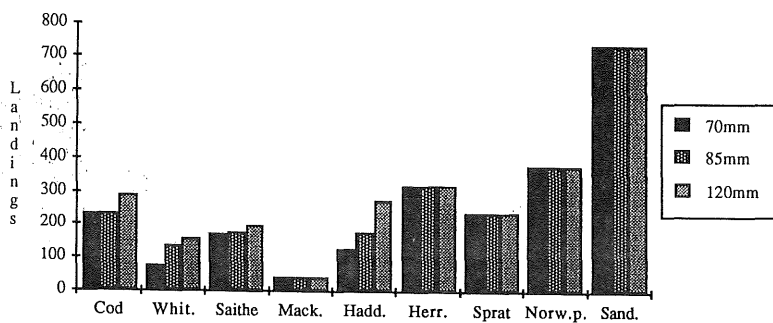


Figure 4.6.2 Total landings ('000 t) for different mesh sizes based on MSFOR model.

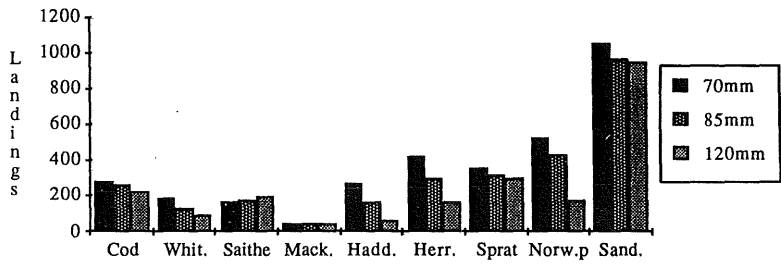


Figure 4.6.3 Value (millions of ECU) of landings for different mesh sizes.

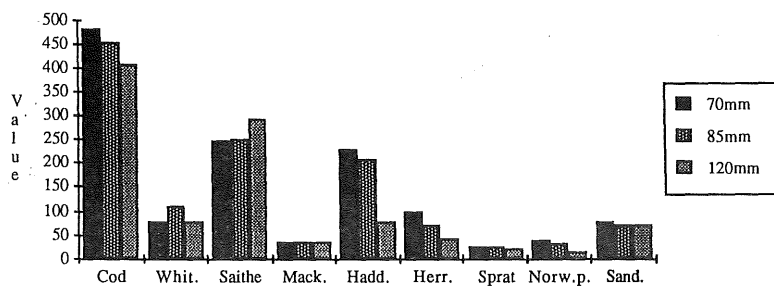


Figure 7.1.1b Prey consumed by predator species.

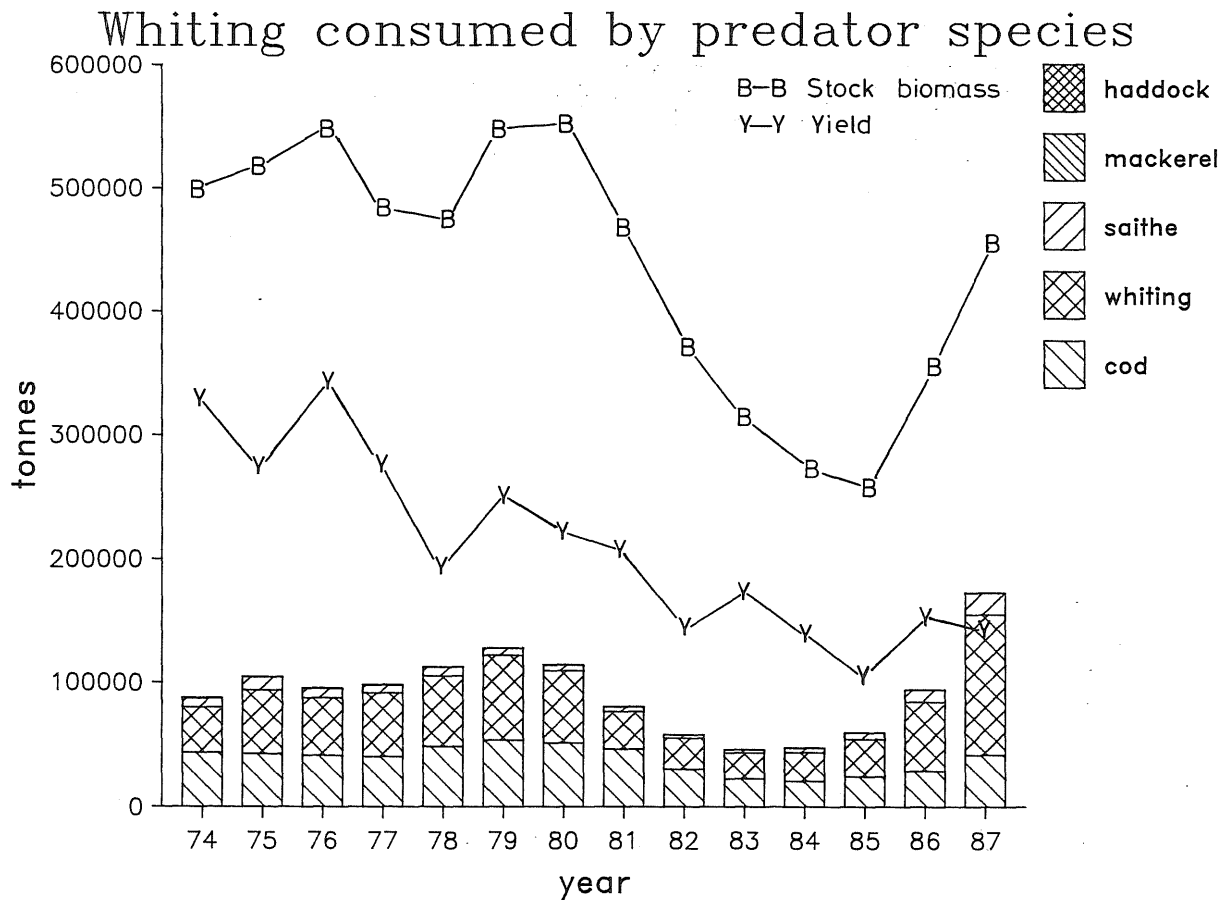


Figure 7.1.1c Prey consumed by predator species.

Haddock consumed by predator species

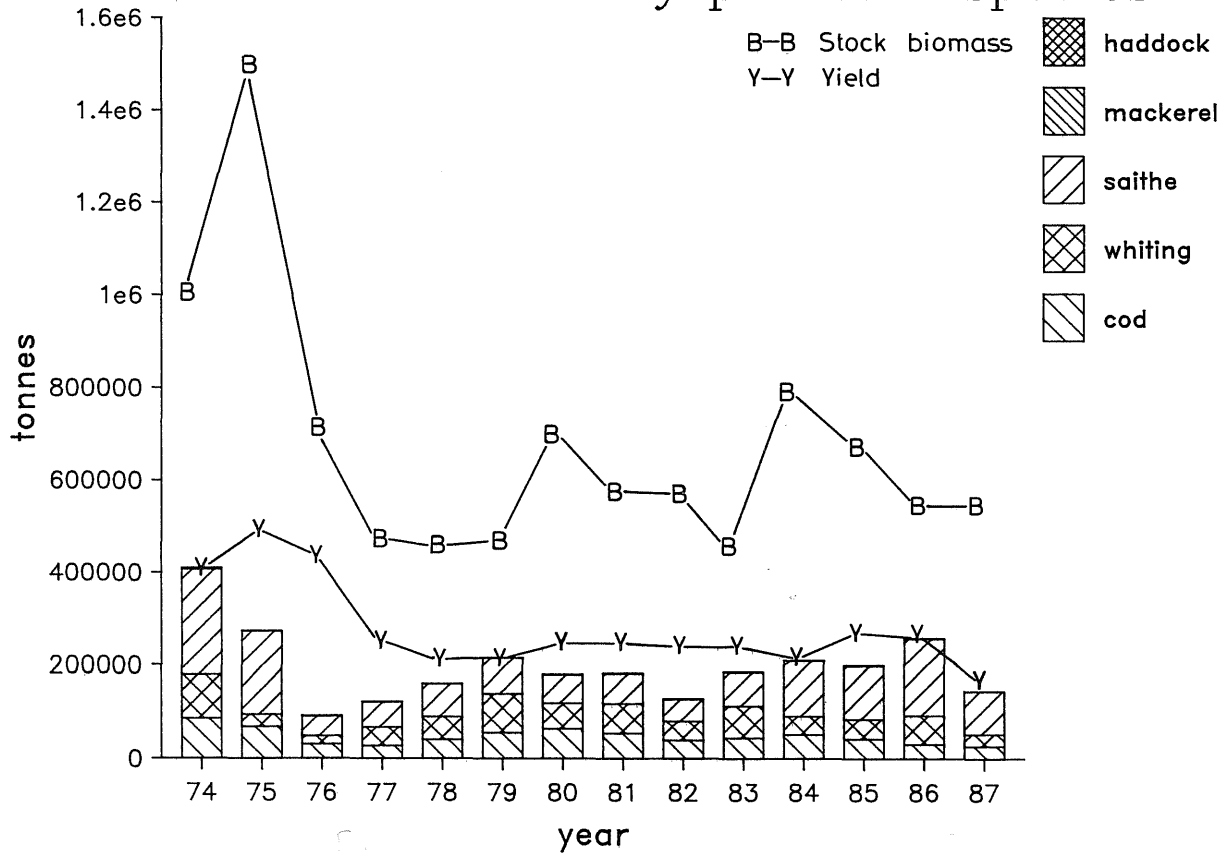


Figure 7.1.1d Prey consumed by predator species.

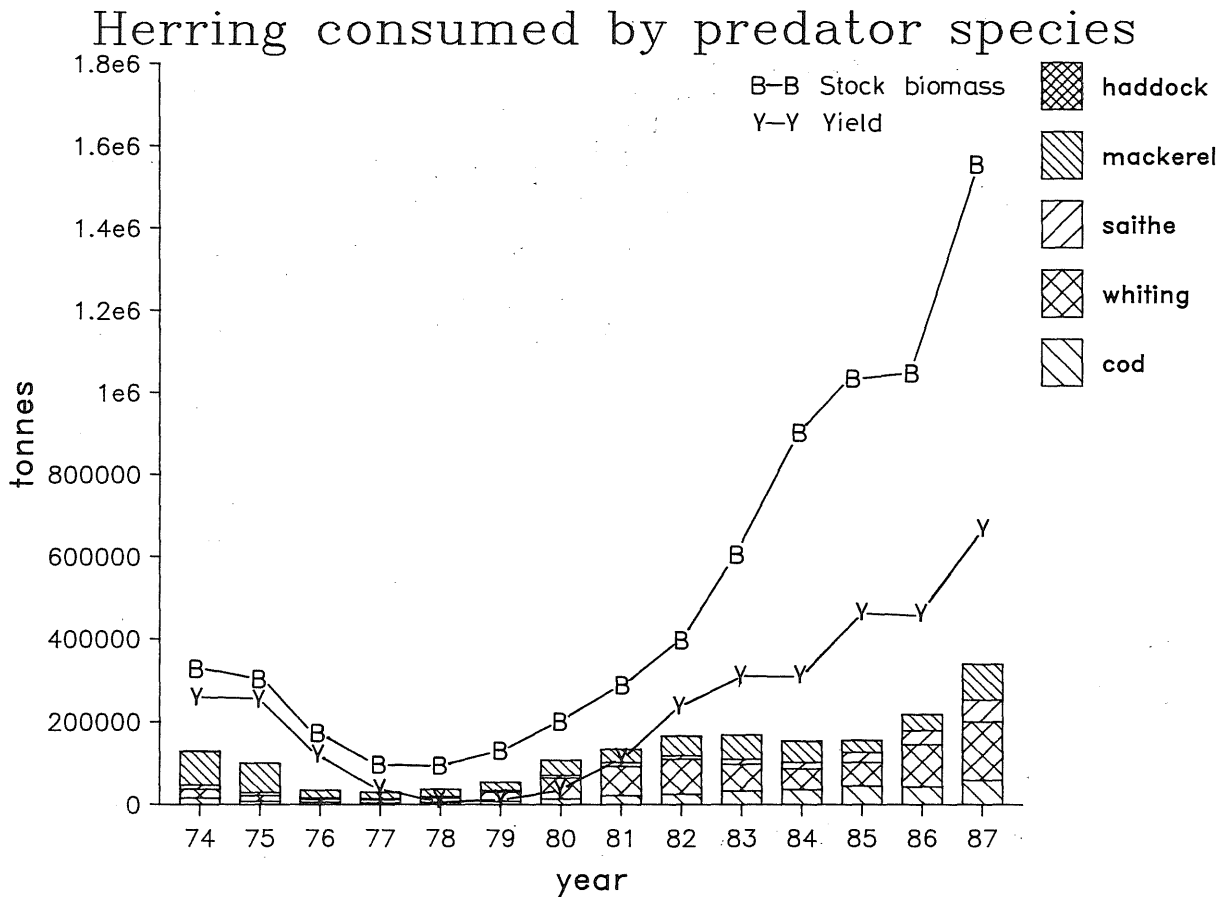


Figure 7.1.1e Prey consumed by predator species.

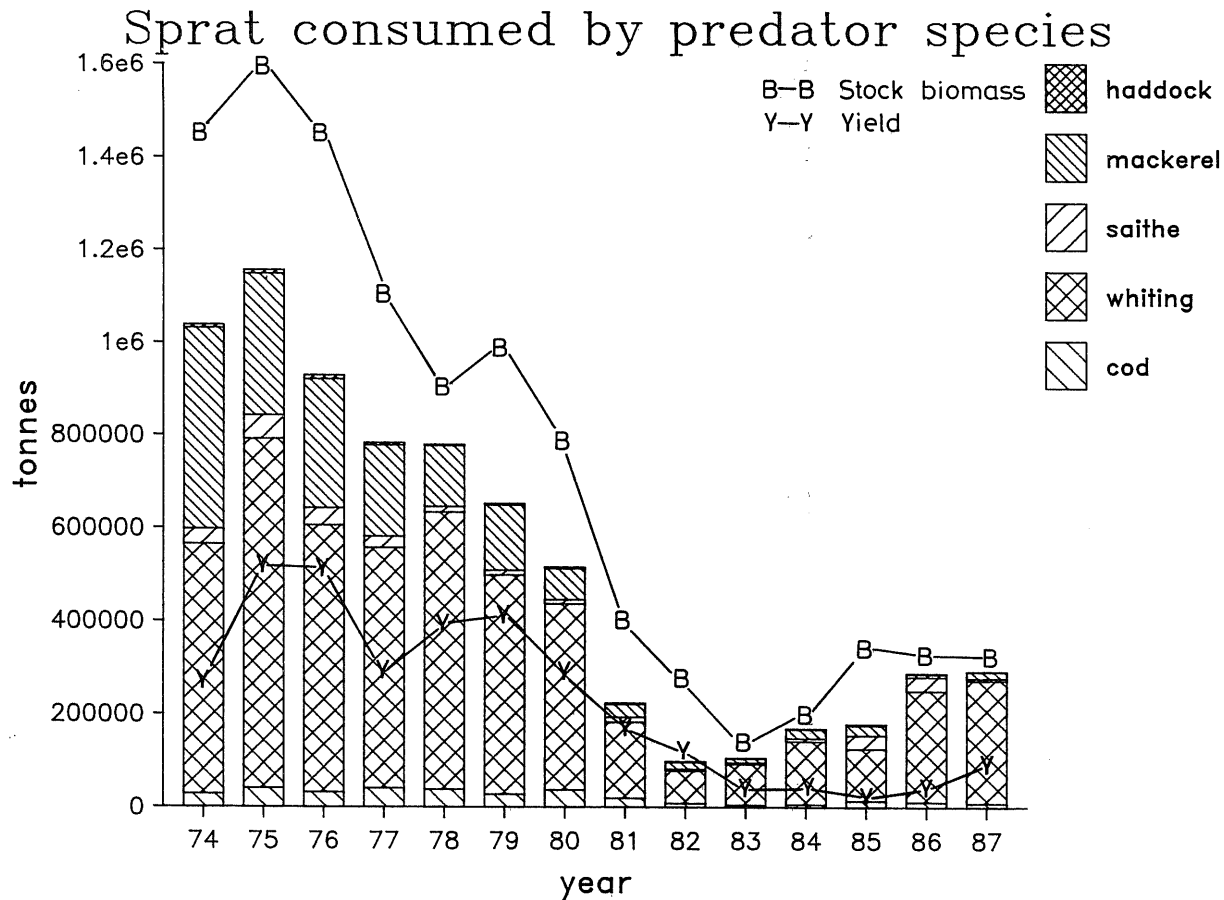


Figure 7.1.1f Prey consumed by predator species.

Norway Pout consumed by predator species

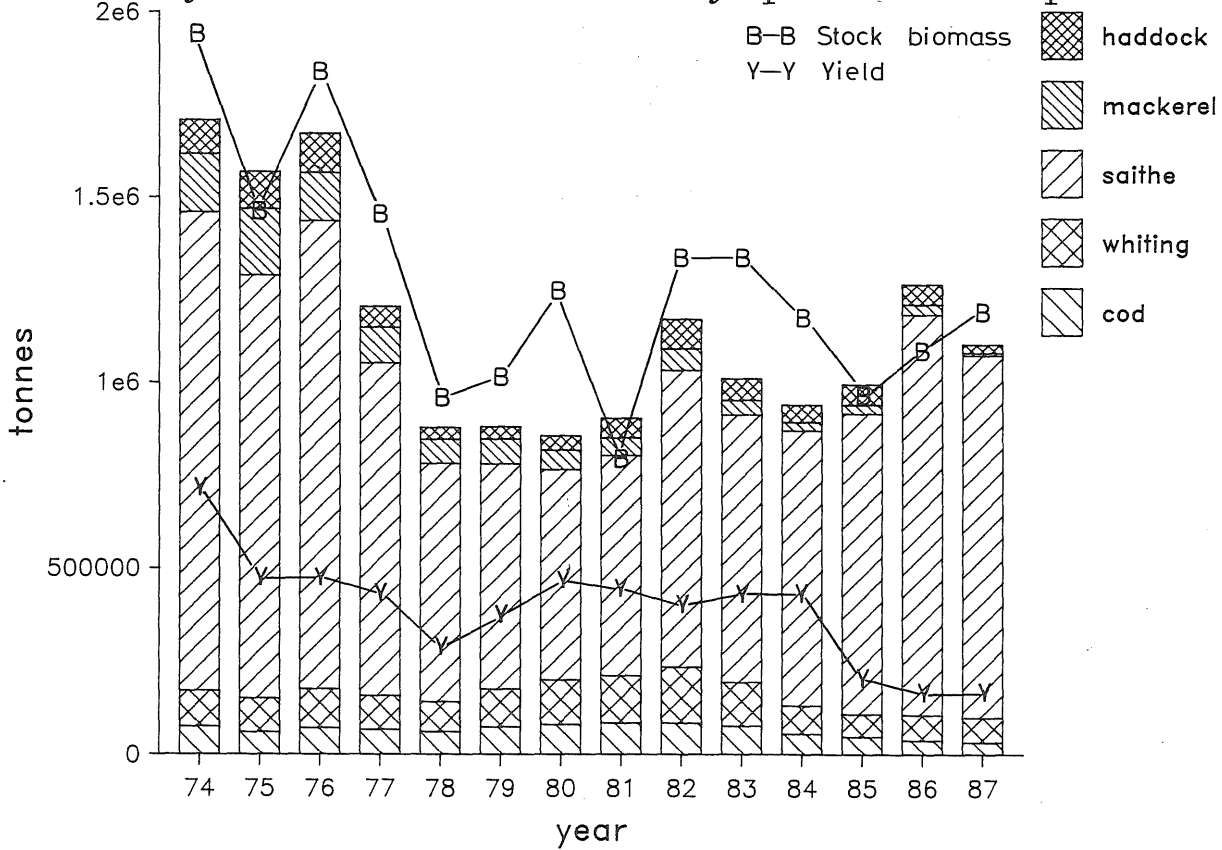


Figure 7.1.1g Prey consumed by predator species.

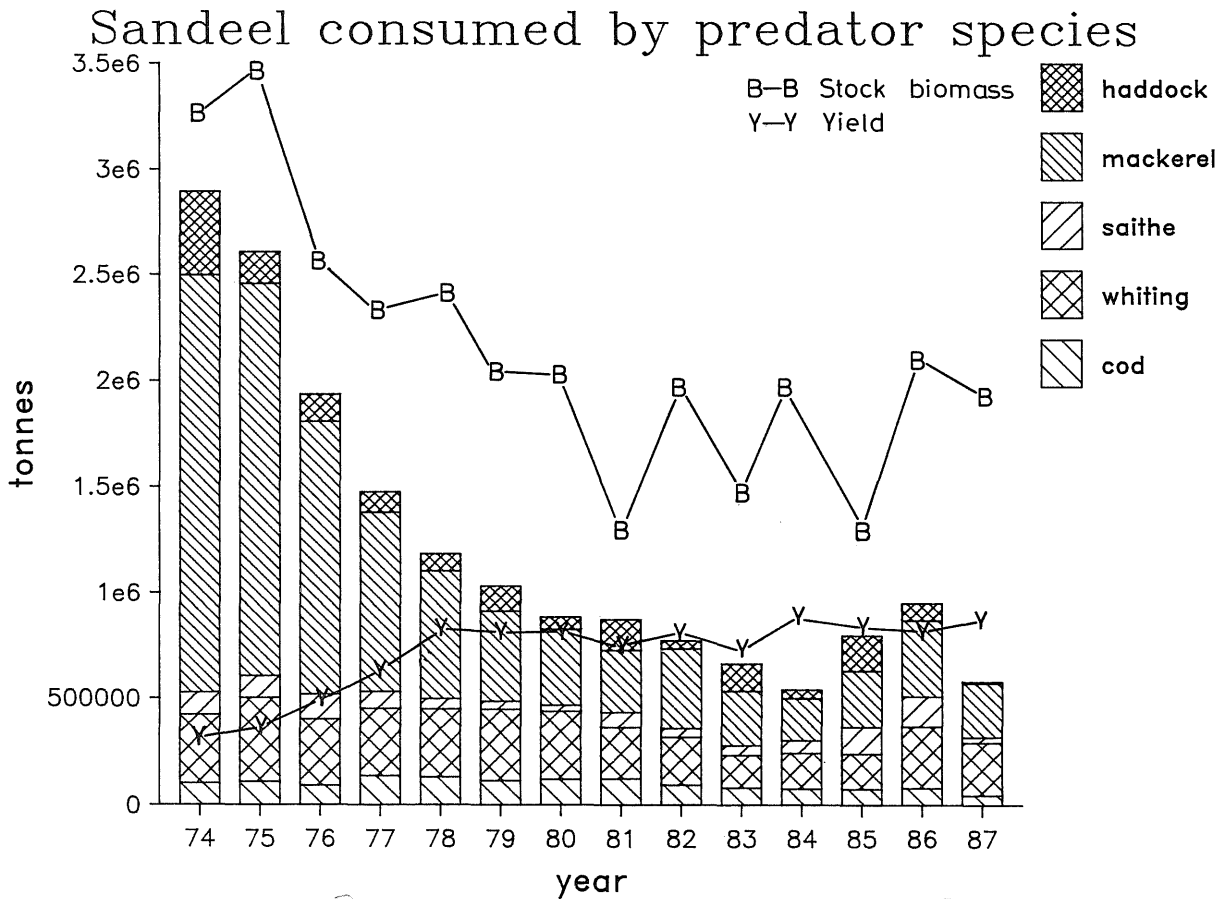


Figure 7.1.2a Consumption by predator species of prey species.

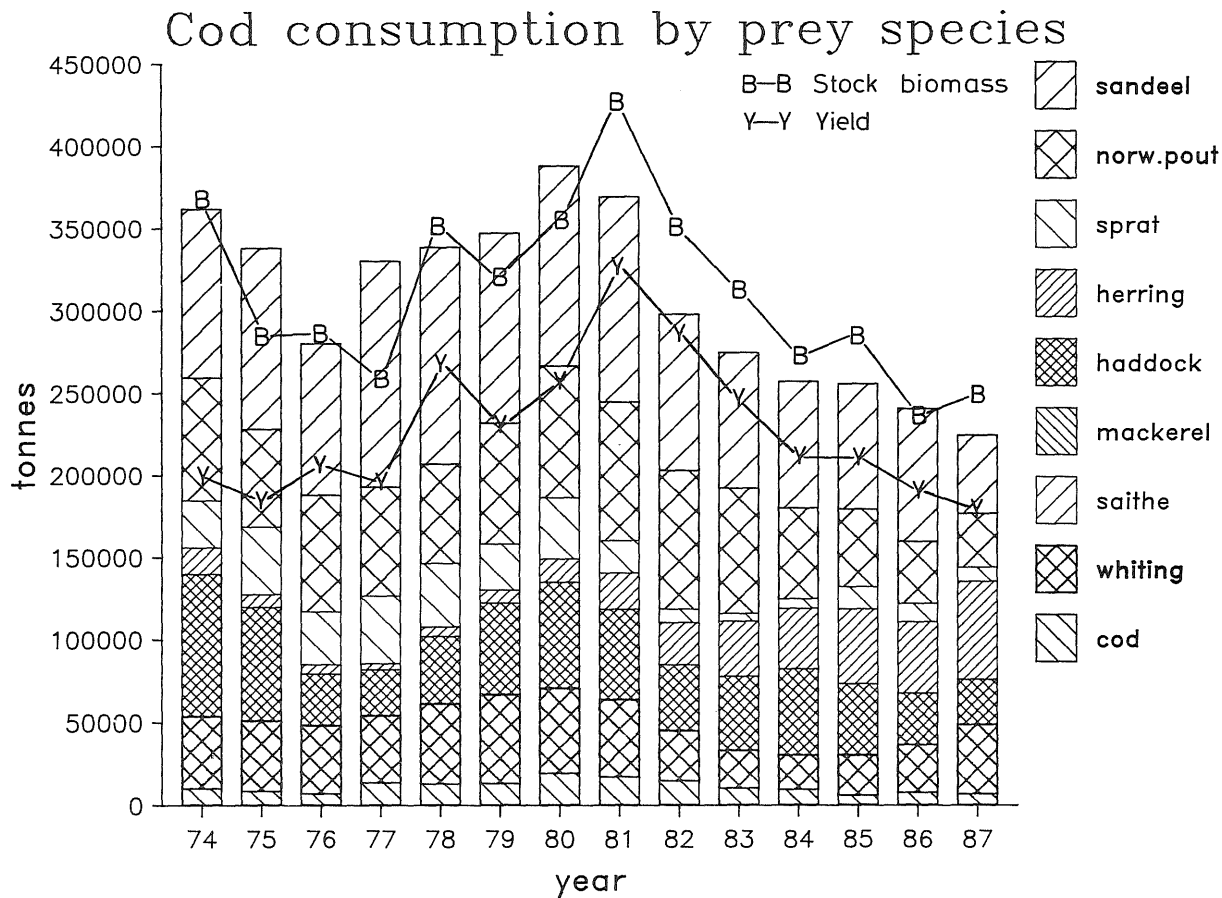


Figure 7.1.2b Consumption by predator species of prey species.

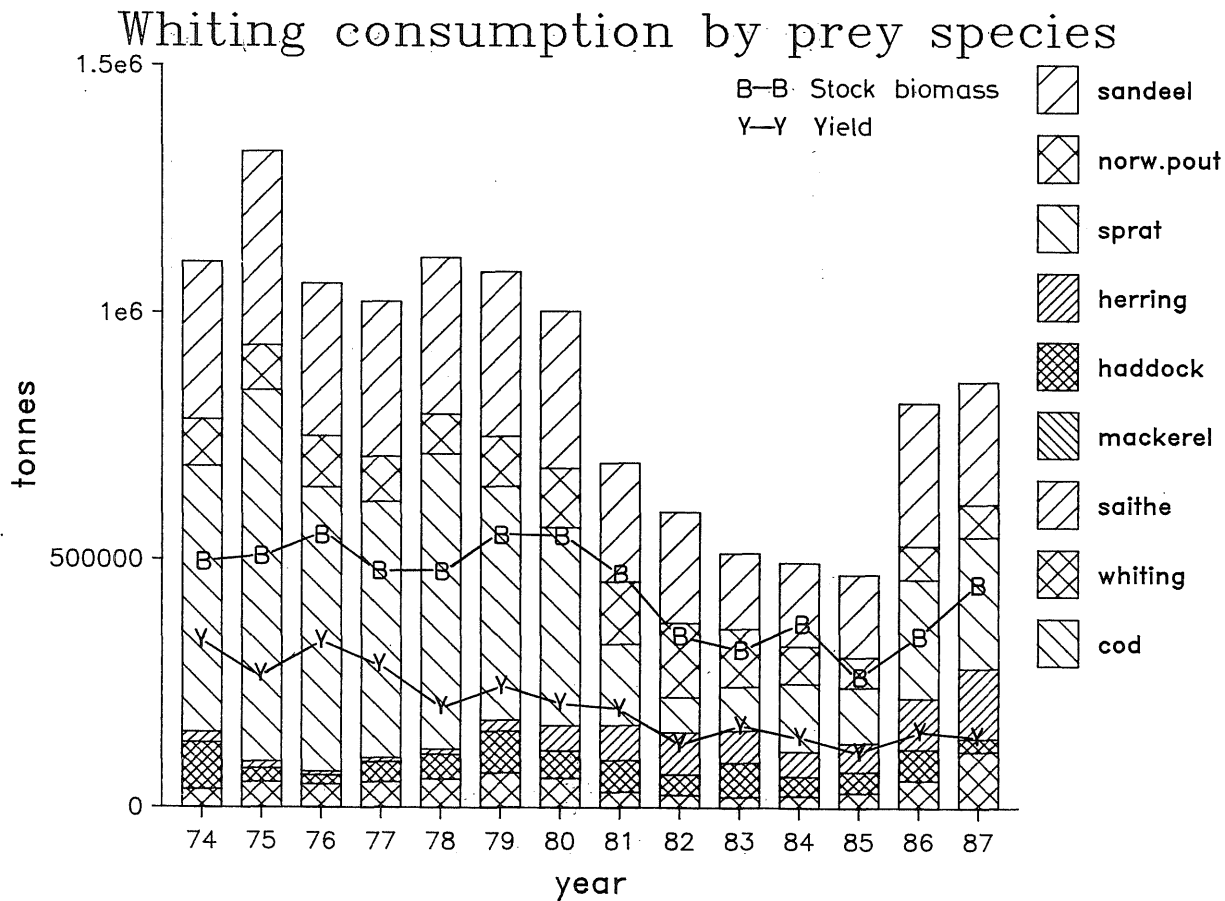


Figure 7.1.2c Consumption by predator species of prey species.

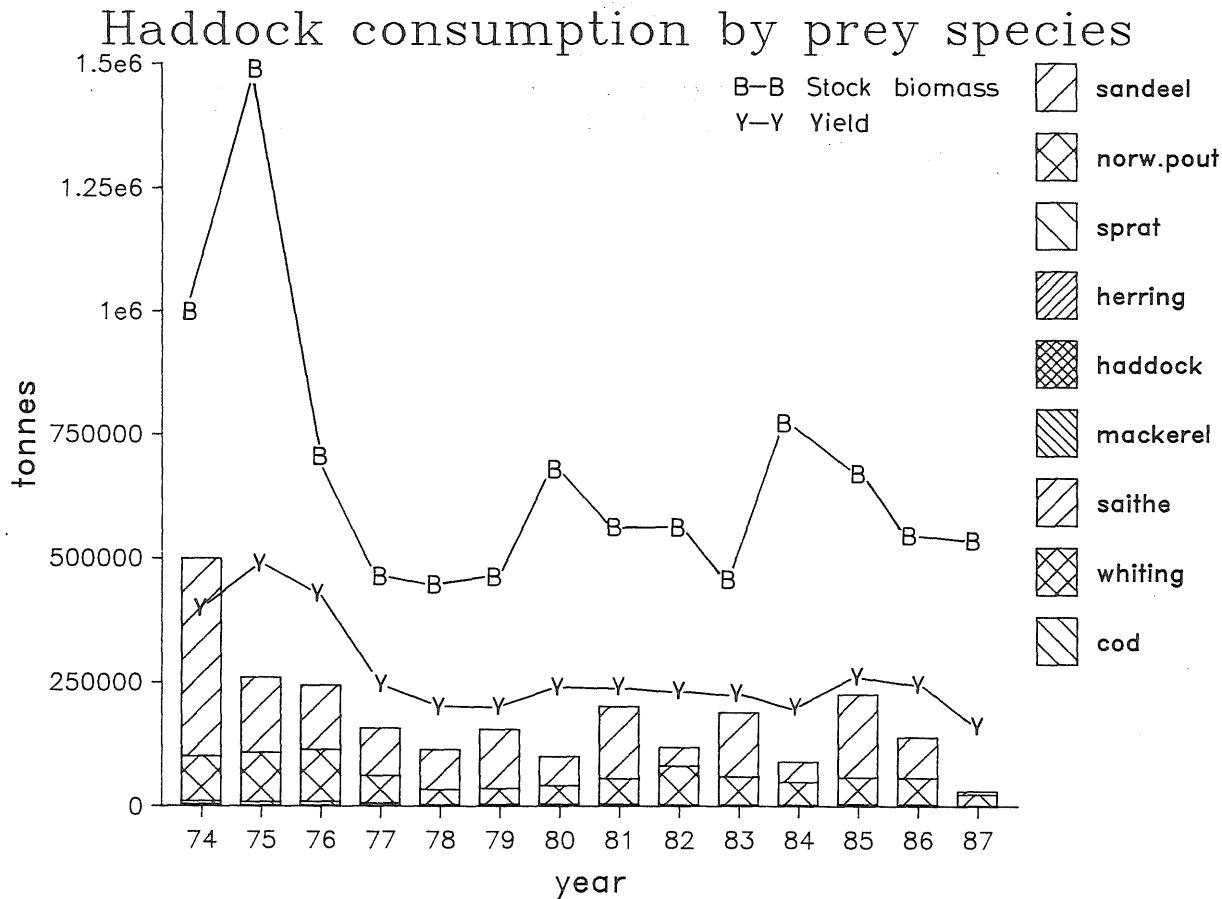


Figure 7.1.2e Consumption by predator species of prey species.

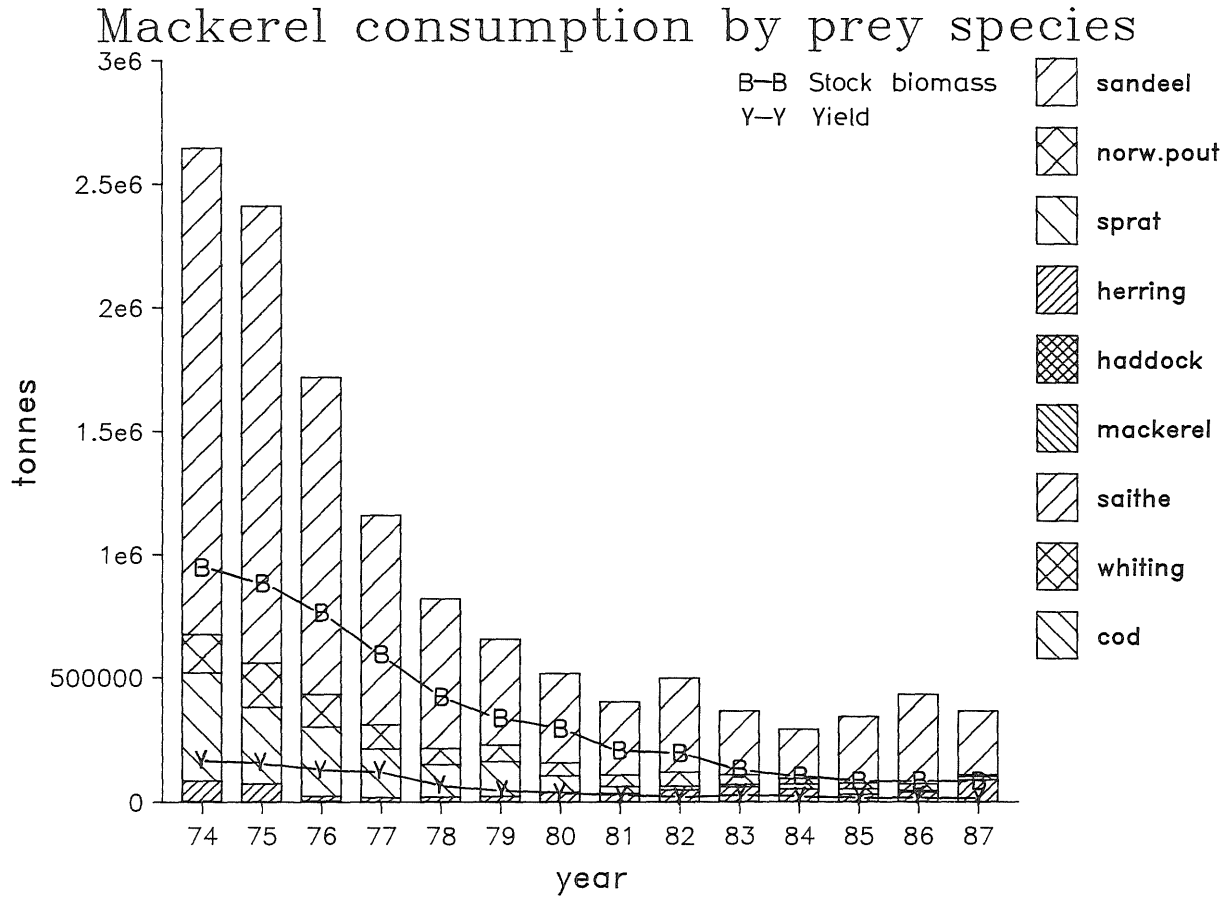


Figure 8.5.1 Relationship between average F for cod and haddock.

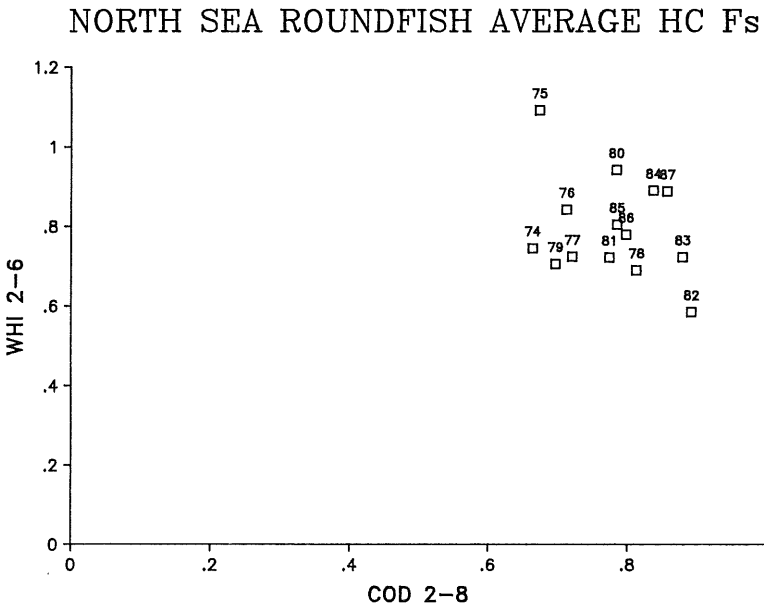
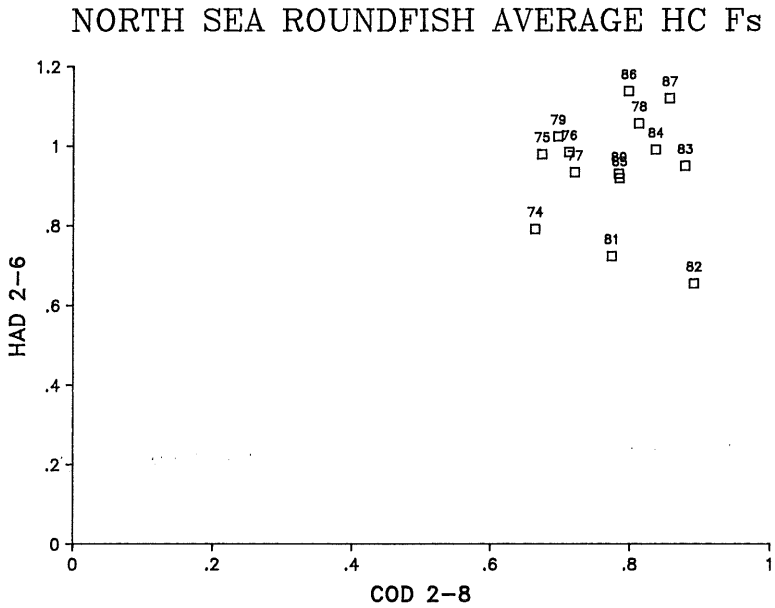
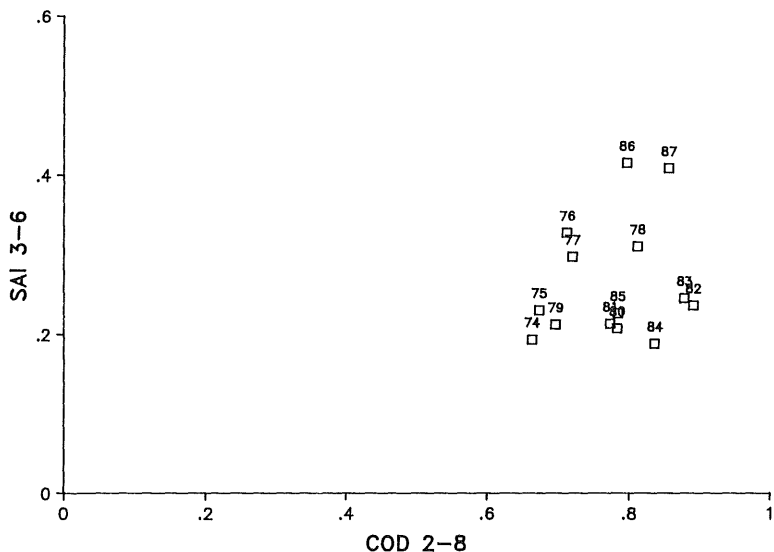


Figure 8.5.2 Relationship between average F for cod and whiting.

Figure 8.5.3 Relationship between average F for cod and saithe.

NORTH SEA ROUNDFISH AVERAGE HC F's



NORTH SEA ROUNDFISH AVERAGE HC F's

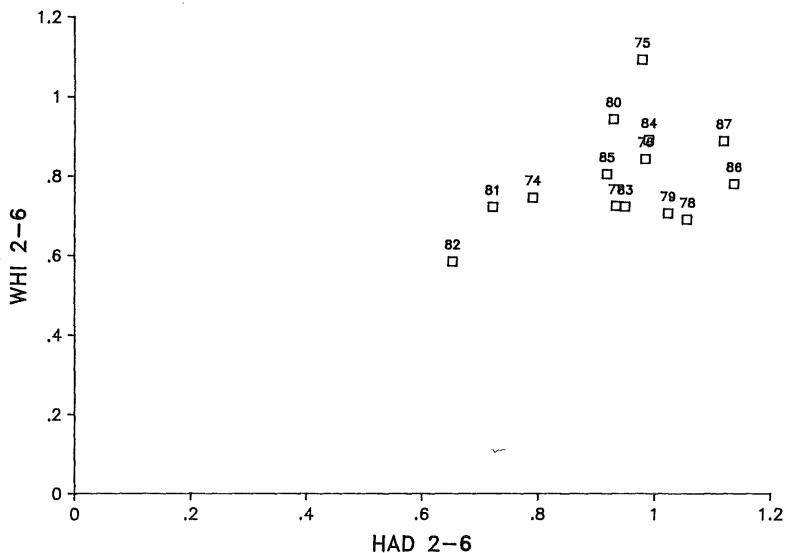


Figure 8.5.4 Relationship between average F for haddock and whiting.

Figure 8.5.5 Relationship between average F for haddock and saithe.

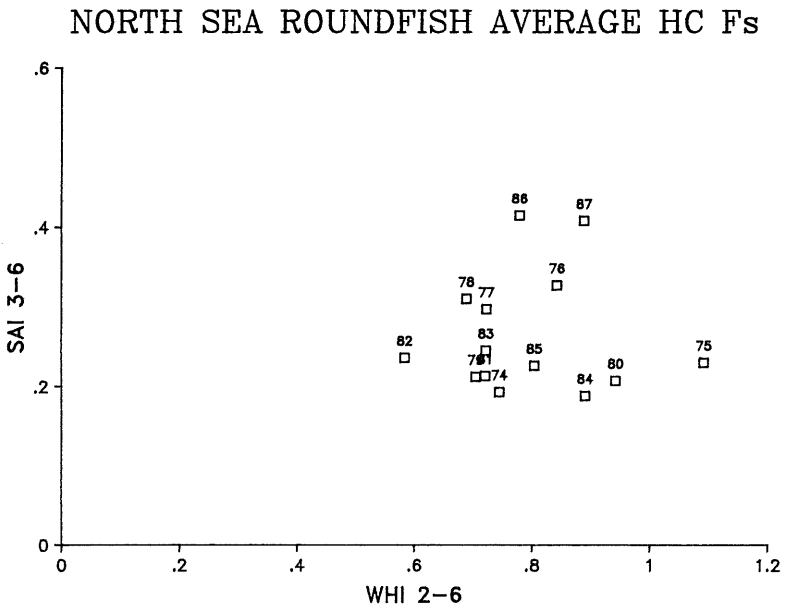
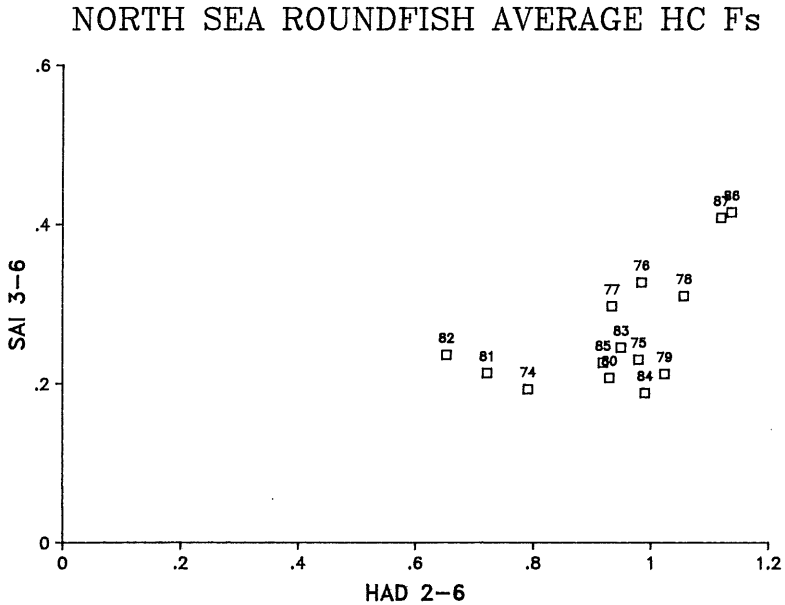


Figure 8.5.6 Relationship between average F for whiting and saithe.

NORTH SEA ROUNDFISH FISHERY

PCA of Average Fs in 1974-87

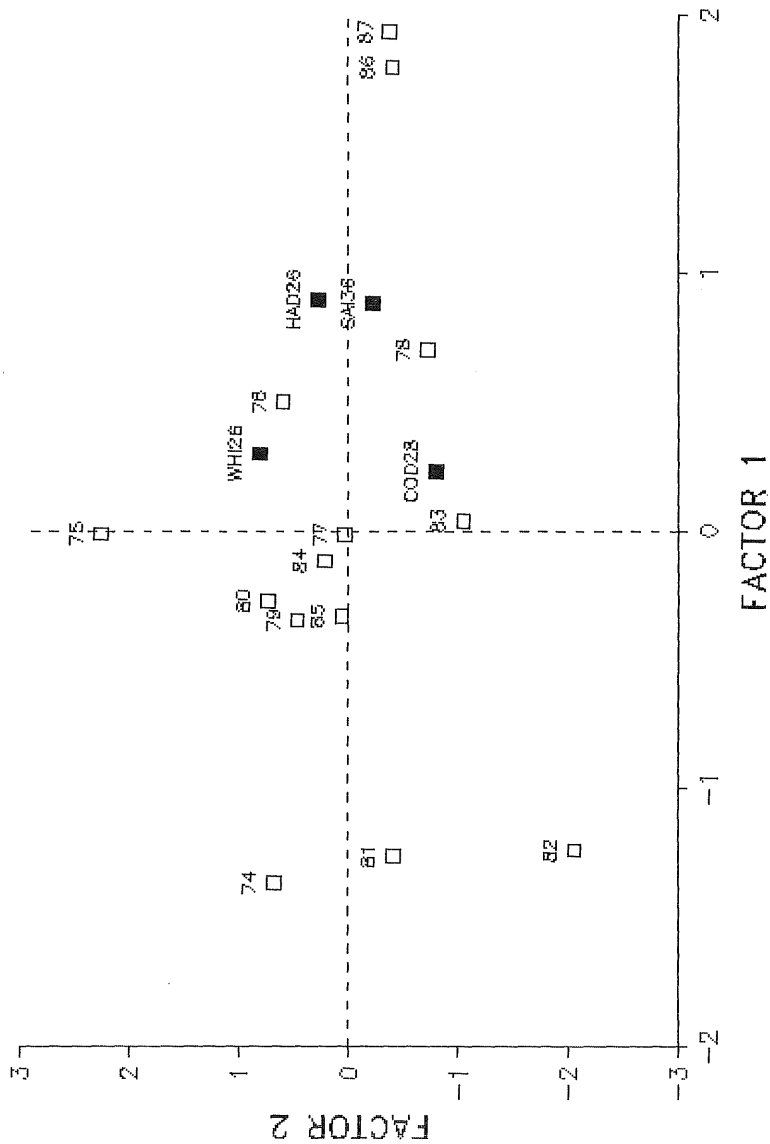


Figure 8.5.7

NORTH SEA FISHERIES IN 1985-87

PCA of Fs at Ages 0-5+ All Fleets

144

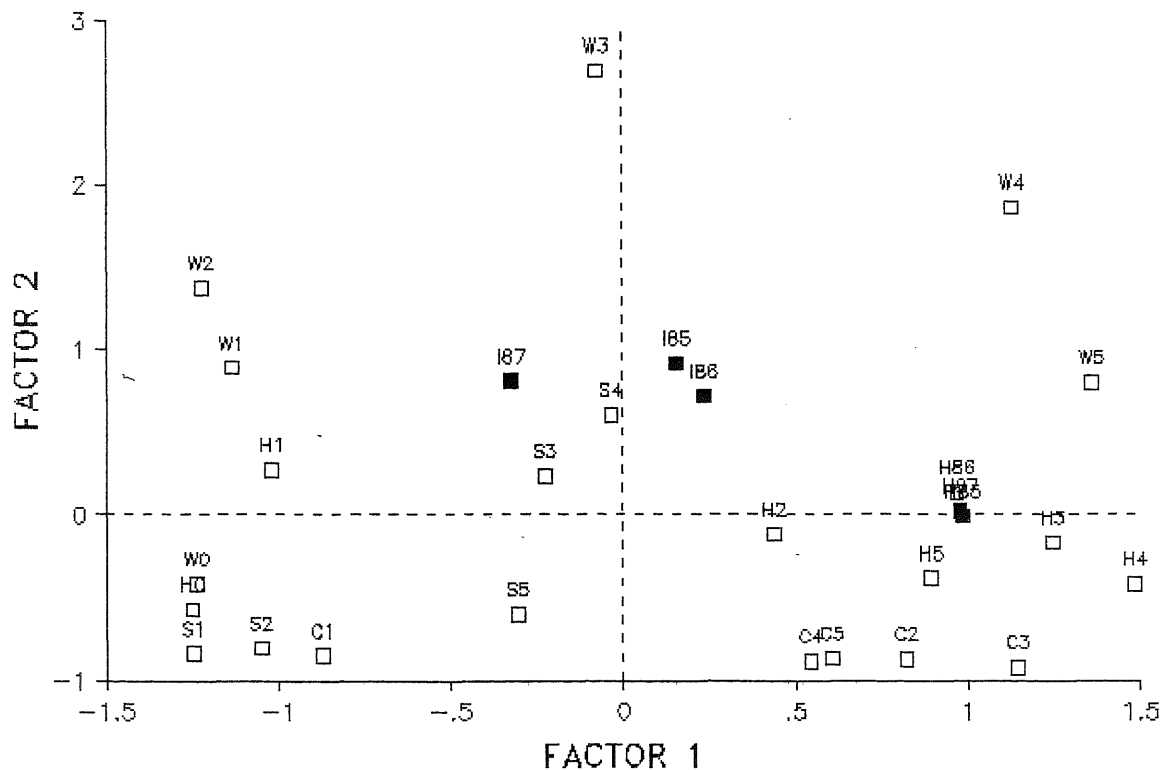
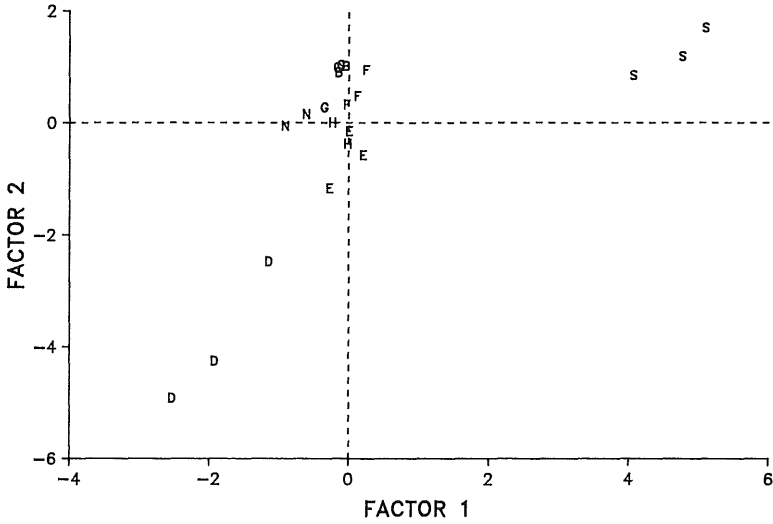


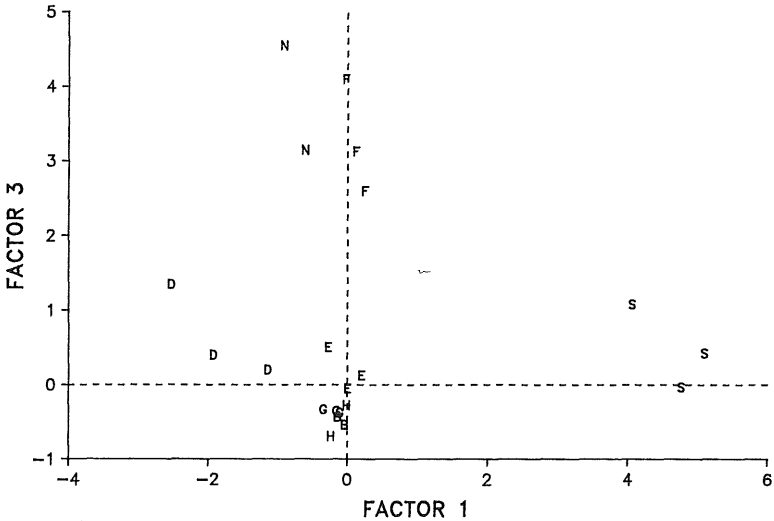
Figure 8.5.8

Figure 8.5.9

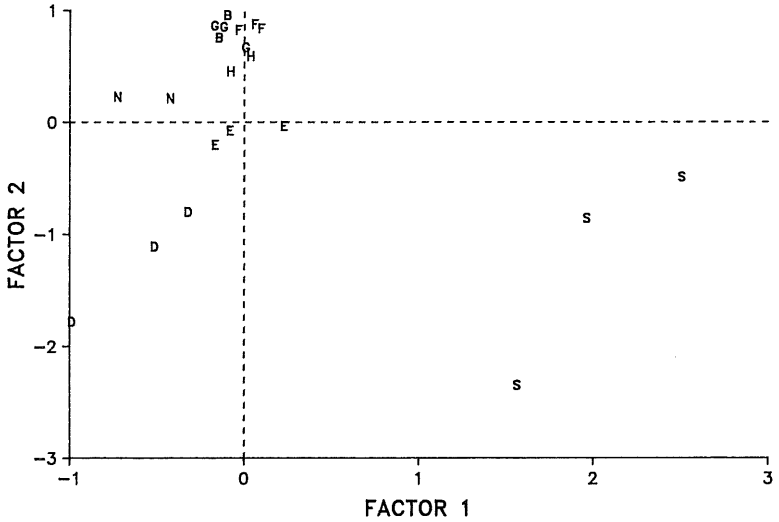
NORTH SEA HUMAN CONSUMPTION FISHERY 1st QUARTER



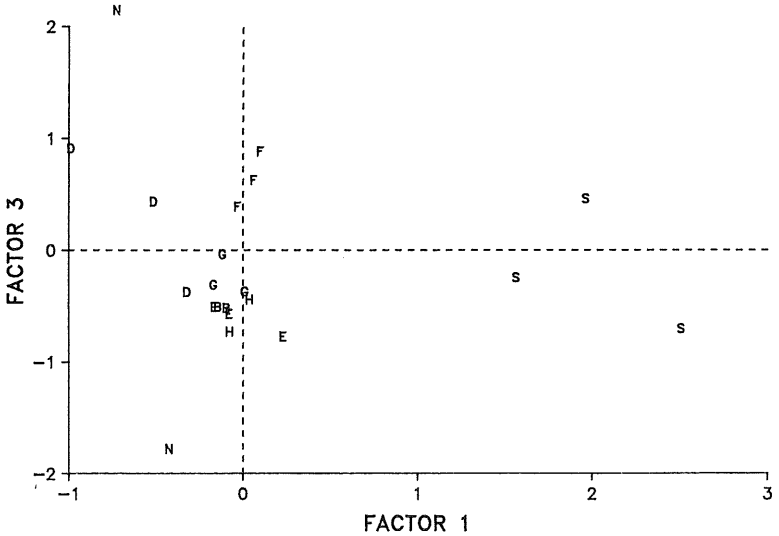
NORTH SEA HUMAN CONSUMPTION FISHERY 1st QUARTER



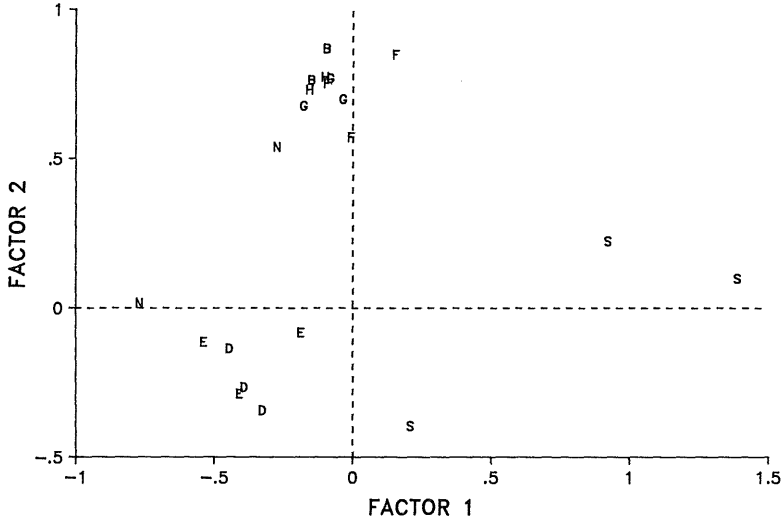
NORTH SEA HUMAN CONSUMPTION FISHERY 2nd QUARTER



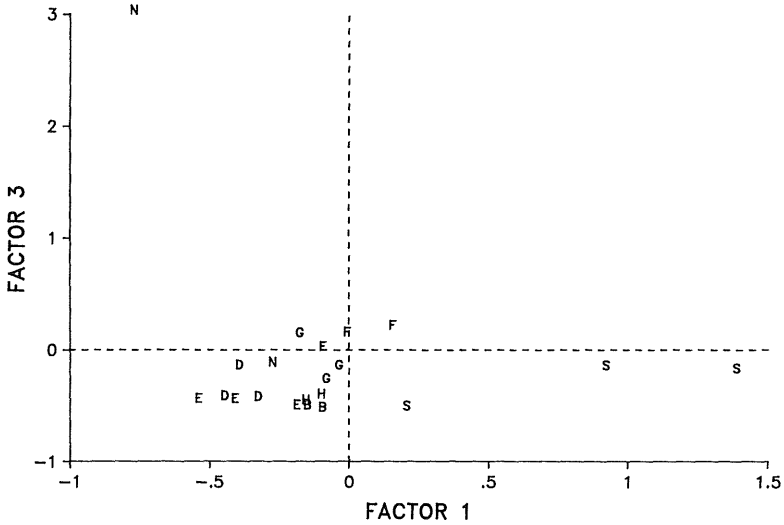
NORTH SEA HUMAN CONSUMPTION FISHERY 2nd QUARTER



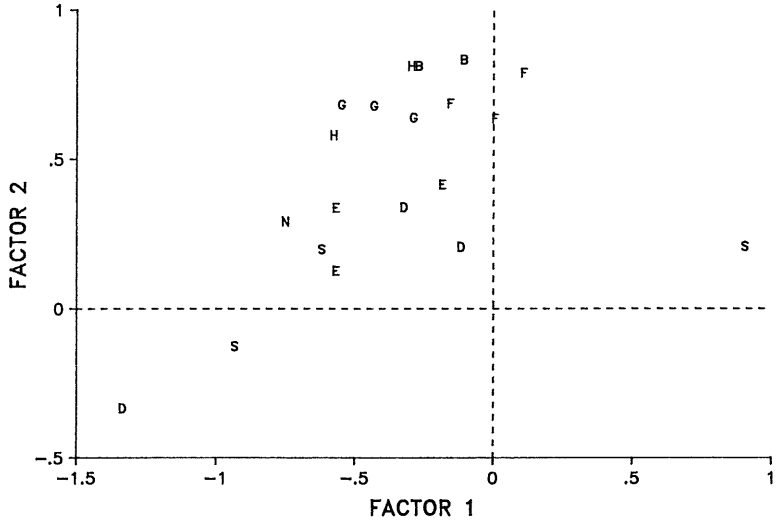
NORTH SEA HUMAN CONSUMPTION FISHERY 3rd QUARTER



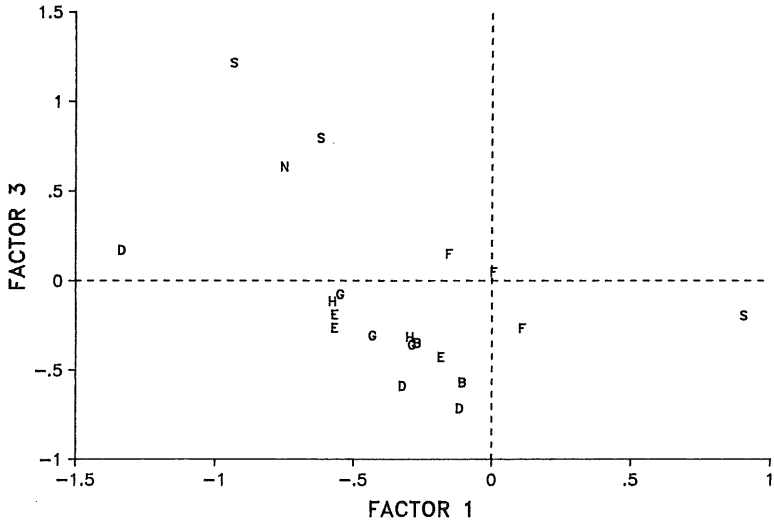
NORTH SEA HUMAN CONSUMPTION FISHERY 3rd QUARTER



NORTH SEA HUMAN CONSUMPTION FISHERY
4th QUARTER



NORTH SEA HUMAN CONSUMPTION FISHERY
4th QUARTER



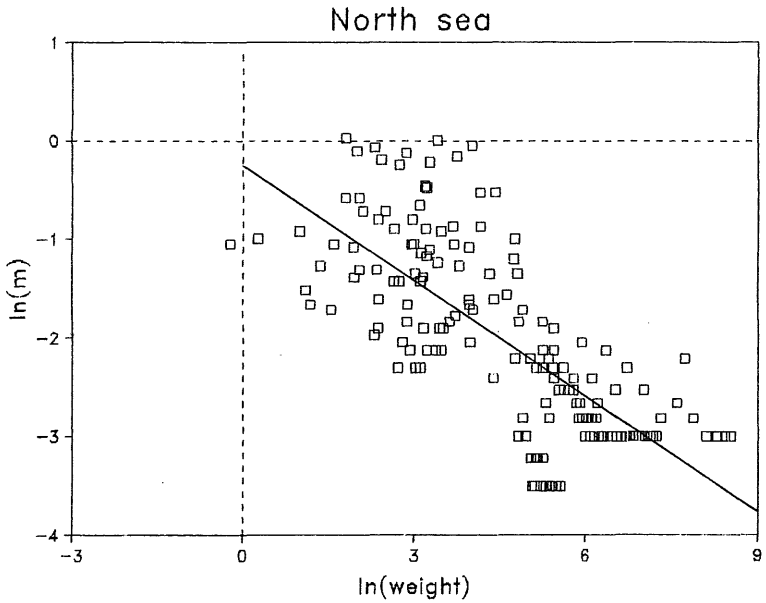
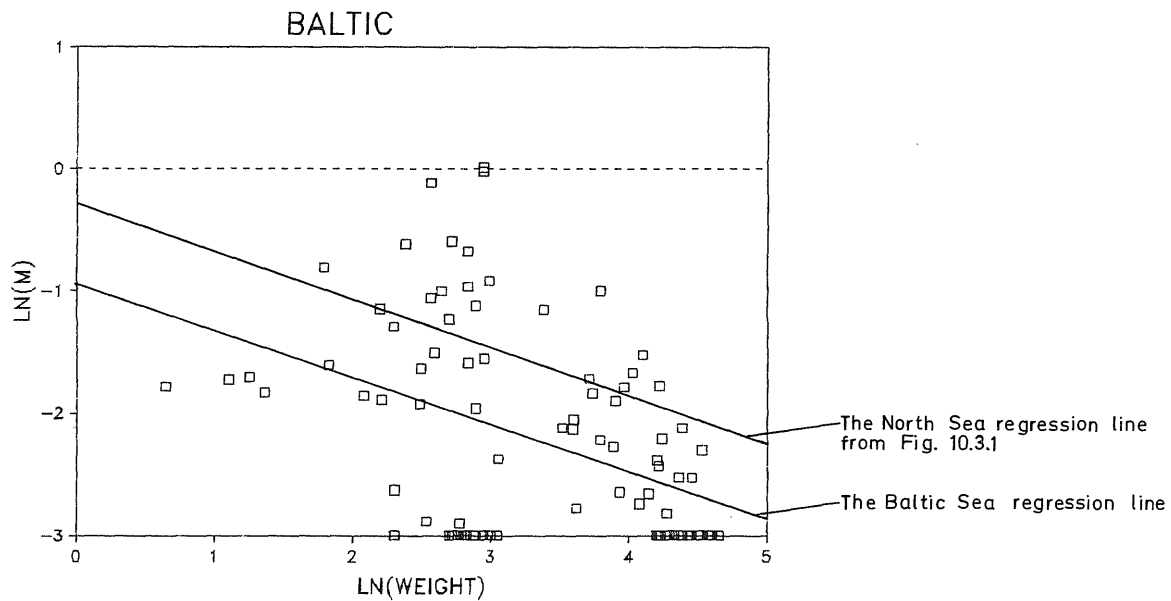


Figure 10.3.1 Natural logarithm (ln) of weight of the North Sea MSVPA prey plotted against ln quarterly natural mortality rate.
The regression:
 $\ln(M) = 0.268 - 0.386 \ln(\text{weight})$, $r = 0.72$,
 $p < 0.0001$.

Figure 10.3.2 Natural logarithm (ln) of weight of Central Baltic MSVPA prey plotted against ln quarterly natural mortality rate.
The regression:

$$\ln(M) = -0.964 - 0.367 \ln(\text{weight}), r = 0.45, p < 0.0001.$$



APPENDIX A

REQUEST BY ACFM TO THE MULTISPECIES ASSESSMENT WORKING GROUP

The Multispecies Assessment Working Group is requested to consider in detail the working paper by Lewy and Gislason, "Long term effects of minimum mesh size changes for North Sea roundfish species. Comparison of multispecies and single species approaches", presented at the 1988 meeting of the North Sea Roundfish Working Group, and to advise on the likely effects of mesh changes.

It would be particularly useful to be able to compare directly the effects as estimated by single-species and multispecies calculations. ACFM would find it interesting if the Working Group were able to provide a tabular presentation, along the lines of that attached, for the species included in the multispecies assessment.

If possible, the effect of simultaneous changes in fishing mortality should also be considered, but ACFM recognizes that this involves much more work, and that the presentation of the results would be more difficult.

Species = Cod

F { ~~Decreased~~
Constant
~~Increased~~

Mesh size

		Small (<70)	Medium (~90)	Large (>120)
Mean weight	SS	Low	Medium	High
	MS	Low	Medium	High
Total landings	SS	Low	Medium	High
	MS	Medium	Medium	Low
Discards	SS	High	Medium	Low
	MS	High	Medium	Low
Expl. biom. (CPUE)	SS	Low	Medium	High
	MS	Medium	Medium	Medium
SSB	SS	Low	Medium	High
	MS	Medium	Medium	Medium
Predictability of catches	SS	Poor	Medium	Good
	MS	Poor	Medium	Good
Stability of catches	SS	Low	Medium	High
	MS	Low	Medium	High

SS - as estimated by single-species model

MS - as estimated by multispecies model

APPENDIX B

3 COMMENTS TO WORKING GROUPS

3.1 Multispecies Assessment

ACFM notes with approval the continued effort of the Multispecies Working Group to refine its estimates of M, and the progress made towards evaluating the management consequences of its work. ACFM suggests that the Working Group takes note of the conclusions and recommendations of the EC Workshop on Technical Interactions in Mixed Fisheries (Nantes, March-April 1987) which refer, in part, to its work. ACFM also suggests that the Working Group consider a more detailed representation of the fisheries in the North Sea now that the methods to handle a larger number of fisheries are available.

ACFM found it difficult to understand the procedure by which the M1 values had been calculated, in particular the "smoothing" by eye. The results appear to contain some discrepancies (notably the reductions in M1 on the O-group for sprat, sandeel, and Norway pout). The Working Group is asked to review its methods for this analysis.

ACFM also noted the discussion by the Herring South of 62°N Working Group on the applicability of North Sea values of M to other areas. Whilst the precise values obtained in the North Sea would not be expected to be valid elsewhere, the conventional constant values do look unfashionably small. Recognizing that there may be no great need to revise M values elsewhere, ACFM, nevertheless, asks the Working Group to consider if a simple generalization of its results (e.g., M values based on size at age) could be derived for provisional application elsewhere, when required.

ACFM also noted that most of the discrepancy between the different methods of long-term assessment may be due to non-comparable assumptions about recruitment and, therefore, would not be worried. The peculiar herring/haddock sensitivity of the MSVPA-based method, however, obviously requires further investigation.

In responding to the Working Group's request for more specific guidance on the questions relating to long-term management to which answers would be of interest, ACFM proposes the following prototype questions:

- 1) What would be the effect of substantial changes in the level of:
 - a) industrial fishing leading to by-catches of haddock and whiting,
 - b) industrial fishing for sandeels,
 - c) all industrial fishing?
- 2) What would be the effect of substantial changes in the level of exploitation of:

- a) cod,
- b) whiting?

(Would stock collapses be expected? At what level of F would maximum cod yield be obtained?)

- 3) What would be the effects of:
 - a) recovery of the mackerel stock,
 - b) a major decline of the herring stock?
- 4) Advise whether there are management strategies which would increase the total yield (measured in cod equivalents or some other value-adjusted aggregate measure) of the North Sea system.
- 5) Is the rebuilding of the cod spawning stock to 250,000 t a feasible objective and, if so, what measures (including changes in exploitation pattern) would be necessary to achieve it and what would be the side effects for other stocks and fisheries?
- 6) Consider whether the effects of closed areas can be evaluated with present models and, if not, what developments of them would be required.