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PART 1

REPORT OF THE MULTISPECIES ASSESSMENT WORKING GROUP

Copenhagen, 7-16 June 1989

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1 INTRODUCTION

1.1 Participants

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ICES Statistician, Dr. R. Grainger, attended the meeting part time.

1.2 Terms of Reference

The terms of reference (C.Res.1988/2:4:25) are:

- a)
 - i) continue the development of multispecies methods of assessment;
 - ii) consider the report of the EC Workshop on Assessment of Technical Interactions in Mixed Fisheries and its implications for future work;
 - iii) evaluate the possibility of a simple generalization of the MSVPA estimates of M for the North Sea stocks for application in other areas;
 - iv) consider multispecies interactions with marine mammals and seabirds;
 - v) consider the implications on long-term yield, spawning stock biomass, and value of the development of a cod fishery based on a 120-mm minimum mesh size;
 - vi) advise on changes in yield, spawning stock biomass and value consequent upon changes in selection patterns.
- b) hold a special meeting in Bergen for 6 days in February 1990 to review progress in modelling multispecies interaction in boreal systems.

1.3 Overview

Progressive refinement of the Multispecies Virtual Population Analysis (MSVPA) approach has occurred in meetings of the Multispecies Working Group (Anon., 1984, 1986, 1987, 1988a). Feeding data originally collected during the synoptic 1981 "Year of the Stomach" program in the North Sea have been supplemented by considerable additional sampling of cod, whiting, and saithe

stomachs in the first and third quarters of 1985, 1986, and 1987 (Anon., 1988a, Table 2.3.1). The inclusion of these new feeding data has significantly strengthened the Working Group's conclusion that the suitability of particular prey for a predator is approximately stable. This assumption, which was evaluated again during the current Working Group meeting, is critical to the medium and long-term evaluation of fishery management scenarios as influenced by predator-prey effects.

The Working Group meeting of 1988 provided initial analysis of various combinations of management options for six nominal fleets operating in the North Sea. In particular, the multispecies effects of increasing the minimum mesh size in the roundfish human consumption fishery to 120 mm was contrasted with similar analyses (Anon., 1988b; Lewy and Gislason, 1988; Anon., 1988a). Preliminary comparisons between single and multispecies results had indicated opposite directionality in aggregate yields and value (in European Currency Units, ECUs) between the two models, as a result of mesh increases in the nominal roundfish - human consumption fishery.

The current meeting had as its main terms of reference to conduct extended analyses of the effects of mesh change under more realistic definitions of the fleets likely to adopt a 120 mm mesh when fishing for cod in the North Sea. Currently, the spawning stock biomass of cod is near record low levels (Anon., 1989a). A decrease in the fishing mortality rates on age 1 and age 2 cod (through the adoption of 120 mm mesh) would, in both single species and multispecies scenarios, result in long-term increases in cod spawning stock biomass. The effects on other stock attributes for cod (catch, value, mean catch weights, predation mortality at age), as well as the other eight species included in the analysis were, in previous analyses, significantly different from the single - versus multispecies perspectives.

Section 2 of this report details the updated retrospective analysis of the multispecies system through MSVPA. Catch-at-age information through 1988 were available either from working groups meeting prior to the Multispecies Working Group in 1989, or through correspondence with appropriate working group chairmen. Updating of the MSVPA to account for 1988 catches was deemed important to allow for convergence in the model with respect to the last year of explicit feeding data (1987). However, due to the preliminary nature of the tuning procedures and recruitment estimates used for certain species (i.e., roundfish) we chose not to include 1988 in the MSVPA results, but instead used 1988 as the first year for prediction of medium-term effects (Section 4).

Updated feeding information for whiting in 1985 and 1986 was available and incorporated into MSVPA data files. Consumption rate data for mackerel were re-evaluated considering the large increase in such values between 1986 and earlier years. Refined procedures to account for the relation between temperature and digestion rates were applied and yielded essentially the same results included since 1986. Thus, the mackerel consumption estimates were not changed. Results from the "Key Run" are summarized and contrasted with those from the previous year.

Section 3 of the report analyzes the long-term changes in expected yield, stock size, and fishery value, contingent on adoption of the 120 mm mesh for the "cod fishery". In the absence

of an explicit definition of rules for the implementation of such a measure, an operational but far from satisfactory definition of the "cod fishery" was taken as the proportion of a nation's catch comprised of cod, saithe, and plaice, divided by the catch of those species, in addition to haddock and whiting. Presumably, this calculation is proportional to the fraction of national fleets converting to the larger mesh. A weighted proportion over nine national fleets projects that roughly 2/3 of the aggregate roundfish human consumption fishery would convert to such a standard. Thus, two roundfish human consumption fleets were analyzed. Discards from the two were calculated separately as catches accumulating no landed value. Relative values among the various species/age groups were calculated based on EC "reference" or guide prices applicable for 1989. Effects of the 120 mm mesh fishery on yields, biomasses, predation and value by species, and aggregate catches and values by fishery were assessed, relative to the "baseline" of the roundfish human consumption fishery based on an 85 mm minimum mesh size. We also explored the relative effects of several scenarios in combination with or instead of the 120 mm mesh cod fishery. However, these additional model runs should in no way be considered to advocate any particular policy or as definitive, since the number of possible policy combinations is virtually infinite.

The Working Group concluded in 1988 that biological interactions within the system may have proportionally little influence on short-term (1-3 year) advice. This conclusion is seen as contingent on further evaluation, particularly since predator-prey effects for 0-groups as predators are not treated in detail within MSVPA. Section 4 of the report presents forecasts in the "medium-term"; that being over a 9-year period from the beginning of the prediction. In particular, the Working Group was interested in the transition effects from short-term to long-term forecasts, and the degree of variability in the medium-term projections that can be expected. The degree of inherent "noise" in the system due to recruitment variability will necessarily affect our interpretation of effects induced by shifting exploitation patterns, etc. for the various species and fleets. Both stochastic and constant recruitment versions of the medium-term forecasts are presented, in relation to the "baseline" exploitation patterns for roundfish, and the inclusion of a 120 mm mesh scenario when fishing for cod.

Section 5 of the report summarizes feeding data collected through 1987, and considers in a preliminary fashion two meetings held earlier in 1989. The first of these meetings concerned the evaluation of stomach evacuation studies (Anon., 1989b). The second was a planning meeting for a reprise in 1991 of the coordinated stomach sampling project last conducted in 1981 (Anon., 1989c). Results of both meetings have important implications for studies conducted by the Multispecies Working Group, and the veracity of long-term advice contingent on such studies.

Testing of the assumptions of the MSVPA has occupied much of the Working Group's previous work, and, in particular, the assumption of constant suitability of prey species to particular predators. Considerable progress in evaluating this assumption has been made in previous meetings, in special studies conducted between meetings, and at the current session. Statistical analyses of raw and smoothed suitability estimates again confirm their general stability over time. The effects on variation in suitability

estimates of the addition of more years of feeding data, and the comparison of observed and predicted food composition are examined in detail. Improvements in the ability to predict food composition with additional feeding data are an important finding relative to future stomach collection studies.

Feeding interrelationships as evaluated in MSVPA are summarized in Section 7. We have compared these results with those presented in 1988, since there is an additional year of catch-at-age information and more feeding data on whiting.

Section 8 has traditionally been the place, in which various new ideas and approaches are treated as speculative rather than definitive. It is hoped that ideas advanced therein will encourage further work and serve as a basis for integrating a wider range of ecological and fisheries information into these analysis.

A quadratic (Shaeffer) model for predicting multispecies/multi-fleet effects on aggregate yields and values is developed as a simplified approach to evaluating effects of changes in effort and selection pattern among fisheries. The model may have particular value in allowing a wide range of scientists and others to explore model results under various management scenarios, although by its nature the quadratic surfaces may lead to invalid results if major changes in fisheries are simulated. Multispecies analogs to single-species bioeconomic reference points for fishery management are discussed in light of projected system responses to effort changes in the various fleets.

A systematic approach to the evaluation of changes in age-specific selection on aggregate yields and stock sizes is developed and explored as a general method to assess questions such as those investigated in Sections 3 and 4.

The Working Group considered in detail the technical feasibility and necessity for including additional predator biomasses in MSVPA, without necessarily simultaneously estimating population sizes of these predator stocks. In particular, inclusion of predation effects due to western mackerel, horse mackerel, skates, marine mammals, and sea birds could theoretically be included through such an interface with the current MSVPA and MSFOR programs.

Current fleet definitions used for fishery projections are inadequate for all but rudimentary projections of the balance of yield and value changes in relation to management. Such was the case in defining the "cod fishery". Evaluation of increasingly sophisticated policy questions is contingent on more precise fleet definitions. Such information will in the future be forthcoming from the STCF Working Group on Improvements of the Exploitation Pattern of North Sea Fish Stocks (Anon., 1989d).

The Working Group also considered again the potential effects on results of various functional feeding relationships among the predators and prey. In particular, work on the validation of functional predator-prey responses independent of MSVPA was considered important.

Section 9 of the report elaborates on the interpretation of ecological processes as re-constructed in MSVPA and simulated in

MSFOR. In particular, the changes in aggregate multispecies size composition of the ecosystem (numbers and weight) were considered in relation to harvesting and predation as size-dependent processes. Effects of harvesting on the stable size compositions were considered in this context.

For a subset of species, attempts were made to extend the MSVPA back in time earlier than that covered for the standard runs (1974-1988). Changes in the fishery ecosystem during earlier periods are re-interpreted in light of these results.

Section 10 of the report considers multispecies analyses in regions outside the North Sea. As has been previously emphasized, the Multispecies Working Group is not the North Sea Multispecies Working Group, but is concerned with the wider interpretation of integrated analyses of biological and technological interactions. The proposal for a separate meeting of the Working Group to consider specifically boreal systems was discussed, in the context of future Working Group projects. The Working Group also reviewed predator/prey systems in the western North Atlantic, and commented on the applicability of general conclusions of MSVPA results for the North Sea to other areas.

1.4 Acknowledgements

Analyses conducted by the Working Group were greatly facilitated by the cooperation of a number of groups and individuals, and in particular the following:

- 1) The ICES Secretariat,
- 2) The assessment working groups and individual scientists providing appropriately disaggregated data and analyses, and especially:
 - a) Chairman of the Roundfish Working Group for supplying preliminary 1988 quarterly catch-at-age data, as well as working definitions of fleet characteristics resulting from potential mesh changes,
 - b) Chairman of the Mackerel Working Group and colleagues for providing updated information on the occurrence of the western mackerel stock in the North Sea,
- 3) coordinators of the 1981 ICES Stomach Sampling Project and their associates,
- 4) authors of the various working papers and computer programs submitted to the Working Group,

The Working Group further noted the importance of being able to utilize the ICES NORD computer system and linked microcomputers for various model runs and statistical analyses. Cooperation of the computer staff of the Secretariat is gratefully acknowledged. Likewise, the efforts of the Danish members of the Working Group in implementing and testing MSVPA software on the ICES computer system prior to the meeting were critical to the completion of its work. Given the demand placed on the Secretariat computer facilities and staff, and the need for even faster computing capabilities for some anticipated analyses, the Working Group

considered potential changes in the meeting venue to other more suitable facilities (see Section 11).

2 TEST RUNS WITH MSVPA

2.1 The MSVPA and MSFOR Programs

Except for minor modifications, the MSVPA and MSFOR programs used were identical to the programs used at the last meeting.

The minor modifications are:

MSVPA:

- The mean F is now calculated as an unweighted average over a user-specified range of ages.
- The total amount of other food eaten by the MSVPA predators is printed.
- Improved possibilities for comparing the estimated and the observed food composition have been provided in the case where the suitability are estimated on a restricted set of stomach content data.

MSFOR:

- The weight at age in the catch by species, quarter, and fleet may now be entered for predicting catch in tonnes. Among other things, this allows for using a discard "fleet" in the calculations.
- The value/kg at age by species and fleet may be entered for estimating the total value of the landings by fleet and species.

2.2 Catch Data

Herring

Catch-at-age data for 1988 were taken from Anon. (1988e, Table 2.10.1). Data for 1987 were not updated.

Cod, Haddock, and Whiting

Data for 1988 were supplied by the North Sea Roundfish Working Group. Data for 1987 were not updated.

Sandeel

Catch at age for 1988 and the revised age compositions of 1987 catches were taken from the 1989 Industrial Fisheries Assessment Working Group (Anon., 1989f). A thorough comparison of catch-at-age data in the single-species and MSVPA data bases was made and several discrepancies were found. First, catches at age from the Shetland stock that were included in the MSVPA from 1974-1985 and left out thereafter, were added for the years 1986, 1987, and 1988. Also, inconsistencies detected in catches in number of age

group 0 in 1978 and age group 1 in 1985 were corrected accordingly.

Sprat

The last year covered in the VPA run by the Industrial Fisheries Working Group is 1984. Since 1985, no sufficient catch-at-age data are available (Anon., 1989f).

Catch-at-age data have, therefore, been simulated according to the following procedure:

1. Stock numbers at age of the last year in SSVPA (1984) were taken as a starting point.
2. Recruitment as 1-group of the 1985-1988 year classes was estimated using a regression of VPA stock number in age group 1 on recruitment index from IYFS (1 group/h in Division IVb; years included: 1979-1983).
3. The relative F pattern was chosen as the average pattern of the years 1979-1983 in SSVPA.
4. The F level was adjusted to meet the nominal catches.
5. In order to get a "more reasonable" stock size estimate for 1986, the numbers of 1-group sprat in 1985 were chosen to be 1/3 of the value predicted by the regression.
6. Simulated catch-at-age data and the corresponding F values were used as input values for the MSVPA key run.

Mackerel

For mackerel, no single-species VPA has been made since 1985 (Anon., 1989g). Estimated catches by age and quarter and spawning stock biomass were provided by the Mackerel Working Group. The SSB was converted to stock size in numbers by age, using the age composition from the 1988 egg survey (Iversen *et al.*, 1989), assuming the same mean weight as in 1985. Numbers for the juveniles were added in proportion to the 1985 data. Terminal Fs were computed from these data, and the created stock sizes were in good agreement with those of the 1985 VPA and subsequent egg survey estimates of the SSB.

Norway Pout

Quarterly catch-at-age data for Norway pout for 1987 and 1988 were taken from the 1989 report of the Industrial Fisheries Working Group (Anon., 1989f). A quarterly single-species VPA with a set of terminal fishing mortalities for 1987 and 1988 identical to the one used by the working group produced unrealistically high stock sizes in 1987 and 1988. The terminal fishing mortalities were, therefore, increased to a level which was supposed to give a trend in biomass more in accordance with the annual VPA of the working group. However, even with a very high value of terminal fishing mortality, a satisfactory agreement could not be obtained. The final MSVPA does, therefore, not show the same drop in stock size in recent years as the annual VPA of the Industrial Fisheries Working Group, but is more in line with the biomass estimates from the quarterly 'hand-tuned' VPA given

in Figure 4.4.3 of their 1989 report (Anon., 1989f).

The Working Group very much appreciated the efforts of the various single-species working groups in supplying quarterly-disaggregated catch data. In particular, such data for roundfish were supplied before this meeting, in a very timely fashion, by the Chairman of that Working Group. One source of problems for the Multispecies Working Group remains, however, in that quarterly estimated catches are rarely updated, even when final data become available for use by the single-species working groups. Accordingly, the Multispecies Working Group throws itself at the mercy of the other working groups, and pleades for revised quarterly catch-at-age data, if such revisions are warranted.

2.3 Relative Food Composition Data

Revised whiting stomach content data had been made available for 1985 and 1986 before the meeting and the input file was updated accordingly. Other than these changes, food composition data were similar to those used last year (Anon., 1988a).

2.4 Estimates of Rations Used in MSVPA Runs

The new quarterly consumption rates and A values calculated for mackerel during the 1986 meeting resulted in surprisingly high annual rations compared to previous estimates and to the results for the other species.

The conversion of the quarterly consumption rates, applying the same temperature relation for the digestion coefficients as for the other species, was revised using a slightly refined procedure. The results, however, were close to those obtained in 1986 and no changes in the A values were made.

The mackerel feeding experiments were conducted at a temperature about 5-10 degrees above the mean temperature in the North Sea. It is questionable to extrapolate the evacuation rate over this wide temperature range. Moreover, these experiments were done with euphausiids only as prey, and it is also questionable whether this evacuation rate also applies to fish prey. On the other hand, since mackerel is an active swimmer, it is reasonable to assume a somewhat higher consumption rate than in the other species. This is further confirmed by Danish *in situ* measurements of the mackerel's consumption rate (Dahl, 1988), and the mackerel analyzed here were feeding mainly on fish prey.

2.5 M1 Values used in the Runs

Values of the natural mortality rates due to sources other than predation by MSVPA species (M1) used in the 1989 'key run' were similar to those used in 1988 (Anon. 1988a). It has been recognized in earlier meetings of the ICES Multispecies Working Group (e.g., Anon., 1988a) that several other stocks, including skates, horse mackerel, and the western stock of mackerel exert potentially significant but variable rates of predation mortality on MSVPA species considered in the model. The estimation of the predation effects of these stocks was not sufficiently resolved for inclusion in MSVPA runs at this meeting, nor was there

necessarily a convenient way to include predation mortality induced by 'other' predators in the current MSVPA formulation. These and other issues are considered in more detail in Section 8.4.

2.6 Feeding Relationships Used in the Runs

As in previous meetings, the Helgason-Gislason feeding relationship (i.e., assuming the biomass of other food to be constant) was used. Because of the consequences of the choice of the functional feeding relationship for predation mortality rates, there was considerable discussion of the implications of feeding models and appropriate methods for field-testing of various hypotheses (Section 8.5). These issues will be considered in detail at the upcoming ICES Multispecies Symposium.

2.7 Weights at Age Used

Three sets of weight-at-age data are used in the current implementation of MSVPA (Anon., 1988a):

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

Weights at age in the stomachs are derived by applying appropriate ALKs to reconstructed length frequencies of prey in stomachs. In theory, this is an appropriate procedure. However, as indicated in Section 6.11.3, in practice there may be some inadequacies in the ALKs employed. These and other issues concerning sampling adequacy will be addressed prior to the conduct of the 1991 intensive stomach sampling program (Section 5.3).

2.8 The Key Run of the MSVPA

A 'key run' of the MSVPA was identified as corresponding to the base conditions for MSVPA. The key run assumed:

- 1) The Helgason-Gislason feeding relationship;
- 2) consumption rations as used in the previous year (Anon., 1988a);
- 3) all stomach data currently available, including revised whiting data for 1985 and 1986;
- 4) the three sets of weights at age (in the sea, in the catch, in the stomachs);
- 5) quarterly catch-at-age data as supplied by the single-species working groups, or estimated from historical splits of annual data;

- 6) terminal F values selected, where possible, to be equivalent to those from single-species working groups.

Listings of input data and resulting complete outputs are available at ICES Headquarters.

Terminal fishing mortalities

Herring

Fishing mortalities for the fourth quarter for the older age groups in each year and of catch age groups in the terminal year were chosen in such a way in the single-species VPA mode of the MSVPA as to create identical stock numbers at age to the ones obtained by the Herring Assessment Working Group for the Area South of 62°N (Anon., 1989e). The only exception was for the stock numbers of the plus group which differed due to the difference in the treatment of this group between the MSVPA model (in single-species VPA mode) and ICES standard programs.

Cod and Haddock

Tuned VPAs for both cod and haddock including 1988 catch data were supplied by the Chairman of the Roundfish Working Group.

The same procedure as for herring was adopted for cod and haddock for choosing terminal Fs.

Saithe and Whiting

Terminal Fs from the 1988 Roundfish Working Group Report (Anon., 1988b) were used as terminal F values in updated single-species VPAs which included 1988 catch-at-age data. These values were then modified to produce mean Fs, recruitment levels, and exploitation patterns which were as consistent as possible with those produced by the 1988 Roundfish Working Group (Anon., 1988b) without producing nonsensical terminal F values. Quarterly terminal F values were then estimated in the same manner as for herring.

Sandeel

The same procedure as used for herring was adopted for sandeel. Computation procedures for terminal Fs on sprat and Norway pout are described in Section 2.2.

Tables 2.8.1a-i show the MSVPA results for the individual species included in the model (cod, haddock, whiting, saithe, mackerel, herring, sandeel, Norway pout, and sprat). The tables give biomass totals, stock size in numbers, and the coefficients of fishing and predation mortality (attributable in the latter case to the M2 predators (cod, haddock, whiting, saithe, and mackerel). Mean values of stock in number, fishing mortality and the various components of natural mortality (M2 predators, "other predators" and residual) are given in Tables 2.8.2a-d for the period 1981-1986.

The MSVPA fishing mortalities for cod, haddock, whiting, and saithe (with 1988 as the terminal year) are, in general, of the same order as those presented in the 1988 Roundfish Working Group report (Anon., 1988b) which have 1987 as the terminal year.

However, comparisons are hindered by the fact that revisions in the catch-at-age data, which take place in the Roundfish Working Group when catch data are finalized, are not passed on in quarterly form for inclusion in the MSVPA catch-at-age data base.

The MSVPA and single-species VPA fishing mortalities are in reasonable agreement for North Sea herring (see Anon., 1989e) but no direct comparisons can be made for North Sea mackerel, sprat, or sandeel. For the first two of these species, VPAs are not performed by the respective working groups, and in the case of sandeels, single-species VPAs are performed on multiple stocks leading to difficulties in establishing overall values of fishing mortality. MSVPA fishing mortalities on Norway pout are, in general, much higher than the single-species VPA values (Anon., 1989 b).

Figures 2.8.2a-f show total and spawning biomass totals from MSVPA and the equivalent single-species working group totals (Anon., 1988b for cod, haddock, and whiting; Anon., 1989e for herring; Anon., 1989f for Norway pout). A single-species VPA run at the Multispecies Working Group on aggregate North Sea sandeel catch-at-age data is shown with 1989 MSVPA estimates.

For cod, haddock, whiting, and herring the differences apparent in biomass estimates between multispecies and single-species VPA appear to be due mainly to differences in weight at age and maturity ogives. Differences in the sandeel biomass totals were considered last year to be due to the MSVPA producing variable natural mortality rates among years whilst the single-species assessment used rates constant among years. This difference still exists. Trends in the biomass totals for Norway pout show major differences in recent years from the single-species assessment suggesting a recent decline in the stock (Anon., 1989f). The more stable Norway pout biomass totals, shown by the multispecies assessment, are more akin to the results of a quarterly single-species VPA run by the Industrial Fisheries Working Group, but not adopted in its report (see Figure 4.4.3 of Anon., 1989f).

The means of the ratio between number at age from MSVPA and single-species Working group estimates for the years 1981-1986 are shown in Table 2.8.3 for cod, haddock, whiting, saithe, and herring. In general, there is good agreement. For saithe, the ratio should be 1.0 for all ages because no predation mortality is assumed in the MSVPA. The fact that it does not equal 1.0 is due to differences in terminal F at age, the inclusion of 1988 catch-at-age data in the MSVPA, and revisions of the single-species catch-at-age data which have not been transmitted to the Multispecies Working Group.

Table 2.8.4 shows the values of natural mortality most recently adopted by the single-species working groups compared to the mean rate, 1981-1986, from the MSVPA key run. With the exception of 0-group cod and haddock and 1-group Norway pout, the values are quite consistent between the two approaches reflecting the adoption by single-species working groups of natural mortality rates at age from MSVPA.

3 LONG-TERM PREDICTIONS

3.1 Introduction

Work presented by Lewy and Gislason (1988), and subsequent research conducted by the Multispecies Working Group last year (Anon. 1988a) illustrated that when predator/prey considerations were taken into account, the net effects of implementing larger mesh sizes in roundfish fisheries were decreases in landings of some key species (e.g., cod). This finding is of course at odds with traditional single-species results for species, such as cod, that are currently fished at levels substantially in excess of F_{max} . Last year's research assumed a uniform application of larger mesh sizes across all roundfish fisheries. Given that, we may be interested in improving the exploitation on individual species, such as cod, while maintaining the current pattern on others. ACFM established a term of reference for the Multispecies Working Group to 'consider the implications on long-term yield, spawning stock biomass, and value of the development of a cod fishery based on a 120 mm minimum mesh size'. In this section we develop a working definition of the fleet likely to adopt the 120 mm mesh (i.e., targeting cod), and perform a variety of long-term simulations to evaluate the impact of such a fishery.

3.2 Description of Forecast Approach

The MSFOR program performs a long-term prediction of the catch and value of landings by fleet and species as well as the total biomass and SSB of individual species. It contains options for predicting both in single species and multispecies mode and for using constant and stochastic recruitment.

The input for the prediction is taken from the MSVPA and may be modified through a number of user specified options. The weights at age, $M1$ values, predation parameters, total food intake at age and stock size at age at the beginning of the first prediction year are taken from files produced by the MSVPA. In the single species case, this input must come from a single species run of the MSVPA. The quarterly fishing mortalities estimated by the MSVPA may be averaged over a period of time and used for the prediction after they have been multiplied by various factors in order to modify the level of fishing mortality, the fleet effort, the selection pattern of the fleet, etc.

If constant recruitment is chosen, the program estimates an average recruitment at age 0 (beginning of third quarter) over a user specified period of time from the recruitment estimates made by the MSVPA. The predictions are then carried forward until the maximum relative difference between any stock number at age is less than 0.01% in two consecutive years.

If stochastic recruitment is chosen, the mean and the variance of the recruitment to each stock is estimated and used to generate a lognormal distribution from which the year-class strength is drawn at random. Various output is generated by the program. Apart from the standard tables of catch by species and fleet, the stochastic mode provides estimates of the coefficient of variation and plots of the expected distribution of catch, total biomass and SSB.

The equations behind the MSFOR program are given in Gislason and Sparre (1987).

3.3 Parameterization of Models

The input to the MSFOR in terms of stock weight at age, M1, etc. is the same as to the MSVPA. Recruitment (1 July, 0-group) was assumed either to be constant at the arithmetic mean (1974-1986) or to be stochastic in which case the parameters of the log-normal distribution were estimated from the arithmetic mean and variance over the same period. The quarterly exploitation patterns used in the predictions was estimated as the mean (1981-1986) fishing mortality of the key run. This fishing mortality was partitioned amongst the fisheries as described in Section 3.4.1. Weight and value at age in the catch was selected as described in Section 3.4.2.

3.4 Long-Term Effects of Implementing a 120 mm Minimum Mesh Size when Fishing for Cod

3.4.1 Fleet definitions

The Working Group has been requested by ACFM to evaluate the effects of a more realistic implementation of "120 mm (mesh) when fishing for cod" along the lines adopted by the Roundfish Working Group (Anon., 1988b). That group split the nation by nation human consumption roundfish fisheries into two portions - those who continue to use the current mesh size and direct their effort towards haddock and whiting, and those who would change to a 120 mm mesh and target (primarily) cod. The split was made on the basis of the percentage of total catch of cod, haddock, whiting, saithe, and plaice, contributed by haddock and whiting. This was done for nine national fleets for the years 1984 to 1987. These figures have been made available to this Working Group by the Chairman of the Roundfish Working Group. In order to estimate the percentage of the international roundfish human consumption fleet that would adopt the 120 mm mesh size, a weighted average (by proportion of total international catch taken by nationality, for cod) was calculated. The derived figure of 68% represents that portion of the international human consumption fleet that this Working Group expects to change to 120 mm mesh. Forecasts of the effects of a 120 mm mesh size, using MSFOR, are based on this figure. The Group considered what changes to make in the saithe fleet structure and decided that the best strategy was to assume no change. This was based on the assumption that the majority of young (up to 3-year-old) fish is taken by Norwegian seiners and would, therefore, be unaffected by an increased mesh size regulation. The directed saithe fishery in the Norwegian zone would be little affected by an increase to 120 mm as this fishery already uses a larger mesh size.

3.4.2 Changes in selection patterns and discarding practices

The selection pattern for the 120 mm mesh is that used by this Working Group at its last meeting (Anon., 1988a), based on the work of Levy and Gislason (1988).

As last year, the selection ogives are based on weights in the catch rather than in the sea. The selection ogive calculation is a little different from that of the Roundfish Working Group, but it is consistent with that adopted by the STCF Working Group on Improvements of the Exploitation Pattern of the North Sea Fish Stocks. The proportional selection at length $S(l)$ is given as:

$$S(l) = 1/2 [\tanh \{b(1-l(50))\} + 1]$$

where l indicates length of fish;

$l(50)$ " length for which 50% of the fish are retained in the trawl;

l " $(w(a)/\text{condition factor})^{1/3}$;

$w(a)$ is mean weight at age;

b is $\ln 3/\text{range}$;

and range is $l(75) - l(25) = \text{fac} \times l(50)$.

Values for selection factor, fac, and condition factor are given below.

Species	Condition factor (x 10e-7)	Selection factor	Fac.
Cod	104	3.6	0.1818
Haddock	90	3.4	0.1667
Whiting	83	3.8	0.1818
Saithe	104	3.6	0.1818

The split of the HC roundfish fishery into discard and landings fleets has been based on the discard-at-age rates used at the previous meeting of the Multispecies Working Group (Anon., 1988b). The fleets have been split into 85 mm and 120 mm landing and discard elements.

3.4.3 Relative value of landings by species and age

In a multispecies context, where the species considered have very different landing value, the evaluation of the consequences of implementing technical measures with reference to landings only in terms of weight can be misleading. Moreover, when considering mesh changes, the size/age composition of landings is also bound to change for each species and this has consequences for revenue when, as is generally the case, unit values vary with the size of fish. It was thus deemed necessary to define a set of scaling factors to correct for disparities in value among and within the species considered in order to arrive at a more accurate appraisal of the economic impacts of various scenarios.

At the 1988 meeting of the Multispecies Working Group (Anon., 1988a), average landing prices from a sample of EC ports were

used. Information from Eurofish Reports was found to be too disparate to enable updating these prices for all species and size categories, using data from a sufficiently contrasted sample of countries.

Under EC regulations, there is a system of reference (or guide) prices which is based on average landing values over the member countries in the 3 most recent years, with corrections for market conditions. These reference prices are defined by EC size (market) category for all the species considered by the Group (except for sprat) and different values apply to products for human consumption and reduction.

Inspection of the reference prices applicable in 1989 (EC, 1988) indicated that these would be adequate to serve the purpose of scaling the importance of species and ages. The EC size categories being defined in terms of ranges of individual fish weight, the relevant prices were allocated to ages on the basis of the coincidence of mean weights at age in the catches with the weight intervals corresponding to the sorting classes, except for industrial species which have constant prices at all ages and for discards which obviously are attributed no value (Table 3.4.3). Since MSFOR only uses prices on a yearly basis, the price arrays apply equally in each quarter.

Although it may be arguable, it was decided to use fishmeal reference prices for all species (including roundfish) caught by the two industrial fleets such as defined within this group.

Considering that the reference prices only partially reflect the actual landing prices, and in view of the approximations mentioned above, it should be made clear that the resulting yields in value should not serve any other purpose than relative comparisons between exploitation regimes.

3.4.4 Projected long-term effects

The evaluation of the effects of implementing a 120 mm minimum mesh size selectively "when fishing for cod", and investigations of possible mechanisms involved have been carried out by comparing various options. The results are shown for each species and each fleet in Tables 3.4.4.1-3.4.4.10. Note that roundfish fleet landings for both 85 mm and 120 mm mesh components have been aggregated, where relevant.

Case 1: This is the baseline case, with constant recruitment and effort under current exploitation patterns, including multi-species effects. The results in Table 3.4.4.1 are given in absolute values, from which comparisons will be made in the subsequent cases.

Case 2: The 120 mm minimum mesh size regulation is simulated for that fraction of the roundfish fishery (68%) which is projected to adopt the 120 mm minimum mesh (i.e., to target cod).

Except for those fleets directed on saithe and mackerel, all fleets would suffer losses in their landings, the only positive effect being a substantial reduction of discards (-66%; Figure 3.4.4.1a-c).

The largest losses in value would occur for herring (-20%), Norway pout (-19%), whiting (-15%) and haddock (-10%). With respect to spawning stock biomasses, SSB increases significantly for cod (+31%), whiting (+27%), and haddock (+23%). SSB declines significantly for herring (-20%) and Norway pout (-10%).

Cases 3 and 4: These are replicates of cases 1 and 2, but in a context of no biological interactions between species. Relative effects in case 4 (120 mm, Table 3.4.4.4; Figure 3.4.4.2a-c) are compared to baseline case 3 (Table 3.4.4.3), which is expressed in absolute values.

With the exception of saithe in the roundfish fishery, the 120 mm mesh regulation would be beneficial to landings in terms of weight and value for all fleets (except discard fleets) and all stocks under the single-species assumption. Large percentage gains are projected for haddock in the roundfish fishery, and for by-catches of gadoids in the industrial fisheries. SSB increases by 98% for haddock, 68% for whiting, and 56% for cod.

Comparisons of cases 1-4 confirm the general conclusion of the Group last year that consideration of the multispecies effects reverses the conclusions drawn from single-species assessments, even in the less extreme option that only a fraction (68%) of the roundfish fishery would be subject to the mesh change.

The magnitude of the differences between single- and multispecies assessments with and without the increase in mesh size to 120 mm is in some cases rather large. For example, in multispecies assessments conducted last year, there was a projected 18% decline in cod landings, with a 26% increase in SSB when the mesh was increased from 85 to 120 mm. Current assessments (Table 3.4.4.2) indicate a much smaller decline in landings (-2.8%), with a slightly greater long-term SSB for cod (+31.2%). For haddock, there was a projected 40% decline in SSB, based on universal adoption of the 120 mm mesh. In the current scenario, haddock SSB increases by 23%. Thus, in assessing the long-term effects of the adoption of alternative mesh restrictions, it seems imperative that managers supply precise definitions of how and under what circumstances mesh regulations are to be applied. Failure to do so may result in erroneous conclusions as to the balance of gains and losses to the various fisheries and species.

Examination of case 2 indicates that the difference associated with multispecies considerations would be partly due to an increase of predation by cod, and also by whiting which shows the second largest increase in biomass after that of cod. Further investigations of the mechanisms involved were carried out by simulations of various scenarios, all of which included multispecies effects. It should be noted that several of the simulated options may be somewhat unrealistic within the context of current management approaches and philosophies.

Case 5: The effort is increased by 10% in all fleets under the current exploitation pattern and mesh regime. Except for haddock and Norway pout, equilibrium biomasses would be decreased compared to case 1, and this result would probably also be achieved in the single-species context. However, it is indicated that all landings would increase in weight, especially in the industrial demersal fishery, and, to a lesser extent, in value. Saithe in the roundfish and directed fisheries would be the only exception.

Again, these results are at variance with single-species assessments of the roundfish species, which indicate that current effort is above the F_{max} level.

Case 6: Case 6 has the same conditions as case 2, but with stochastic recruitment. The results in Table 3.4.4.6 are averages over runs. This option was examined to test the robustness of the conclusions under varying stock conditions, since the species interactions are likely to induce non-linearity in the responses.

The conclusions drawn from case 2 remain essentially unchanged. The reductions in cod yield are slightly amplified, and discards are slightly reduced. The most striking differences occur in the landings of haddock and Norway pout, in which large losses shown in case 2 change to gains or very small losses as a result of increased biomasses of these species. However, these results obviously depend on how the specific recruitment values were drawn from the underlying frequency distributions of recruitment.

Case 7: This is a variation of case 2 in which the recruitment of cod is halved compared to the historical long-term average. This was thought to be more representative of recent years in which the spawning biomass of cod has been reduced. The main effect is to reduce catches of cod by about 40% in the long term. SSB declines by 18%. The increase in the biomass of whiting is amplified as compared to case 2. Sandeel and haddock landings and biomass increased somewhat as compared to case 2, whereas sprat and Norway pout are relatively unaffected.

Case 8: It has been suggested that the implementation of the 120 mm mesh regulation in the fishery for cod might induce a compensatory increase in fishing mortality to maintain landings. A 10% increase in effort in the roundfish 120 mm mesh fishery is simulated in case 8. This option has a very small effect on cod, except for a decrease in total and spawning stock biomasses compared to case 2. This slightly reduces the losses in the roundfish fishery (e.g. for cod, saithe, whiting, and haddock) but total landings are generally unaffected.

Case 9: The previous cases indicate that cod may not be, at least directly, the major determinant in the predator/prey system, but that whiting could also play a significant role. In order to test this assumption, a trial was made in which fishing mortality on whiting was selectively increased by 100% in the roundfish 85 mm and industrial fisheries.

Of course, the main implication is on whiting itself. The losses of aggregate landings in the roundfish fishery, predicted under case 2, are increased, but the most dramatic effect occurs in the industrial sector and for herring. Losses previously predicted in the herring, industrial demersal and industrial pelagic components are converted to gains or only very small losses. The main beneficiary is the pelagic component. This scenario essentially emphasizes the technological interaction between fleets catching whiting. There is a slight increase in the overall landings; but the spawning stock biomasses of cod, haddock, and herring would be increased substantially compared to case 2, while those of whiting would of course be decreased.

Case 5 analyzes the scenario of increasing effort by 10% in the North Sea. However, ACFM has recommended that the TACs for 1989

should be based on a 20% reduction of effort in the roundfish and saithe fisheries. This policy has been evaluated in the multi-species context under case 10 (Table 3.4.4.10; Figure 3.4.4a-c).

Results for case 10 indicate long-term total losses of about 9% both in terms of weight and value, with variable effects in the fisheries subjected to the decrease of effort (roundfish and saithe) and in those maintaining their current effort. The major impact is on the biomass of saithe (+22% in total, +51% in SSB) inducing large decreases of the biomass of its preys, namely haddock and Norway pout, and their catches. This is not sufficient to explain the decrease of landings of cod and whiting which may be due to their own interaction in a context of increased biomass (+39% for SSB of cod). With respect to biomass of cod, case 10 results in approximately the same increases as observed in case 2, but of course with greater reduction in landings.

These results are actually consistent with those of case 5, indicating a proportional relationship between effort and landings. They emphasize the additional importance of saithe in the MSVPA system, and this species obviously deserves additional analysis, particularly considering the relative crude approximation of the saithe fishery exploitation patterns.

It should be kept in mind that reductions of effort have additional virtues of increasing biomass, and, therefore, of catch rates, in the short run, and of potentially decreasing costs of fishing thereby improving profitability.

Predation Effects

Table 3.4.4.11 shows the multispecies baseline (case 1) total consumption of different species in tonnes, and predation relative to average prey biomass (%) by individual predators. The two main predators in the system are saithe and whiting. Saithe takes mainly Norway pout (64% of its average biomass), while whiting is the most important consumer of sprat (25% of its average biomass). Relative to its average biomass, Norway pout is most heavily preyed upon (85%), followed by haddock (38%), sprat (35%), and sandeel (33%). In total, the 'baseline' system 'eats' 38% of itself annually. This result is compared to the predation pattern resulting from simulation of case 2 (120 mm mesh when fishing for cod).

Table 3.4.4.12 gives the percentage changes in consumption when the long-term 120 mm minimum mesh size option is simulated. The resulting changes in the percentages of predated biomass relative to average prey biomass are also shown. The main result is that both cod and whiting increase their consumption of all the prey species (due to higher TSBs). Consumption by these two predators is increased by 6% to 39% on individual prey species. In total, the consumption by cod and whiting increases by 12% and 15%, respectively. Increased predation by these two predators is likely to be the source of decreased yields, especially for cod, when the 120 mm mesh option is simulated (Table 3.4.4.2). For both cod and whiting, the consumption relative to the biomass of its prey species increases for all species except for themselves. The increase in predation, both absolute and relative to the average prey biomass, is largest for Norway pout, cod, and haddock. Except for haddock, all other predator species show modest changes

in their absolute consumption, and the fraction consumed of the available prey species. Haddock predation increases dramatically on some species (e.g., herring, whiting, Norway pout) due to the increase in haddock SSB under the 120 mm mesh option. Overall, the consumption/biomass percentage remains virtually the same (increasing from 38.2% in the baseline case to 38.4 % under the 120 mm mesh option).

Fitted Suitabilities

Long-term simulations of the 120 mm mesh option were also undertaken using 'smoothed' estimates of the suitabilities, derived from work reported in Section 6. Compared to the values of average M2 estimated by the 'key run', the smoothed suitabilities produced, except for cod, a general decline in the M2 values for ages 0 and 1, and an increase in M2 for the older ages.

The long-term prediction of an increase in mesh size tells the same general story as before, of a slight decrease in cod catch, but an increase in SSB. Additional research is required to assess the general feasibility of using smoothed suitabilities, subject to the following considerations: (1) smoothed suitabilities probably do not take into account differences in spatial overlap with age effects of predator and prey, and (2) smoothed suitabilities are probably smoothing unexplainable variation in suitability at age for sprat, Norway pout, sandeel, and perhaps herring, for which either the ALKs used to split the stomach contents into age groups are poor (Section 6.11.3), or the VPA is performed on a very short age range.

3.5 Elaboration of Fleet Definitions for Analysis of Technical Measures

This Working Group has considered the effects of various management options by the splitting of fishing mortalities between six or, at this meeting, nine fleets. These fleets, however, are only extremely rough representations of real North Sea fishing units. It should, therefore, be stressed that any advice that has resulted from short- and long-term, multispecies predictions, whilst capturing underlying multispecies effects, does not satisfactorily represent how individual fisheries might be affected. The Working Group, however, is increasingly being asked for advice on particular management options and feels that if genuinely useful advice is to be given, more representative fleet definitions should be adopted.

The STCF Working Group on Improvements of the Exploitation Pattern of the North Sea Fish Stocks (STCFWG), in collaboration with Norwegian scientists, is investigating fleet definitions and currently considers 47 separate fleets (by gear, nationality, and vessel sizes) in its deliberations (STCF, 1989). This number of fleets (which are often small and localized, or not catching stocks considered by this Working Group) is clearly not appropriate for incorporation into this Group's proceedings but might form a basis for the definition of more exact, and functionally more useful, fleets.

The STCF currently considers the results of VPAs conducted using advice from this Group. It would, therefore, be appropriate for

the STCFWG to make available the fleet definitions that it currently employs, so that simplified, more realistic, and compatible fleet definitions can be adopted by this Working Group. Moreover, given the needs of the STCF Group for a functional predator/prey 'module' in their analyses, close cooperation between the two Group seems essential.

4 MEDIUM-TERM PROJECTIONS

4.1 Impacts of the 120 mm Mesh Regulation

Long-term forecasts such as those presented in Section 3 are generally used to establish the bases of management advice with consideration of expected gains and losses. However, the interim effects of measures aimed at long-term gains are seldom explored although they may indicate hardships for some fleet components in the short term and, as a consequence, likely enforcement and other problems.

The Working Group investigated the trajectories of landings over a 9-year period, with comparison of results between the envisaged 120 mm mesh regulation in the cod fishery and the status quo trajectory, using a multispecies model with parameters estimated by MSVPA. In order to better approximate average stock conditions, the option of stochastic recruitment has been used, and the results for each year are averages over varying recruitment.

For the sake of simplification, the results were aggregated over species into 5 basic entities: roundfish and saithe fishery landings, roundfish discards, industrial demersal, industrial pelagic, and a herring and mackerel group. However, since the measure is basically intended for cod, the results for this species are also considered in detail. Finally, the total landings of all MSVPA fisheries in the North Sea are analyzed. The results of these analyses are given in Tables 4.1.1 and 4.1.2 and in Figures 4.1.1-4.1.7.

Not surprisingly, the results for cod (Figure 4.1.1) in the roundfish fishery (85 mm and 120 mm) indicate some short-term losses in weight and value during the first two years as compared to the status quo. The total biomass (Figure 4.1.2) declines slightly in the first year under both 85 and 120 mm mesh options, thereafter the gains are positive, and converge gradually to long-term means. Spawning stock biomass makes a more gradual ascent to the long-term mean.

Landings in the total human consumption gadoid fishery (including saithe) (Figure 4.1.3) indicate modest gains over the first three years, followed by several years of progressive losses and a convergence to the long-term mean. As for cod alone, the 120 mm mesh trajectory passes under the status quo about mid-way in the trajectory. As is often the case, the consideration of values dampens the effects, as future catches with the 120 mm mesh would comprise larger fish, fetching on average higher unit prices.

The industrial demersal fishery (Figure 4.1.4) is not subjected to the envisaged regulation and, therefore, suffers no immediate relative losses between fishing scenarios. However, the short-term increases in biomass of cod and other gadoids result in

increased predation of the industrial demersal species considered, with the effect of reducing short-term landings. Expressed in value, the results, however, show very small differences.

The industrial pelagic fishery (Figure 4.1.5), catching herring and sprat, shows rather complex trajectories, with gains recorded from the first year on. There is no direct effect of the regulation here, but only secondary effects via the predator fish. This is still clearer in the pelagic fishery fishing for herring and mackerel (Figure 4.1.6) in which landings decrease consistently, more so under the 120 mm regime than under the status quo scenario.

The total landings from the North Sea, given in Figure 4.1.7, summarize the effects mentioned above, with aggregate losses in weight directly related to those in the industrial demersal fishery in the first years, then increasing in later years. The total landings tend to stabilize in weight and increase slightly in value towards the end of the period.

Finally, the Working Group compared short-term losses and long-term gains in cod landings and SSB, as indicated in single- and multispecies runs with MSFOR, with previous medium-term results presented to ACFM by the Roundfish Working Group (Table 4.1.6). Both single and multispecies results from MSFOR (assuming constant recruitment) show about a 10% decline in landings in the first year, followed by gains in converging to long-term means. Results of the Roundfish Working Group differ in that much larger short-term losses in landings are experienced (-43%) in the first and (-25%) in the second years, as compared to 1988. SSB also declines slightly in the first two years. Some of the difference is probably attributable to different recruitment assumptions used by the Multispecies Working Group and the Roundfish Working Group. However, it is likely that some of the discrepancy in short-term changes is due to the inclusion of quarterly analyses in the case of MSFOR. The Roundfish Working Group calculations are done on an annual basis. Because of the rapid growth rate of cod in its first few years of life, short-term yield losses in the first quarter of the implementation of the mesh change, may actually be converted into gains by the fourth quarter. Thus, the balance of gains and losses has a seasonal as well as interannual component. Further work is obviously required to reconcile these apparent differences.

4.2 Issues Relating to Stochastic Population Simulations

The medium-term forecast was run over a period of nine years to explicitly study the transition from short- to long-term forecasts (Tables 4.1.3-4.1.5). We are also interested in the development of variability induced by introducing a stochastic recruitment element.

Essentially, the medium-term response is a combination of the transient response to the perturbation introduced by applying model parameters (recruitments and fishing mortalities) that are mean values of those from previous years, and the stabilizing effect of applying fixed parameters, or parameters with a fixed mean.

In the long-term forecast, the values were stable at the end point in all cases studied, which means that the system has no sustained oscillations or chaotic behavior, as far as the present experience goes.

On the medium-term scale, some species, in particular haddock, showed far more pronounced oscillations in the multispecies mode. For Norway pout, the response was delayed in the multispecies mode both for the catches and, to some extent, the biomass. For several of the species, damped oscillations seem to be induced by the multispecies model which are barely encountered in the single species mode. The practical implication of these findings is that, if the multispecies approach is taken to be the more realistic description of nature, the effects over the first years of changes in recruitment or fishing mortalities may be larger and more sustained than one would infer from single species considerations. In addition, the outcome of the medium-term prediction may be highly dependent on the adequacy of the input parameters.

To further explore the effect of stochastic recruitment on catch and biomasses of haddock, new recruitment numbers were drawn randomly for each year from lognormal distributions of recruitment. These distributions were based on data from 1974-1986, with expectation values equal to the values used under the constant recruitment option. Sixty 9-year runs were collected, which represent 60 different random recruitment patterns. The means and coefficients of variation from these 60 runs are presented in Figures 4.2.1. and 4.2.2.

The coefficients of variation increase with time, but have generally reached the long-term values by nine years. There is a general expanding of the standard deviations in the multispecies simulations over time. When comparing single and multispecies modes, one should not consider these standard deviations necessarily as true confidence intervals, since they only represent one of the potential sources of variation. One should note, however, the dependence of results on the patterns of recruitment.

In its present form, the distribution of recruitments is not adjusted for changes in the spawning stock biomass over time. If this could be done in a realistic way, in terms of different distributions at different spawning stock biomass levels, one would have an opportunity to evaluate the risk of driving a stock to collapse. The fact that the coefficient of variation for most stocks is in the order of 30 to 60% with a mean recruitment at recent historical levels, suggests that this risk may be more than hypothetical.

Another interesting aspect is that for some species which have a highly variable recruitment, the stochastic recruitment option in the multispecies mode gives larger values for catches and biomasses than the constant recruitment option, in particular in the medium term period. This is best seen for haddock and Norway pout (Tables 4.1.1-4.1.3). The explanation for this probably is found in the Helgason-Gislason functional feeding relationship, by which the fraction of an incoming year class which is eaten becomes smaller for very large year classes. The form of this functional feeding relationship obviously is critical to the overall tenability of these results (Section 8.5).

Analyses conducted on medium-term population trajectories have identified the potential time-sequence of balance in losses and gains (for example, in the case of the 120 mm mesh option for cod). Perhaps more interestingly, the stochastic medium-term may hold promise for understanding the interactions of multispecies predation with the recruitment process. Given these considerations, the Working Group feels that additional medium-term stochastic simulation work, in combination with inclusion of more biological detail in 0-group predation effects, is particularly important and should be pursued.

5 FEEDING STUDIES

Since the 1981 'Year of the Stomach' program was conducted there has been an enormous amount of activity directed at archiving the data collected in 1981, and additional sampling of some of the more important predator species. Similarly, there has been a significant amount of work on important aspects of feeding and digestion that are critical to the estimation of total consumption from food habits data. This section updates progress in analyzing feeding data collected specifically for MSVPA studies, and considers results of the Workshop conducted on stomach evacuation rates. Finally, progress on planning for an intensive resampling of major predators, to occur in 1991, is reviewed.

5.1 Status of Feeding Data Collected Through 1987

Except for the whiting data collected in 1987, all stomach content data have now been worked up and incorporated into MSVPA files.

A summary of the results obtained during the 1981 Stomach Sampling Project has now been published (Daan, ed., 1989). Because of the importance of documenting these data for future comparisons (e.g., with data from 1991 experiments), it is of some importance to pursue publication of the cod, whiting, and saithe data collected in 1985-1987.

5.2 Report of ICES Workshop on Stomach Evacuation Rates

This Workshop, under the chairmanship of Dr Peter Bromley, was held at Lowestoft in early April, 1989, to evaluate the results of digestion experiments with a view to estimating rates of food intake in natural fish populations on the basis of stomach content data (Anon., 1989b). At the outset it was hoped that the Group might be able to agree and develop a generalized model for predicting feeding rates. It was further intended that the Group consider the design and methods of analysis of evacuation experiments in order to be able to advise the planners of the 1991 Stomach Sampling Project on data requirements.

The Workshop started with a discussion of the "state-of-the-art" in gastric evacuation experiments. This discussion covered techniques, experimental design, and analysis. It revealed a fundamental difference of opinion about whether or not stomach clearance curves are linear or curvilinear. It was realized that such differences of opinion were likely the result of differences

in experimental design but also, possibly, of artifacts in the fitting of models. It was agreed that certain data analyses in the literature were far from perfect and that great care should be taken in the future. The question of how laboratory results from single fish, fed single meals, could be extrapolated to natural fish populations was also raised. The feasibility of experiments using sequential meals was, therefore, discussed and it was agreed that such experiments could provide useful data to validate models based on single feed experiments.

The Group heard reports of field work on fish feeding rates and agreed that the approach deserved further attention both as a means of determining food consumption rates and for helping to validate experimental findings.

The Group also considered the modelling of gastric evacuation. Not surprisingly, the Group could not agree on a general model. Because of this, it was suggested that any future stomach sampling program should collect data to enable testing between different evacuation rate hypotheses. The clearest difference between exponential and linear models is that the former requires information on levels of stomach fullness (since evacuation rate varies with amount of food in the stomach), whilst the latter requires information only on the percentage of fish with food in their stomachs (equivalent to the proportion of time food is in the stomach). Appropriate data collection at sea could help to resolve the appropriateness of the different model types.

One variable that was available from many experiments reported at the Workshop was the half-life of food in the stomach. An attempt was made to consolidate as many data as possible on this variable and to begin some analyses. An ANOVA of log half-life revealed that most of the variance could be explained by predator type, then prey type, temperature, and log meal size. Log-predator size did not have a significant contribution.

This analysis was not made so much in the belief that it would yield encompassing results, but to begin the process of data consolidation/collaboration and unifying analyses. The Group agreed to extend this idea, and Peter Bromley agreed to set up a data base of results. If this is achieved in time, and if preliminary analyses are performed, it will be presented at the ICES Multispecies Symposium to be held in The Hague in October, 1989.

The Group also discussed the field sampling of stomachs. In particular, there was much discussion on whether or not to bulk stomach samples at sea. There are clear advantages to collecting individual samples (e.g., ability to estimate errors, more scope for calculating prey species compositions and evacuation rates), but there are also major practical obstacles. The Group discussed the practicalities of how individual sampling and processing might be achieved but reached no conclusions. It was agreed, however, that John Last and John Hislop should analyze existing whiting data sets to evaluate the advantages of single- and multiple-stomach data processing in time for The Hague meeting.

Concerning analysis of stomachs sampled at sea, the Group agreed that fine scale analysis of fish prey was desirable and appropriate but that coarser grained data should be collected for other prey. In this respect, it was considered desirable to

encourage North Sea ecologists to participate in stomach analyses. Peter Bromley will recommend this to the Chairman of the ICES Biological Oceanography Committee.

It was also agreed that field data (indeed any data!) on O-group fish feeding were scarce. It was suggested that research in this area would be beneficial.

In summary, the Group came to few firm conclusions as to models of gastric evacuation, but made realistic moves to ensure future cooperation and progress. Work was initiated to help resolve the question of stomach sampling protocols at sea. Areas of common interest were affirmed and areas requiring further research were discussed and noted.

5.3 Report of Planning Group on the Stomach Sampling Project for 1991

The Working Group considered the report of the Planning Group on the Stomach Sampling Project for 1991 (Anon., 1989b) and welcomed the firm proposal to repeat the 1981 exercise at a comparable scale. This should allow a definite validation of the essential underlying assumption of MSVPA that suitability is constant. The objective to include O-group fish explicitly in the project as well as some important predator species not previously sampled was also underlined, because this should provide an opening for further improvements in multispecies assessment. Because the collection of a new data set is absolutely essential to the development of sound long-term management advice, the Working Group strongly endorses the recommendations made by the Planning Group.

It was noted that one major problem encountered in 1981 was related to the transformation of size class distributions of certain prey species to age distributions due to lack of appropriate age/length keys. The Group stressed the need for a careful planning of the collection of age/length keys during the surveys to be carried out in 1991.

6 TESTING THE STABILITY OF SUITABILITIES

6.1 Analysis of Computed Suitabilities

MSFOR is used as a tool to explore likely consequences of management actions. The matrix of suitabilities input to MSFOR is retained for the duration of the simulations. Because these suitability values largely determine the species interactions in the forecasts, it is important that they reflect general aspects of feeding patterns of predators, and not the special conditions of any particular year. Work to examine the stability of the suitability values commenced last year, and continued after the meeting (Rice, 1989).

6.2 Data Used

The data used for these analyses are described in last year's report, as data sets NS81, NS85, NS86, NS87. Briefly, NS81 contains suitabilities estimated only from stomachs collected in

1981. NS85 contains, for cod and whiting, only data collected in 1985; for other species of predator, 1981 data were used. NS86 contains, for cod and saithe, only data collected in 1986; for other predators, data from 1981 were used. NS87 contains, for cod and saithe, only data from 1987, for other predators data from 1981 were used. In all cases, only data from the first and third quarters were considered. Moreover, there are no saithe predation estimates for the first quarter.

This year, an additional data set was created. From NS85, NS86, and NS87 the new suitability estimates for cod (all years), whiting (1985) and saithe (1986 and 1987) were taken off, and added to NS81 as new predators. This data set now had data for eleven "species" (cod 81, cod 85, cod 86, cod 87, whiting 81, whiting 85, saithe 81, saithe 86, saithe 87, mackerel 81, and haddock 81), and will be referred to as G11.

NSALL was also used in some analyses. It is the matrix of suitabilities from the 'Key Run'. Estimates are based on all years of feeding data regardless of year of collection.

Also described in the 1988 Working Group report (Anon., 1988a) is the 'kernel model' fit to the suitabilities. It contains terms for the main effects of quarter, predator species, and prey species, as well as the three two-way interactions among those terms. This kernel model can be used with a variety of representations of the size preference function of predators, depending on how the weight ratio term (Predator weight/Prey weight) is formulated.

6.3 Results

6.3.1 Total variance

Preliminary analyses reported at the 1988 meeting of the Multi-species Working Group (Anon., 1988a) suggested that when feeding data from several years were used to estimate suitabilities, the total variance increased around 12%, compared to the variance in suitabilities estimated with only the 1981 data. In the report, reservations were expressed about that result, however, because of uncertainty about the statistical routines that were used; subsequent analyses have confirmed that result, however, so this year there is confidence in it.

Contrasting G11 results to results using NSALL indicated both data sets were quite comparable. The total mean square for G11 is 5.4% larger than the total mean square of NSALL, despite the estimates in NSALL being based on more data than the component estimates of G11. Likewise, for any of the models fit to the suitabilities (Section 6.2 of the 1988 report) the root mean square errors differ by between 1.0 and 1.5%, with the model fits to G11 being consistently the better ones. (It is expected that a model fit to G11 would explain slightly more variance than the same model fit to NSALL, where patterns identical in the two data sets because G11 estimates more parameters, as it has more levels to the factor "predator species".)

6.3.2 Stability of parameter estimates

From models fit to G11, it is possible to obtain separate parameter estimates for the mean suitability of each predator in each year. These values can be contrasted directly, to investigate the amount of change in feeding pattern of a given predator over two or more years. For cod as predator, main effect parameter estimates for the 1988 kernel model with a single slope for the log weight ratio term are extremely close for 3 of 4 years, with the 1987 estimate differing (Table 6.3.2.1). The two whiting estimates and three saithe estimates differ somewhat more than for cod. However, for both species 95% confidence intervals of the parameter estimates generally overlap each other, except saithe 86 contrasted with saithe 87. Moreover, all estimates for whiting and saithe, except saithe 87, have 95% confidence intervals which include zero.

For parameter estimates of the combined predator-prey main effect plus interactions, suitabilities for years 1981, 1985, and 1986 are very similar for most prey (Table 6.3.2.2). The estimate for cod preying on whiting is somewhat low in 1984, cod on herring is high in 1985, and the pattern with Norway pout is irregular. Only for cod on Norway pout do two standard error bars not overlap for pairs of years, however. Data for cod in 1987 are quite different for cod, herring, and sprat as prey. For whiting, combined parameter estimates are quite similar for all prey except whiting and Norway pout as prey (Table 6.3.2.2). In both cases the two standard error bounds do not overlap. For saithe, the combined parameter estimates are fairly similar among years for all prey. The specific values fluctuate somewhat, but relative sizes are quite consistent. In general, the combined parameter estimates are quite comparable for a given species of predator across more than 1 year. Even more reassuringly, in only one case did a parameter estimate switch from significantly less than zero in 1 year to significantly greater than zero in another (whiting on whiting).

For the final parameter estimates, the slopes of the weight-ratio covariates do not differ among the 4 years of cod or 3 years of saithe data (Table 6.3.2.3). The two S.E. bounds around the data for whiting in 1981 and 1985 do not overlap, although the gap is very small (lower bound 1981 = 1.115, upper bound 1985 = 1.105). It is worth noting none of the individual slopes are very different, even given the small standard errors of the estimates. Because of uneven representation of cases among groups in the G11 data set, it was appropriate to use a least-squares procedure to estimate group means.

Using the LS mean approach, the means of 4 years of suitability estimates for cod and two for whiting do not differ amongst themselves (Table 6.3.2.4). For saithe, 1981 differs from 1985, but not 1986, nor 1985 from 1986. Generally, the means for other contrasts did differ, although cod and saithe were similar in 7 of the 12 pairings, and whiting and saithe were not different in 5 of 8 pairings.

With so many pair-wise combinations of interaction means, it is both boring and statistically inappropriate to review all tests. General patterns can be reviewed, however. Across all 2,701 pair-wise contrasts of means among predator-prey interactions, 960 or 35% were not "significant" at $P < 0.01$ (to the extent that signifi-

cant has any meaning with so many tests). Of the 42 contrasts of cod in one year feeding on a specific prey with cod in another year feeding on the same prey, 29 were not significant at $P < 0.01$. This is many more than expected from the overall rate ($\chi^2 = 22.32$, $df = 1$, $P < 0.01$). For saithe, 15 of 21 pairings were not significant, again many more than expected by change ($\chi^2 = 11.80$, $df = 1$, $P < 0.01$). Of the seven whiting pairings, five were not different at $P < 0.01$ (binomial test, $P = 0.059$). Even with an extremely highly inflated error rate, at least 70% of the comparisons suggest the mean suitabilities of particular prey for particular predators have not changed.

6.3.3 Summary

Two general lines of evidence were used to evaluate change in suitabilities across the 4 years of stomach data (1 year of complete data, 3 of partial); total variance in suitabilities and differences among parameter estimates. For total variance, both overall increased variance and comparisons of full data sets to the G11 set indicated an increase in variation in the neighbourhood of 5-10%. Differences among parameter estimates and among LS means for various predators and predator prey combinations were generally small enough to be consistent with sampling variation of the scale seen in total variance.

Some differences among parameter estimates of the same species from different years. Most apparent changes related to data from 1987, particularly for cod. It is possible that with suitabilities estimated in 1988 for 1987, the input population values were a source of some variance. These analyses should be repeated once cohorts have converged back to 1987, so there can be confidence that input population numbers, which affect the MSVPA calculations of suitabilities, are accurate.

It is also worth emphasizing that the experimental design for these analyses was not ideal. Feeding data were only replicated for some species, in some years, and for different combinations of years for different predators. A complete replication of feeding data would allow more rigorous contrasts of the stability of suitabilities. Nonetheless, from these several different looks, it is clear that suitabilities, and by inference the feeding patterns of the predators in MSVPA, changed relatively little over the study. The overall consistency of the suitabilities is a necessary prerequisite to using MSFOR to explore consequences of management actions.

6.4 Smoothing Suitabilities and Mortalities

6.5 Rationale

The suitabilities and M2 values produced by MSVPA reflect the input information on stomach contents data, including any sampling variance from the stomach collection project. Because the sampling variability may be large, it is possible the suitabilities calculated from them, and the M2 values calculated indirectly from the suitabilities may contain substantial variance as well. A model fit to the observed suitabilities and M2 values may produce results which are closer to true feeding relationships than the original observations.

Even if the smoothed values are no more reliable than the observed suitabilities and M2s, there are other reasons for fitting models to the raw values. A relatively few parameter estimates from the models may represent most information in the several thousand suitability and M2 estimates. The parameter estimates are informative in themselves, especially relative to each other, and can serve as sources of insight into biological interactions underlying the MSVPA. The models and parameters can also serve a variety of predictive and analytical functions, for projecting, for optimization, and similar purposes. For these reasons the Working Group had devoted substantial attention to fitting appropriate models to the suitability and M2 values from MSVPA.

6.6 Data Sets Analyzed

Prior to any analyses, some screening of the data sets was done. Because there was only repeated stomach sampling of some species in each year, and only in the first and third quarters, records from quarters 2 and 4 were deleted. Also, although all predator species were present in the MSVPA output for 1981; for 1985, 1986 and 1987 only records of predators for which new stomach data were available were used.

Two different data sets were analysed in these investigations. The first set, referred to as the OBSERVED set, included the indices for the factors (year, quarter, predator species, etc.), suitability, M2, and predator and prey weights and biomasses for every combination actually observed in the feeding data. This is the data set analyzed during smoothing studies at past working group meetings.

The OBSERVED data set does not contain every possible combination of quarter, predator species/age, and prey species/age. If the theoretically log normal distribution of suitability as a function of the ratio of predator size to prey size is considered, some of the combinations not observed in the feeding data lie to the right of the peak of the curve, some to the left. Cases missing to the right are instances where it is possible that a predator was found not to be feeding on prey much smaller than optimum. These missing low suitabilities were considered to be sampling errors: predators were expected to feed, at least occasionally, on prey much smaller than optimum. However, if the feeding was at a low rate (towards the right tail of the theoretical distribution), the prey may not have been recorded in the stomach analyses. These right zeros were replaced with suitabilities and M2 values of .00001, smaller than any values observed in the MSVPA output. The data set containing these values was called the RZ (right zero) set.

Missing cases to the left of the optimum were a different consideration. It was thought that as the prey neared the size of the predator, suitability might fall off much more quickly than it rose. Inspection of the frequency tables of age of prey by age of predator was consistent with this notion. Although the suitability curve with the weight-ratio function undoubtedly fell to low values of some point, it was far from clear where the "left zero" values should lie. Since decisions about where the zero values were placed could greatly influence the left parameter

estimates for the covariates, and the optimum predator to prey weight ratio, there was little reason for placing the zeros at any particular point and "left zeros" were not added at all. Rather, when the parabolas of suitability by weight ratio are fit, it was decided to simply not extrapolate beyond the observed range of weight ratios for a given species of predator.

6.7 Models Fit

All models fit to the suitabilities and M2s contained the kernel model agreed on at the 1988 meeting (Anon., 1988a). The kernel model contains factors for quarter, predator species, prey species, and all two-way interactions of these terms: $q \times \text{pred}$, $q \times \text{prey}$, $\text{pred} \times \text{prey}$. Models differed in how the covariates were treated.

One dimension of difference was in which covariates were included. All models contained the weight ratio (predator weight/weight of prey in the stomach) and weight ratio squared terms. In most models, these terms used the natural log of the weight ratios, but the NOLOG runs used these ratios untransformed. Another set of analyses included the log of the predator weights with the log weight ratio terms. These models, of greater interest in the M2 fittings, explored the absolute effect of predator size on predation mortality, regardless of prey size.

In addition to variation in which covariates were included in different models, models differed in how the covariates were related to the factors. Each combination of covariates (log and nolog, with and without predator weight) was included as a single global term, nested under predator, and nested under predator and prey. This diversity of models allowed evaluation of which factors and relationships were most appropriate, on grounds of statistical criteria (total variance explained, variance captured by particular model terms), and grounds of biological plausibility (do the parameter estimates of the covariate levels make sense biologically?). Parameter estimates of the levels of the factors are not considered in detail in this report. Results are consistent with those reported in past working group reports.

6.8 Results

6.8.1 Model fits

Adding the right zeros increased the total variance in the data by 40% for suitabilities, but only by 8% for M2s (Table 6.8.1). This suggests that although the low value used for missing suitabilities may have been too low, the value entered for missing M2s was in the proper order of magnitude. Further work, projecting exactly what a legitimate value for unobserved suitabilities should be, seems warranted.

Regardless of whether right zeros are added or not, models containing only the log weight ratio covariates consistently explain less variance than the model with comparable degrees of nesting, but the predator weight term as well. The difference is generally small (1-3%) for suitabilities but is much larger (20-30%) for M2. This suggests that if one intends to conduct analyses or simulations using smoothed M2s, the model used in the

smoothing should contain the predator weight term.

Both the OBSERVED and RZ data sets show only a gradual increase in model fit with increased levels of nesting of covariates. The gains in r^2 when predator species and prey species are added as nesting factors are of comparable magnitude for suitabilities, generally 2.5-4%. For M2, the gain when adding predator as a nesting factor is substantially larger than the gain when prey is added as well (4-6% vs 1.5-2%).

When the non-transformed weight ratio is used as a covariate, fits to suitabilities are generally poorer than equivalent models with the log weight ratio, but by only 1.5-3%. For M2 values, the differences in r^2 are again generally 1-3%, with the models containing transformed terms slightly better. The difference is much larger for the single slope model fit to M2s, where the nolog model (without predator weight) fits much worse than the model with a log term.

Overall, in the light of these results, there are no strong statistical grounds for preferring one level of nesting over another. It does appear proper to use models containing predator weight as a covariate, however, as fits to M2s are consistently much better. It seems to make little difference to most fits whether the weight ratio covariate is logged or not. With theoretical underspinnings for the log value, its continued use is appropriate.

6.8.2 Parameter values from the models

The key parameters of biological interest from the models fit to the suitabilities and M2 values are the slopes of the covariates. There are theoretical reasons to expect the slopes of the log weight term (LWTR) to be positive, with the log weight ratio squared term (LWTRSQ) to be negative. Together these produce the parabolas of suitability and M2 first increasing as for a given predator size, the increasing size of prey becomes more appropriate (suitability and M2 increasing) and then descending, as the prey become too large to feed on effectively (the descending limb). Note that in figures with the weight ratio as the X-axis, large ratios to the right of the figures are actually small prey for a given predator size. As prey become large, curves move up and to the left.

For the OBSERVED data set (Table 6.8.2), parameter values are implausible for the most simple and two most complex models. For the intermediate models, values are consistent with theoretical expectations. For the predator nested model with LWTR and LPDW terms, preferred on reasons of model fit (Section 6.8.1), parameters indicate that the size preference function ascends more steeply from the right to the left for saithe, haddock, and whiting than for cod and mackerel. The mortality inflicted by the predators is similarly more size-dependent for saithe, haddock, and mackerel than cod and whiting. As predator size increases (LPDW terms) inflicted mortality (M2) decreases for all predators. The decline is fastest for haddock and whiting, slowest for cod. Differential suitability of potential prey (SUIT) is relatively low for cod and saithe of different sizes (LPDW slopes close to zero). Mackerel appear to become more selective as they grow, whiting and haddock less so.

The RZ data set was examined largely to increase the biological reality of the parameter estimates. For the fit of the model with log pred weight and log weight ratio both nested under predator to suitabilities, relative slopes change marked for mackerel and haddock (Table 6.8.3). The values for mackerel appear implausible for the markedly negative preference function (LWTR) and the steeply positive impact with increasing predator size (LPDW). Otherwise, patterns of parameter estimates for fits to suitabilities are comparable to those from OBSERVED.

For fits to M2s, the addition of right zeros decreases the slope of all parameter estimates for the size preferences, rather than increasing them, as expected. The value of the curvature term also becomes less negative with the addition of the right zeros, again, contrary to expectation.

6.8.3 Parabolic shapes

The preferred model from these investigations includes the kernel plus the log W ratio and log predator weight, both nested under species. These models define a curved surface in the two axes, with the kernel providing different intercepts for different combinations of predators and prey. To illustrate these surfaces, several graphs were produced for three species of predators, at two weights, for Norway pout, whiting, and herring as prey. The parameter estimates come from fits to the RZ data, and the parabolas may be a bit flatter than ideal.

In these figures (6.8.3a-c), saithe as predator always peaks at the largest weight ratio (right-most on the X-axis), cod shows the fastest ascent from the lower right in every graph. Figures can be scaled by the dotted line on each one, indicating grand mean M2 across all combinations of predator and prey. For example, for Norway pout, both modest sized (weight = 0.5 kg) cod and saithe inflict substantially more than average mortality across a wide range of weight ratios. For large predators (weight = 2.0 kg), the mortality inflicted is relatively large only for fairly small weight ratios of cod and large weight ratios of saithe. This suggests cod switch from Norway pout with size at a faster rate than saithe do.

Interpretation of these parabolas is complicated by the lack of scaling information on how frequently various combinations of sizes of predators and prey occurred, and the largest weight ratios actually observed in the data sets. Moreover, as explained above, the parabolas probably should be more strongly curved, if the very small values added to the RZ data sets were not of the proper size. More appropriate values could be estimated from the data available, but the work could not be completed at this meeting.

Despite these qualifications, the parabolas constructed from the smoothed M2 parameter estimates provide biologically useful results. As surfaces of various predator-prey and size combinations are considered, many of the dynamics of species interactions can be represented and reviewed.

6.9 Miscellaneous Matters from the Smoothings

These smoothing analyses have been pursued for several meetings. It seems clear, from the accumulated results, on both statistical and biological grounds, that a model containing the kernel plus the log weight ratio and log predator weight terms, both nested under predator, is an appropriate representation of the observed suitabilities and M2s. The predator weight term is particularly important for fitting M2 values.

The input data to the smoothings should now be the focus of more attention. At this meeting, attempts were made to replace missing observations of predators preying on prey smaller than the largest (oldest) observed case of each combination, with very low suitabilities and M2s. It was believed that these missing observations were likely to be for instance of very small prey relative to predators, so adding these values would increase the steepness and curvature of the parabolas. In practice, that did not occur as discussed in Section 6.8.3.

It was noted that in the residual plots from all models which included fitting predator weight to the M2 values of RZ, three extreme outliers occurred. These appeared to be cases where combinations of sizes of prey and sizes of predator were highly appropriate, but not observed in the stomach data. Possibly these were relatively large predators, which were often poorly sampled. If so, these missing cases were just sampling error due to rareness, not to weakly-preferred prey. They should not have been replaced by low values for suitability and M2.

This uneven sampling of stomachs across sizes of predators also suggests that the variance of the suitability and M2 values from MSVPA might vary substantially across sizes of predators. If so, it might be appropriate to weight the various predator-prey by age combinations differentially by representation in the stomach data, when calculating parameter estimates. This was not explored at the meeting.

Finally, the issue of how many, and where to place, left zeros needs further attention. As discussed in Section 6.6. some true zeros are appropriate for very large prey relative to predator, but where to place them on the weight-ratio axis is far from clear. All of these factors can be pursued much further with available information, and will lead to parameter estimates for the preference functions which may be biologically extremely informative, as well as having many uses in modelling and forecasting.

6.10 Summary and Prognosis of Smoothing

These results suggest that the kernel model, with log weight ratio and predator biomasses, is an appropriate model for smoothing the suitabilities. Additional work should focus on improving the quality of the data to which the models are fit. Previous parts of Section 6 have discussed the need to account for realistic values for cases which are missing in the MSVPA data sets. Much work remains to be done in this area. Singh and Pope (1989) discuss alternative approaches which make the smoothing at different stages in the processing of the feeding data. Other alternative uses of the feeding data to provide

parameterized feeding relationships (e.g., see Section 8.5) may also pay high dividends.

The other line of potential future work is to begin to use the resultant parameter estimates to explore in more depth the biological relationships among the species. It was noted that the parabolas (actually cylinders, due to the log predator weight axis, which is sliced through in Figure 6.8.3) constructed from the preferred model in Section 6.8.2 convey information very consistent with the biomass spectrum analyses (Section 9.2). Because of the superior analytical tractability of the parameterized models over the very large data matrix of suitabilities and M2s, it is likely that these models can provide a powerful link between the empiricism of MSVPA and fields of theoretical ecology such as system stability, food web theory and theoretical population ecology.

6.11 Comparison of Observed and Predicted Stomach Content Composition

In 1985, the Multispecies Working Group first attempted to compare prey fractions observed in 1982 with the predicted fractions by means of MSVPA (Anon., 1986), which yielded promising results.

This topic was picked up again, now that more detailed stomach content data sets have become available. As a first start, the cod data were selected for a detailed analysis, since there are in total 8 stomach content data sets available for the first and third quarters of 1981, 1985, 1986, and 1987. In total, 7 MSVPA runs were made according to Table 6.11.1, and the predicted and observed prey fractions were taken from selected data years for subsequent regression analysis by means of SPSS.

Three different approaches were taken. First, a comparison was made between the predicted and observed fractions of diet composition on the basis of singular year data sets, excluding all other years from the analysis in order to ensure that the data to be compared were completely independent. The main purpose here was to test the model performance against the simpler assumption that food composition would remain constant from year to year. Secondly, comparisons were made between the predicted and observed fractions, when gradually the data base was expanded to include an additional year of stomach content data at a time. This should give some guidance as to the gain in reliability to be expected from an additional year of the stomachs. Thirdly, a comparison was made from the run which included all the available data for cod, whiting, and saithe, between the regressions obtained based on individual observations for prey age groups and based on the overall amount of each prey, summed over age groups, in each predator age class. It was anticipated that this might point to inadequacies in the age/length keys applied for some prey species.

In all analyses, the square root transformation of the observed and predicted stomach content proportions was taken in order to normalize the distribution of the observations.

6.11.1 Predictions based on single-year data sets

Table 6.11.2 summarizes the results of the regressions of the observed stomach contents of cod of the four years for which data have been collected versus the predicted values based on the fourth year, taking each possible year as a starting point for calculating suitabilities. Also, the results are presented of regressions of the observed fractions in the three years against the observed fractions in the fourth year directly, because this should indicate the baseline level of agreement between the stomach content data sets and, thus, the difference between the two sets allows an evaluation of the gain that is obtained by modelling predation as a function of prey biomass in the MSVPA. Obviously, the data sets used in this set-up are completely independent.

The variance over all species explained by the suitability estimated from one data set or ranges between 26% to 32% for individual years indicating approximately similar levels of accuracy between species. Within individual prey species, however, the r squared values show considerable variations.

Overall, there is also a small but systematic improvement of the variance explained by the MSVPA model compared to a model where a constant food composition is assumed. In general, the latter model yields already highly significant correlations indicating a large level of coherence between subsequent data sets in terms of important and less important prey age groups.

6.11.2 Gains to be expected from additional data sets

In trying to evaluate the gain that can be expected from an additional data set, regressions were made of the observed vs predicted fractions after including subsequently one more data set, starting with 1981. This imposes a statistical problem, because if we use the four available data sets as the starting point for our comparison, the predicted and observed, fractions are to a greater or lesser extent dependent on each other, so that the results cannot be used for performing a statistical test. Nevertheless, this approach was taken, because it was argued that the relative increase in variance explained should reflect the gain in variance explained by adding more data sets to the system.

The results are presented in Table 6.11.3. The r squared for 1981 are higher than the comparable values in 1981, because in this case the 1981 data have been included, which by definition give a 1 to 1 correspondence between the model predictions and the observed values.

The data clearly indicate a steady increase in r squared when more stomach content data are available. However, by far the largest gain is derived from the second data set improving the variance explained by 12%. The third and fourth data set yielded corresponding gains of 6 and 4%, respectively. The other important aspect of this exercise is that the number of cells in the system for which there are data, increases considerably by approximately 17% when one goes from one to two years of observations, whereas additional years do not seem to add much more cells. These results do seem to strongly underline the need for

another Stomach Sampling Year in 1991, because for most of the predator-quarter combinations we as yet do have only one year of observations. On the other hand, it is a comforting idea, that there is a limit to the amount of stomach sampling that has to be done in future, because there does not seem to be much gain to be expected from collecting data year after year. In fact, the ability to explain approximately 60% of the variance in food habits data is about the maximum one might hope to explain in such a complex biological system.

6.11.3 Inadequacies in age/length keys

One general worry in the stomach sampling programme has been related to the quality of the age/length keys employed for the industrial species and herring. Whether this aspect might explain some of the variance encountered was explored by evaluating the effect of summing over prey age classes on the r squared. The figures are given in Table 6.11.4. In general, the variance explained by the model decreased when prey age classes were added for those species where ALKs are under suspicion. Only for sprat eaten by cod and for herring eaten by whiting the variance explained increased significantly by regressing the total prey fractions. In others, notably whiting eaten by whiting and Norway pout eaten by saithe, r squared was dramatically reduced indicating that the total fraction has been heavily affected by an extreme value.

7 MSVPA PERSPECTIVES OF FEEDING RELATIONSHIPS IN THE NORTH SEA

7.1 Who Eats Whom?

Figure 7.1 summarizes the trends in biomass, yield and predation for the period 1974-1987. Deviations from previous years' results as indicated in Table 7.1 are due to changes in some input parameters (Section 2) as well as to the inclusion of additional feeding data, and catch-at-age data for 1988.

Overall average biomass has declined by approximately half from 1974 (10.3 million t) until the mid-1980s (~ 6 million t). Since 1985, biomass increased. (It should be noted, however, that these results are highly sensitive to input data.) The long-term forecast based on constant recruitment predicts at least some 7.5 million t biomass.

A decrease in total biomass during the 1970s was mainly due to the decline of mackerel and sprat and a temporary reduction of haddock, saithe, and sandeel (Figures 7.2 and 7.3). The increase in total biomass since the mid-1980s reflects primarily the recovery of herring and, to a minor extent, that of haddock, saithe, and sandeel.

These changes in biomass levels and species compositions led to a lower level of predator biomass (Figure 7.2) and hence to a reduced overall consumption. The amount of (MSVPA species) fish eaten by (MSVPA species) predators has declined by more than half since 1974, and since the beginning of the 1980s is roughly equal to the total yield harvested by man. The decrease in the quantity of fish eaten is also influenced by a drop in the rate of consumption per predator biomass (Table 7.1). This probably reflects

a shift in relative species and size composition of the predator community. Large gadoids and mackerel were the main fish predators in the 1974 system (Figure 7.4). A biomass unit of predators in the 1980s contains more fish with high preferences for 'other food'. However, a corresponding increase in the amount of 'other food' eaten per unit fish biomass cannot be seen in Table 7.1. This might be an effect of the changing species composition, as the daily rations of the species differ to some extent. Changes in the fish-fish interactions and in biomass structure are summarized in Figures 7.4-7.6 for 1974, 1985, and for the year 2032 (long-term forecast), together with information on yield composition.

Yield has fallen from 3 million t in 1974 to less than 2.5 million t in 1987. According to the long-term forecast, yield will stabilize at approximately the 1974 level.

The decrease in yield since 1974 coincident with the reduction in total biomass was partly compensated for by increasing overall exploitation rates (Table 7.1) and a gradual shift in species composition of the catch.

8 FOOD FOR THOUGHT

As is custom of this Working Group, this section is reserved for developing new approaches and 'testing the waters' with innovative and at times controversial research topics. Given the quest for simpler methods for conducting and displaying the results of multispecies fishery calculations, much of Section 8 is devoted to these considerations.

8.1 Fitting Overall Yield Surfaces and Calculation of Reference Points

In a working document (Pope, 1989), it was demonstrated that quadratic approximations to the yield and value surfaces with respect to the six standard fleets could be simply fitted using the estimates of the partial derivatives of yield and value of each fleet with respect to changes in fishing effort in each other fleet.

Such partial derivatives can be simply calculated from the output of MSFOR when runs are made for the status quo situation and with each fleet effort increased by 10% in turn. Tables in that form have been a standard feature of past reports.

It was also established in the course of the meeting that surfaces in the form of a multispecies Fox model (Kirkwood, 1981) could be fitted in a similar way since each in the model parameters had a simple relationship with the partial derivatives of fleet-based yield or value with respect to effort changes.

Both forms of models have been programmed as SuperCalc 4 spreadsheets and are available on the ICES IBM PC. The program name is MSQUAD. Table 8.1.1 shows the results page from the multispecies quadratic surface program for a general 10% increase in all fleets.

Given the simple mathematical structure of the quadratic surface, it is possible in principle to use standard linear algebra results to estimate such reference points as the multispecies MSY, the $F_{0.1}$ point of the overall surfaces and the $F_{0.1}$ point of the yield and value with respect to individual fleets. If it is further assumed that at the status quo situation, fleet costs are more or less equal to the value of the catch, then it is also possible to calculate a multispecies MEY.

In practice, linear algebra solutions for these reference points are frequently infeasible since they may include the possibility of a negative fishing effort from some fleet or a negative yield from heavily exploited species. To achieve feasible solutions, it is, therefore, necessary to include constraints on the effort changes to be permitted of 0.1 <effort change <2.0.

Further restriction had to be imposed where yields became negative within this range as was the case for saithe.

Calculation of such constrained reference points was then made for both models. Those for the multispecies yield quadratic surface are shown in Table 8.1.2, and those for the multispecies value quadratic surface are shown in Table 8.1.3.

Table 8.1.2 indicates that both the MSY and the overall $F_{0.1}$ is apparently at higher levels than the status quo for all fleets except the industrial pelagic. The current situation is near to the individual fleet $F_{0.1}$. It is noticeable that all these solutions lead to negative profits as defined above.

In Table 8.1.3, the reference points with respect to multispecies value occur at lower values of effort than the yield results. The MSY result is rather unsatisfactory in that the effort of 4 fleets had to be arbitrarily constrained.

Again, MSY and the overall $F_{0.1}$ solutions are in line with one another and the individual fleet $F_{0.1}$ is close to the status quo position. With profit defined as the difference between value (unadjusted by price elasticity) and cost (defined as equal to value at status quo levels of effort), the MEY can be calculated. Again it was necessary to impose a constraint on the industrial pelagic fishery. This solution is obtained by substantial reductions on the first three fleets and maintaining the status quo in the last three fleets. The reader is cautioned that extrapolation of these results beyond the effort changes simulated is not necessarily warranted because of the assumptions inherent in the method, and the fact that interaction effects among the individual fleets may not be fully represented.

8.2 An Age-Specific Approach to Changes in Selection Pattern

In previous sections, the effects of mesh change have been considered in relation to the changes that a specific mesh change in a specific fleet would have on the yield by species in all modelled fleets. Such an approach is realistic, because it considers the effects of the changing by-catches of other species as well as the effect on the species the mesh change was mainly aimed at. In this section, an alternative approach is adopted. This is to look at the effect of decreasing the fishing mortality on specific ages of fish by 10%. This would produce changes in popu-

lation in each of the ages of the various species of fish. Table 8.2.1 shows the percentage population changes that a 10% change in the younger ages of cod, whiting, saithe, mackerel, and haddock would cause if it were applied only to that age and species. It also shows the effects on populations of altering the fishing mortality on the 3+ age groups of these species. As an example of the use of the table, a 10% reduction in fishing mortality of 1-year-old cod would cause an increase in the populations of ages 3 and older of 1.1%. These population changes can be easily converted to yield changes by multiplying the average catch weight at age (assumed to be in a steady state) by the appropriate change in population of that age group. For the ages modified by the 10% change in effort, 10% should be subtracted from the change in population number. Thus, in the case of 1-year-old cod, a decrease in fishing mortality would cause a $-10\% + 0.6\% = 9.4\%$ change in yield of that age group of cod.

Table 8.2.2 shows the results of such yield calculations. For example, a decrease in the fishing mortality in 1-year-old cod would increase the total yield and also the yield of cod, but decrease the yield of other species, except sprat. A 10% decrease in the mortality of 2-group cod would lead to increases in the yield of cod, but to compensatory decreases in whiting and haddock. Decreases in the mortality of older cod would decrease the yield of cod, whiting, and haddock.

It is thus possible to see that, in principle, decreasing mortality on 1- and 2-group cod would be beneficial to cod, but would have yield consequences elsewhere in the system. In practice, the possibility seems remote of reducing mortality on young cod without also decreasing mortality on other predators, and it is, therefore, proper to consider these technical interactions when considering mesh changes. However, it is also useful, as here, to consider how in an ideal world the exploitation patterns of various species might be manipulated to maximize yield.

The calculations in this section were made using the Jacobian matrix approach (Pope, 1985) which makes slightly different assumptions from the MSFOR approach and may, therefore, give slightly different results. Clearly, these changes in mortality should also be considered under MSFOR to give results consistent with other parts of the report.

8.3 The North Sea before 1974

An attempt was made to hindcast conditions in the North Sea prior to the period that is currently being used in standard runs of the MSVPA (1974-1987). A simplified version of MSVPA was used to back-cast fishing mortality, M2s and population size for the period 1963-1973. Five species (cod, whiting, saithe, mackerel, and haddock) were included in the analysis. Catch-at-age data were used as inputs to the model for the period 1963-1980 for all species except mackerel; values for mackerel were available for 1963-1968 based on biomass estimates from Hamre (1978). Additional inputs for the model included mean weight at age, M1s, 1981 population size, terminal population size, and the M2s/unit predator numbers. All were taken from the current MSVPA run.

Results indicate that predation mortality rates (M2s) were probably higher in the 1960s than at present (Figure 8.3.1). Although these results are interesting, they do not explain the large increase in gadoid biomass that occurred in the mid-1960s in the North Sea after major declines in the biomass of mackerel and herring (Cushing, 1980).

Trends in recruitment for 1963-1973 did not appear to be related to spawning stock biomass although the size of several year classes of cod, whiting, mackerel, and haddock were much larger than during more recent times (Figure 8.3.2).

8.4 Inclusion of Additional Predator Species in Future MSVPAs

Since 1986, it has been assumed that the diet of other predators acting upon the system prey species was the same as the mean of that of the five MSVPA predators. This predation was included in the M1s for the model prey species. The biomass of the other predators is summarized in the 1988 report (Anon., 1988a, Table 2.5.2). From this it was concluded that the M1s could be taken to be constant throughout the period 1974-1987.

For some of the important predators, sufficient data may be available to incorporate them in the model in a less crude way, taking into account both species-specific feeding habits and abundances, including abundance variations due to seasonal migrations into and out of the area.

The principle is to assess the abundances of each of these predators separately and input these data into the model. Suitabilities for these predators and their contribution to the M2s can be computed within the model in the usual way. An algorithm is suggested in Figure 8.4. Because of the programming effort required, no attempt was made at the present meeting to implement this extension of the model.

The data that must be available are quarterly data for the abundance by age for the component which is within the North Sea. Furthermore, feeding data are needed as for the MSVPA species.

The Western Mackerel Stock

Data for the percentage of the western mackerel stock in the North Sea were presented in a working document (Iversen and Skagen, 1989). The necessary abundance data can be obtained by combining these percentages with the assessment data from the Mackerel Working Group. There is no reason to believe that the western mackerel in the North Sea has feeding habits different from those of the North Sea mackerel, except for their different distributions. The adult western mackerel is confined to the northeastern North Sea and a substantial part of the juveniles are in the southeastern North Sea. Hence, feeding data should be revised using the 1981 stomach sampling data from the appropriate areas.

Horse Mackerel

According to the latest report of the Working Group on Pelagic Stocks in Divisions VIIIC and IXa and Horse Mackerel (Anon., 1989h), two stocks of horse mackerel are recognized in the North

Sea. The North Sea stock is mainly confined to the southern North Sea, while the western stock is assumed to have a seasonal migration into the northern North Sea, resembling that of the western mackerel stock. Abundance estimates by VPA are given for the western stock back to 1982. The total biomass has varied between 584,000 and 1,403,000 t, but the fraction migrating into the North Sea is not known. Specific feeding data for this fraction are not available. For the North Sea stock, biomass estimates from acoustic surveys and egg surveys are available, giving an estimated total stock biomass of 153,000 t and a spawning stock biomass of 140,000 t, respectively. There seems to be a substantial reduction in the size of this stock since 1986, when it was in the order of 500,000 t. This is attributed to the rarity of strong year classes, the last being the 1982 year class. The available stomach data are summarized in Anon. (1988a). These are largely from the 3rd quarter. According to these data, the horse mackerel may be an important predator, in particular on 0-group whiting and herring.

Hence, the horse mackerel probably exerts both a substantial and variable predation pressure on the MSVPA prey species and it would be highly desirable to have the supplementary data for including them in the model.

Skates

Skates are considered as a predator on the MSVPA species and their predation is incorporated into the M1 values used in the present MSVPA model. Their biomass is assumed to be 300 000 t in the North Sea, based on tentative estimates of mean biomass for 1983-1985 made by Sparholt (1987). Daan *et al.* (1989) confirmed this estimate for the period 1977-1986 in which period they estimated the biomass to be 390,000 t.

The biomass estimates of skates was based on the assumption that the catchability of skates in the bottom trawl surveys (IYFS and EGFS) is equal to that of plaice. Preliminary calculations of catch rates obtained from the Dutch Beam Trawl Survey in August 1985-1986 indicated that the biomass of Raja radiata is 100,000 t, if it is assumed that 100% of the R. radiata in the swept area of the beam trawl is caught. If the catchability in the beam trawl is assumed to be similar to that of plaice, i.e., about 33%, the biomass of R. radiata is about 300,000 t. Thus, in agreement with the value used at present for estimating the contribution of skate's predation to M1.

Stomach content data for R. radiata were presented to the Working Group in a document by Vinther (1989) based on the examination of 1,838 stomachs from the first and the third quarter of 1983-1988. These data are given for the fish preys by length classes of R. radiata in Table 8.4.1. Fish contribute increasingly to the diet with increasing size of R. radiata. About 1/3 to 1/2 of the diet was fish for R. radiata greater than 25 cm. Sandeel are the most important fish prey and constitute about half the fish diet. Gadoids and flatfish are the next important fish preys.

Based on the length distribution of R. radiata from the Dutch Beam Trawl Survey and annual consumption rations estimates from the equation:

$$r = 2.0 * W^{0.67}$$

where r is ration, W is body weight, Vinther (1989) estimated the consumption by each length class, and the sums of the consumptions over the length classes are given in Table 8.4.2. The total consumption was 573,000 t if it is assumed that the total biomass of R. radiata is 200,000 t. The consumption of fish was 218,000 t of which sandeel constituted 111,000 t. Approximately, sandeel constituted 2/3 of the MSVPA preys eaten by R. radiata. This is at variance with the assumption that the diet of R. radiata is equal to the mean diet of the five MSVPA predators in 1981, where sandeel only accounted for about 30% of the MSVPA preys.

The other skate species are not accounted for by Vinther (1989) but as they are almost 100% fish eaters in the North Sea (Rae and Shelton, 1982) and as they constitute about 100,000 t [in the IYFS 176,000 t and in the EGFS 40,000 t in 1983-1985 (Sparholt, 1987), and 82,000 t in 1976-1986 (Daan et al., 1989)] they are of potential importance for the MSVPA model. The fact that the skate species other than R. radiata generally are larger and that catchability of larger skates is higher than of small skates in the IYFS (at least for R. radiata) could indicate that the biomass estimate of the other skates is an overestimate. However, in the context of predation on the MSVPA species, this is to some extent counteracted by a much higher proportion of fish in their diet than in the diet of R. radiata.

Thus the contribution from the other skates to the M_1 used at present seems reasonable and there seems to be no basis at present for improving the M_1 values in this respect.

However, there seem to be possibilities for improving the M_1 values according to the new data available on diet of R. radiata from Vinther (1989).

Because of the relatively moderate predation of R. radiata compared to the five MSVPA predators, R. radiata could probably be dealt with in a more crude fashion than the five MSVPA predators. Some ideas of how this can be done are given below:

- 1) A crude way of dealing with R. radiata could be to assume the mortality matrix to be constant over time, in which case the predation mortality matrix could just be added to the M_1 -mortality matrix.
- 2) The R. radiata could also be incorporated in the MSVPA model as indicated in Figure 8.4 for western mackerel. The abundance of R. radiata by age is not available from VPAs but a rough estimate of abundance by length class by year could be obtained from the IYFS and EGFS surveys. The stomach data available could be given by length class resulting in suitability by length class.
- 3) The predation of R. radiata by species and age could be transformed into a matrix of predation mortalities like fishing mortalities of a fishing fleet and treated in a similar way as a fleet. Then fluctuations in biomass of R. radiata could be regarded as fluctuations in effort of a fishing fleet. This relates in the present versions of the MSVPA only to the forecast situation.

8.5 Predator/Prey Response Models

An important component of recent efforts to model biological interactions in large marine ecosystems is the response of predators to changes in prey abundance. Most studies suggest that predator mortality rates (M2s) for the youngest age groups are much higher than previously thought from single species analyses. Results to date from several independent modelling efforts also suggest that predation may only act as a scaling factor on recruitment, thus recruitment estimates from SSVPA and MSVPA are highly correlated (Gislason and Sparre, 1987). If this is true, it could be an important improvement in our understanding of marine ecosystem dynamics. However, other interpretations are possible, and model structure may be a major contribution to current results.

If predators respond differentially to changes in prey density, then predation may be a source of variation in cohort strength for marine fish populations (Hildén, 1988). Theoretical work tends to suggest that predation in some cases may be a stronger influence in determining year-class strength than our present understanding may suggest.

Several examples of possible instances of differential response of predators to fluctuating prey abundance were discussed in the Working Group. Major diet composition changes in Northeast Fisheries Center data during 1969-1986 were noted and possible instances of predator crowding or switching on a large mackerel year class were mentioned. These examples from the NMFS data base are suggestive, but do not provide conclusive proof.

The responses of predators to prey under several different model formulations were discussed. Some of these response models have already been, or are currently being used in the MSVPA (Figure 8.4). The type 3 model has not been utilised to date but it may be of interest since it does provide a differential response over the range of prey density (Figure 8.5.1).

The possibility of doing additional theoretical simulation and field work to increase our understanding of these critical issues was discussed. It was suggested that another year of comprehensive stomach sampling in the North Sea (1991) was essential for the resolution of the problem of changing suitabilities. Additional special field sampling to study particular problems of interest was also recommended.

The Working Group also felt that more theoretical and simulation work on this subject was also warranted. In particular, for species with wide annual variation in recruitment (e.g., haddock) there may well be reduced predation rates on vulnerable sizes, as predators are "swamped" by the large year classes. Stochastic simulations employing variable recruitment and alternative predation-response models could be of great utility in interpreting potential density-dependent predation rates.

9 INTERPRETATION OF ECOLOGICAL PROCESSES FROM MSVPA RESULTS

An important aspect of the analyses conducted by the Working Group, apart from assessing potential management-related impacts, is to elucidate the underlying ecological processes and mechanisms involved in biological interactions among components. In this section we integrate some of the specific results of MSVPA and the predictions from MSFOR, into the wider context of trophic studies in the North Sea and elsewhere. Results from MSVPA and related analyses allow for comparison with energetics studies conducted in the North Sea system, particularly by Jones (1984). We also consider aggregate size compositions (in numbers and biomass) as potential indicators of system-level change due to intensive exploitation along the size spectrum of fishes in the North Sea.

9.1 Aggregate Size Distributions as Indicators of System Response to Exploitation

Aggregated length distributions (of all fish species combined from groundfish surveys) have been studied for the North Sea and Faroe Bank by Pope and Knights (1982) and more recently for the North Sea and Georges Bank by Pope *et al.* (1988). In those papers it was noted that the slopes of the size distributions may be conservative despite species composition changes, but responsive to changes in exploitation regime.

Although the multispecies system considered by this Working Group consists of only a small subset of the total North Sea species complex, it seems a potentially instructive exercise to calculate aggregate length distributions for the MSVPA species. These distributions might then serve as useful diagnostics of the health of the multispecies system both in the past and in the future, in response to various management options. Consequently, length distributions have been constructed for early and late MSVPA years (1974 and 1984) and various long-term predictions (baseline, change to 120 mm. mesh for cod fishery, 50% effort reduction overall, in the industrial fishery, and in the human consumption fishery).

To compute the length distributions, average stock weights at age, as used by this Group, were converted to lengths at age via appropriate condition factors, coupled with a cubic length relationship for weight. The estimated numbers at age for the various MSVPA years or prediction runs were then assigned to 5 cm length groups and aggregated over species, to give aggregated size distributions. Figures 9.1.1-9.1.4 show these logged distributions for each quarter for the seven years/scenarios considered. Each scenario is plotted as log (aggregate numbers) plus i , where $i = 1..6$. This is done for clarity of presentation only. Also, age 0, and the plus groups of all species are eliminated from the plots.

Although presented on a quarterly basis, there are no statistical differences in the slopes by quarter. Grouping scenarios over quarter and fitting slopes within scenario, indicates no statistical difference between the 1984 estimated distribution and either the baseline or 120 mm mesh change scenario distributions. These are also not statistically different to the 1974 distribution. The statistics on this comparison, however, whilst not

significant at the 5% level, are indicative of a change. That is, in 1974 there were more large fish in the system. By 1984 and under current exploitation conditions, or a change to 120 mm mesh for cod, there are not, and are not likely to be, as many large fish in the system.

This conclusion also applies to reducing the industrial fishery effort by 50%. A 50% effort reduction overall in the North Sea fisheries, or in the human consumption fisheries, however, does produce significantly different slopes of the size distributions. These two strategies, in fact, would return the predicted size distribution close to that observed in 1974.

Such drastic reductions in human consumption fishery effort, though, are predicted to have major impacts on haddock stocks. Table 9.1 shows percentage changes from baseline, of various statistics, for the 50% effort reduction scenarios. It is clear that reducing mortality on roundfish stocks may lead to a rapid expansion of saithe which, in turn, has a severe, detrimental effect on haddock and Norway pout stocks.

The question, therefore, arises as to what is a healthy system. Clearly, size distribution alone cannot be used as a measure; just as simple overviews of particular stock statistics, they can be misleading. A combination of fishery statistics and biological information, such as size or biomass spectra, might give us better ideas of how our actions may change the systems that we exploit and seek to manage wisely.

The shape of the distribution is lower in these scenarios but the whole distribution pivots around a point of size category 4-7. The intercept, therefore, also reduces (though not significantly). Overall, therefore, the total numbers (and may be biomass) in the system might be invariant. This needs to be investigated.

9.2 Biomass Spectrum as a System Descriptor and Basis for Analysis of Predation and Exploitation

The normalized biomass spectrum of an ecosystem is assumed to synthesize the basic biological processes of the system besides providing a condensed description of overall system structure (Platt and Denman, 1978). Normalized particle spectra are comparable between systems and allow comparison within one system over time. The first attempts to compare systems and relate the slopes of their normalized biomass spectra to basic system characteristics have been made (e.g., Sprules and Munawar, 1986) and applications to fish stock assessment have been proposed (Dickie *et al.*, 1987).

The biomass spectrum characterizes the ecosystem by two parameters: the biomass at a reference particle interval and the slope (Figure 9.2.1). Predation can be analyzed in terms of two further parameters: the predation distance within the spectrum [$\text{mean log}(\text{prey}/\text{weight}/\text{predator}/\text{weight})$] and the predation window width, that is the width of that fraction of the spectrum which is utilized by the predator size in question. The predation window width can, for instance, be expressed as the standard deviation of $\text{log}(\text{prey}/\text{weight}/\text{predator}/\text{weight})$ (Andersen and Ursin, 1977). Since the normalized biomass spectrum is

integrable, the biomass available to a predator is directly proportional to the width of the predation window (Figure 9.2.1).

The size structure of the stocks included in the MSVPA has been analyzed on a spectrum basis. Average stock sizes, predation mortalities, and individual weights for the period 1974-1988 have been used to calculate the biomass spectrum and predation parameters. Mean consumption (partial natural mortality times prey biomass) has been used as weight for computation of mean predation distance and predation window width.

The spectrum for North Sea MSVPA stocks (Figure 9.2.2) has a slope of -1.4 for the linear part of the spectrum. A slope of -1 is to be expected on theoretical grounds for pelagic planktonic systems, and has been found to conform well with findings in unperturbed systems (Sprules and Munawar, 1986). No independent spectra for the size window containing fish have been found in literature, but the theoretical basis of the normalized spectrum is that the slope is maintained over very large particle size ranges. The slope of the average North Sea spectrum is thus lower than expected for an unperturbed system. This is to be expected in a state of exploitation and the difference between expected unperturbed slope and actual slope can be utilized as a measure of exploitation rate.

Mean predation distance shows a tendency to increase with size for all predators taken as a whole (Table 9.2.1). This increase is, though, not sufficient to keep up with predator growth; the predation window does move with predator size. The width of the predation window is constant with increasing predator size for all predators (Table 9.2.1). A population of predators acting in a linear biomass spectrum will maintain a constant availability of prey biomass relative to its own biomass if predation distance and predation window width remains constant during predator growth. In the North Sea case, the predators do have access to an increasing prey biomass base relative to their own biomass by moving the window slower up the spectrum than their own growth while at the same time keeping the predation window width constant. This observation must, though, be qualified by the fact that other food, which is most important for the smaller predator sizes, is missing from the lower end of the spectrum as well as in the calculation of predation distance and window width.

This general pattern of predation is applied by all individual predator species except mackerel, which shows a constant mean predation distance across sizes (Table 9.2.2).

The predation pattern shows consistent patterns across predators (Table 9.2.2). The predation window width is largest for cod (mean .42), followed by mackerel, whiting, and haddock, with saithe the narrowest (mean .17). The mean predation distance for similar size predators is lowest for cod (-1.18 for 800 g fish) and highest for saithe (-2 for 1,000 g fish). This inverse relationship between predation distance and predation window width can be interpreted as a compensatory mechanism securing a constant prey biomass base with variable predation pattern.

These findings and the predation patterns of individual predator species are in general accordance with the results of the suitability analyses (Section 6.8 and appropriate figures).

The response of system structure and predation parameters of the spectrum to exploitation has not been investigated in the present exercise. It would be valuable to look at the spectrum and predation patterns in subsets of the time series of MSVPA data available.

9.3 Energy Budget

Jones (1984) proposed a possible pathway for the flow of energy in the North Sea from the primary production to the commercial fish stocks. The basis for his proposals of the pathway directly related to the fish was rather limited due to lack of data on the food composition of the fish and their consumption rations. In connection with establishing the North Sea MSVPA, these data have been collected and worked up since 1981. Therefore, it seems possible to improve Jones's proposals for the energy flow through the fish stocks.

Figure 9.3 shows the pathway proposed by Jones (1984) for 1968-1970 compared to a proposal for 1974 based on the present version of the MSVPA model. Energy flow through plants, herbivorous zooplankton, benthic detritivores, meiobenthos and bacteria, large benthic carnivores, and invertebrate carnivores are equal in the two proposals and like those proposed by Jones (1984). These could however be underestimates because the primary production of $130 \text{ g C/m}^2 \text{ yr}$ used by Jones are too low according to Franz and Gieskes (1984), who estimated it to be about $200 \text{ g C/m}^2 \text{ yr}$ based on measurements between 1971 and 1981, although they do not take into account the influence of the microbial loop, which would permit a part of the energy to go to the zooplankton and benthic organisms.

In the Jones-proposal, the entity for mackerel and herring has been changed to contain mackerel alone and herring have been included in the entity of other primary carnivores in order to make the comparison to the MSVPA estimates easier. In making this modification, it is assumed that the energy flow from other primary carnivores to the mackerel-herring entity is unchanged by the transfer of herring from the mackerel-herring group, i.e., no primary carnivores are eaten by herring. The harvest by man is added to Jones's model in the following way:

1. Mean catch of mackerel in the North Sea and Division IIIa for 1968-1970 taken from Hamre (1978), and western stock mackerel caught in the North Sea or Division IIIa are included.
2. The harvest of other primary carnivores are herring, sprat, sandeel, and Norway pout. Data from Popp Madsen (1978).
3. Demersal fish catch only includes cod, haddock, whiting, and saithe. Data from Holden (1978).

As can be seen, 0.5 million t are not accounted for in the harvest by man. These are mainly plaice, sole, dogfish, and various industrial fish.

The entities mackerel and demersal fish only includes exploited stocks.

In the MSVPA-proposal the entity "other primary carnivores" consists of herring, sprat, Norway pout, and sandeel plus some of the small specimens of cod, haddock, and whiting. Mackerel's consumption of these species is taken as its consumption of MSVPA species and mackerel's consumption of herbivorous zooplankton is taken as mackerel's consumption of other preys from the MSVPA run. The entity "demersal fish" consists of cod, haddock, whiting, and saithe. Their consumption of "other primary carnivores" is, as for mackerel, taken as their consumption of MSVPA species and their consumption of other food is assumed to consist of "benthic detritivores".

The mackerel catch does not include the western stock mackerel caught in the North Sea or Division IIIa. According to Hamre (1978), the total mackerel catch in the North Sea and Division IIIa was 318,000 t in 1974 and, therefore, the amount of western mackerel in the catch must have been 120,000 t.

Comparing the two proposals it can be seen that generally the MSVPA-proposal indicates higher food demands than the proposal by Jones. For mackerel the demand of food is 6.2 million t in the MSVPA-proposal while it is only 3.8 million t in Jones proposal. The biomasses of the mackerel stock are approximately equal in the two periods 1968-1970 and 1974 and the reason for the difference must, therefore, be a higher consumption rate used in the MSVPA-proposal. The reliability of this is discussed elsewhere in this report. The relative contribution to the food from herbivorous zooplankton and other primary carnivores is in the MSVPA-proposal 56% and 44%, respectively, while in Jones' proposal it is 53% and 47%, respectively, and thus very similar.

Demersal fish in Jones' proposal include commercial exploitable stages of cod, haddock, whiting, saithe, plaice, sole, and a group of other species containing a rough estimate of the food demand of about 30 minor species. The food demand of these other species was set by Jones to 37% of the food demand of cod, haddock, whiting, saithe, plaice, and sole. In the MSVPA version the demersal fish unit contains the biomass at 1 January of cod, haddock, whiting, and saithe. Except for the other species in Jones' proposal the biomass in the demersal fish unit is almost identical in the two proposals. The food demand is 9.3 million t in Jones and 9.0 in the MSVPA and thus rather similar. The relative contributions from benthic detritivores and other primary carnivores for the Jones method are 53% and 47%, respectively, while they are 62% and 38%, respectively, in the MSVPA, and fish are thus less important in the MSVPA than proposed by Jones.

9.3.1 The biomass of other food

In some of the versions of the MSVPA model it is important to have a measure of the biomass of other food or of the total biomass of the MSVPA species and the other food, although not in the version presently used by this Working Group.

According to the pathways of the energy flow shown in Figure 9.3 the trophic levels of mackerel and the demersal fish are approximately similar. According to Jones (1984), the biomass of food of these two groups are also similar. However, the production of the food items of mackerel are much higher (caused by the high production of herbivorous zooplankton) than that of the demersal

fish food items (benthic detritivores). This indicates that the food potential for mackerel is much higher than for the demersal fish, which can only benefit from the pool of herbivorous zooplankton indirectly by predation on "other primary carnivores". This indicates that it is unlikely that the demersal species can increase much above the 1974 level due to the lack of food while the mackerel have better prospects, as have the "other primary carnivores" exploiting the same pool of herbivorous zooplankton (although mackerel and "other primary carnivores" obviously differ with respect to which compartments of the zooplankton they can utilize). This corresponds to the fact that the demersal fish biomass has never been higher than around 1970 and that the mackerel stock has been as large as 3 million t before its decline in the late 1960s. One interesting consequence of these considerations is that not much food was left for dab around 1970, and it might be possible to check whether this corresponds to the biomass of dab in the North Sea at that time, for example, by considering catch rates in bottom trawl surveys.

However, in all these considerations it must be remembered that both the level of primary production given is probably an underestimate and that the transfer efficiencies arbitrarily are set to 15%. Another problem is that transforming the production to biomass estimates demands a P/B ratio which is difficult to give a precise estimate of and which probably varies considerably from season to season [for example, the zooplankton biomass estimate given by Steele and Henderson (1977) varies between 0.5 and 14 g m⁻² DW].

As shown in Section 9.2, the size spectrum of fish in the North Sea seems reasonably constant. If this holds true for other "particles" than fish, we can obtain the biomass of other food for each size group of fish if we know the food size "window" for each group.

9.3.2 Upper limit to the biomass and production of fish

There is of course an upper limit for the production and biomass of fish in the North Sea and the biomass of fish is, to some extent, limited in the present version of the MSFOR model by assuming the recruitment to be constant or varying stochastically around a constant. However, this could create unrealistic biomasses of some fish or group of fish and depends of course on the actual recruitment values used. The above energy flow considerations might give some ideas about the value of these limits. As stated above the demersal fish reached their upper limit around 1970 according to the pathways for the energy flow presented above and there was room for an increase of mackerel as well as for the other primary carnivores fish such as herring, sprat, Norway pout, and sandeel. If we are assuming that the other primary carnivores have a transfer efficiency of 15%, their demand was 51 million t in 1974. This would leave 11 million t for the invertebrate carnivores which potentially is available for other "primary carnivores" and mackerel. As the catch of these species was 1.8 million t in 1974, these catches could potentially be about $11/51 * 1.8 = 0.39$ million t higher, if all herbivorous zooplankton was eaten by those fish instead of by carnivorous invertebrates.

Again it must be stressed that all these considerations are at most qualified guesses and can only give some very rough indications of the potential output of some crude ecological groupings of fish from the North Sea. The data and assumptions are indeed so variable that they do not exclude the possibility for, say, doubling the output from the North Sea, which probably nobody would believe anyway, and it can thus indeed be questioned whether such considerations are of any value at the present stage of knowledge of the various components of the North Sea ecosystem.

10 MULTISPECIES MODELS IN OTHER AREAS

10.1 Introduction

The Multispecies Working Group was established in part to improve and expedite the general development of numerical approaches to evaluation of biological and technical interactions in fisheries ecosystems. This is reflected in the continuing term of reference to 'continue the development of multispecies methods of assessment'. To this end, the Working Group has routinely evaluated multispecies research efforts in various locations other than the North Sea, including the Baltic Sea (Anon., 1988a), the Barents Sea (Tjelmeland and Bogstad, 1989), in Icelandic waters, and in the western North Atlantic. Working Group members consider this wide geographical scope to be important for two reasons: 1) because a wider scope results in a larger number of experts in the field who will participate in Working Group activities, and 2) we believe that the collective expertise of the Group can be of considerable use in evaluating the various programs as they develop. In this section, multispecies research programs in the boreal waters and off the Northeast USA are reviewed. Also, we consider aspects of methods developed explicitly for the North Sea that may have more general applicability to analyzing multispecies problems.

10.2 Boreal Multispecies Meeting

A specific term of reference for the Multispecies Working Group this year is to hold a special meeting in Bergen, Norway, to review progress in modelling multispecies interactions in boreal waters. Currently, considerable multispecies research is being undertaken in such systems (e.g., by Norway, Canada, Iceland, USSR, etc.). Norwegian and Canadian researchers have considered the format and some potential topics to be considered in the boreal multispecies meeting, including:

- a) comparative review of boreal ecosystems with special reference to species interaction,
- b) establishment of a common framework for the analysis of such systems,
- c) technical issues related to the exchange of information among various researchers,
- d) unified progress in understanding attributes of such systems, including migration, growth, maturation, predation, etc.

The meeting will be held in early 1990, with specific details to be forthcoming. The Multispecies Working Group is very supportive of this effort and urges participation not only of researchers and governments specifically involved in boreal research, but of a wider scientific community as well.

10.3 Predator/Prey Interactions off the Northeast USA

Potentially large numbers of marine mammals reside on the east coast of the USA, but the impact of these animals on specific fish prey has not been quantified. A simple method for estimating consumption by marine mammals on the pelagic fish ecosystem was presented to the Working Group. Aerial and shipboard estimates of seasonal abundance, available food habits literature, results from current feeding studies, and seasonal distribution data for mammals (Figure 10.3.1) and fish were used in a simple energetics model to estimate age specific consumption by ten species of mammals.

Since there are no population age-specific data available for marine mammal populations off the eastern USA, a simple energetics approach for calculating consumption was utilised (Hinga, 1978; Kenny *et al.*, 1983). A model that uses average body size (Lockyer, 1981) was used to estimate consumption as

$$(1) \quad \text{NBR}_i = (\text{Wt}_i)^{.783}$$

where NBR_i = net daily basal ration in Kcal
 Wt_i = Body weight of mammal in kg
 i = species

This model has been used to estimate consumption for a many marine mammals (Kenny *et al.*, 1983). To correct for an assimilation rate of 80%, this estimate was increased to account for basal respiration as

$$(2) \quad \text{GBR}_i = 1.24 * (\text{NBR}_i)$$

where GBR_i = gross basal ration Kcal/day.

Since marine mammals are actively feeding during the time they are found on the east coast of the USA, another correction for active metabolism is necessary as

$$(3) \quad \text{DAR}_i = \text{GBR}_i * (\text{AC})$$

where DAR_i = daily active ration
 AC = activity coefficient (1.5 or 3.0).

Hinga (1978) suggests that activity coefficients for marine mammals probably range from 1.5-3.0 times the basal rate. Using energy equivalent methods, the daily ration in Kcals/day is converted to g/day with coefficients available from the literature (Steimle and Terranova, 1985).

$$(4) \quad \text{DR}_i = \text{DAR}_i / C$$

where DR_i = daily ration g/day
 C_i = 1.3 Kcal/g (conversion for fish and squid).

Consumption by marine mammals was then calculated by using quarterly estimates of abundance and assuming that animals obtained their full daily ration (DR) during each day of the quarter.

$$(5) \quad C_{ijk} = DR_i * N_{ik} * S_{jk} * 91.25 \text{ days/qr}$$

where C_{ijk} = consumption by marine mammals
 N_{ik} = quarterly numbers of marine mammals
 S_{jk} = quarterly stomach % by weight
 i = species of mammal
 j = fish prey species
 k = quarter.

Since quarterly estimates of abundance were uncertain, direct estimates of stomach contents were in some cases not available, and the preferred estimate of activity coefficients were not apparent, a sensitivity analysis of consumption estimates to these factors was made. The analysis was designed to look at a range of results for the three factors.

Total consumption by marine mammals ranged from 46,000 t to 828,000 t, depending on the combination of factors (abundance, diet composition, metabolism) used in the analysis. A best estimates of consumption based on the current point estimates of abundance, and activity coefficient of 1.5 and a set of mid-range diet percentages was about 120,000 t (Figure 10.3.2). Results suggest that five species (finback, pilot, humpback, common dolphin, and harbour seal) account for most of the consumption. Finback whales probably account for about half of the total consumption. The approach outlined to the Working Group may be useful for assessing the impact of marine mammals in the North Sea or other areas.

10.4 Generalization of MSVPA Results to Other Areas

The specific results from MSVPA studies of the North Sea are generalizable to other systems in a number of dimensions. Preliminary work conducted at last year's meeting (Anon., 1988a) examined the utility of general relationships between calculated M2 values and the mean weight of the prey organisms. When corrected for the relative predator density of systems, such relationships may be a comparable measure among systems. The Working Group stresses, however, that M2 values computed for North Sea stocks are not necessarily those to be expected for the same or similar species in other regions.

Section 9 of this report presents MSVPA results in a manner which may be more generalizable among areas. Although preliminary, analyses of the length and weight spectra of the system may indicate predation processes that are conservative within the North Sea system, and which are consistent with such studies conducted elsewhere. It should be noted, however, that these results have only considered the processes of fish feeding on fish, and not the 'other food' category. Thus, the ratio of fish to 'other food' consumed by fish must be considered when comparing these

results among systems.

The comparative analysis of aggregate species size compositions among systems (e.g., North Sea and Georges Bank; Pope *et al.*, 1988) holds promise as a simple method for understanding in a crude manner the influence of size and species-specific predation on exploited fishery systems. Further tests of this method by comparison with trawl survey results from other areas seem highly desirable.

11 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- 1) Multispecies analyses of the effects of adopting a 120 mm minimum mesh-size regulation when fishing for cod indicated a slight decline in expected long-term cod yield (~3% as compared to long-term simulations with 85 mm mesh), but significant gains in total and spawning stock biomasses (17% and 31%, respectively), and in the landed value of cod (4%). Under the 120 mm mesh scenario, long-term catches of some species (haddock, whiting, Norway pout, and herring) would decline substantially, primarily as a result of increasing predation by higher cod and whiting biomasses.
- 2) A series of alternative policies were evaluated as to their long-term implications for the balance of gains and losses in yields and stock biomasses. However, these analyses should only be considered suggestive rather than definitive, since only a limited set of potential management scenarios was simulated.
- 3) A series of medium-term (9-year) projections was made to simulate the transition effects on yields and biomasses from the short to long term, of implementing the 120 mm mesh policy. These analyses indicated less short-term loss of cod yield, and more rapid accumulation of biomasses than have previous single-species assessments.
- 4) The analysis of economic consequences with regard to particular management scenarios should be considered tenuous due to the fixed price/volume relationships included in the MSFOR model. The model accounts for the differing prices expected by market (size) categories for some species, but does not incorporate the elasticities of price to volume of the same species or market substitutes.
- 5) Stochastic simulations were based on recruitment drawn from a log-normally distributed recruitment function, with parameters estimated from results of MSVPA. Stochastic yield simulations incorporating explicit stock/recruitment relations are potentially an important extension to these analyses. The interaction of stock/recruitment relations and the functional response of predators to prey densities is likely a key element in understanding the role of predation in determining year-class strength.

- 6) The Working Group stresses to ACFM and others its increasing confidence in the underlying assumptions of the predator/prey feeding relationships that are the basis of MSVPA. In particular, information reviewed on the estimation of predator/prey suitabilities and the prediction of empirical feeding data by the model are the basis of such confidence.
- 7) The attention of ACFM is drawn to our conclusions regarding the use of smoothed values of suitabilities and/or M2s. Statistical modelling of these attributes resulted in acceptable overall model fits, but the underlying processes implied by such fits may not be biologically realistic [e.g., parabolic relationships of suitability to predator size predict a small number of cases in which prey (meal) size exceeds the size of the predator]. Additional work on this subject appears warranted particularly with regard to the apparently asymmetric distribution function of prey selection by predators.
- 8) A general conclusion of the results of the Multispecies Working Group is that long-cherished single-species bioeconomic reference points ($F_{0.1}$, F_{max} , $F...$) are not necessarily appropriate or desirable in a multispecies/multifleet context. This conclusion then implies the articulation of alternative bioeconomic reference points for the system as a whole. Such reference points could include aspects of species composition and aggregate size structure, degree of stability in catches and stock sizes, and marginal economic performance by various fleet sectors, among others. One such set of alternative system-wide reference points is explored in Section 8.
- 9) One of the terms of reference for the meeting was to advise on the effects on yield, biomasses and value consequent on changes in selection pattern. In principle, this is not difficult to do. However, if changes in selection pattern are to be accomplished through mesh changes, the number of potential options to be explored is limiting (i.e., which mesh sizes applied to what fisheries?). In Section 8, an age-specific approach to the estimation of changes in selection pattern is proposed. These analyses have the virtue of being independent of the operational details of how the selection pattern is to be modified (e.g., how mesh regulations are implemented), and thus establish the basis for attempting mesh or other regulation intended to improve selection patterns.
- 10) Results of MSVPA have primarily been seen as an aid to the development of fishery management policy and advice. In Section 9, we evaluate the results of MSVPA with regard to trophic ecological studies of the North Sea and elsewhere. Results have important implications since they suggest that compensatory responses observed in the North Sea system are consistent with contemporary ecological theory. Of particular interest are the aggregate species length and biomass compositions, which appear to be conservative biological properties of the system, even under intensive size-dependent harvesting. Energy budget calculations for the North Sea are updated, and compared with earlier estimates.

- 11) Finally, the Multispecies Working Group reiterates its belief that it should not be considered the North Sea Multispecies Working Group, but rather a more general group devoted to methodological development and application. In this regard the Group feels it is unwise to pursue a separate exercise involving boreal multispecies or other such systems. Rather, the members of the Working Group believe that the considerable expertise heretofore developed should not be diluted among several working groups pursuing similar problems.

Recommendations

- 1) The stomach content data for cod, whiting, and saithe collected during the years 1985-1987 should be published in the Cooperative Research Report series, under the editorship of N. Daan.
- 2) The Working Group heartily endorses the recommendations of the Planning Group on the Stomach Sampling Project for 1991, and, in particular, the recommendation to national governments for additional ship time and related resources for the timely collection and analysis of feeding data in 1991.
- 3) The Working Group emphasizes that results of the Workshop on Stomach Evacuation Rates (Lowestoft, April 1989) are, and will be, of vital importance to the evaluation of multispecies interactions, and strongly endorses its recommendations, especially concerning guidelines for the conduct of gastric evacuation experiments, and the comparison of alternative sampling schemes for stomach contents (e.g., bulked vs. individual stomachs).
- 4) The Multispecies Working Group appreciates the cooperation of various single-species working groups in providing timely access to quarterly catch-at-age data. One problem encountered, however, is that the quarterly catch-at-age data are rarely updated when final catches are available to the other working groups. The Multispecies Working Group respectfully requests that updated quarterly catch-at-age information be provided, if such updates are warranted.
- 5) The ICES Multispecies Working Group and the EC STCF Working Group on Improvements of the Exploitation Patterns of North Sea Fish Stocks are conducting a number of complimentary research projects relating to biological and technological interactions of North Sea fish stocks. It is recommended that there be close cooperation between the Multispecies and STCF Working Groups, and, to the extent practicable, Chairmen of the two Groups participate in both meetings.
- 6) It is recommended that the next meeting of the Multispecies Working Group occur in 18 months time (early December 1990), and that the following terms of reference be considered by ACFM for that meeting:

- a) continue the development of multispecies methods of assessment;
 - b) consider how to better incorporate 0-group predation in quantitative models of interspecies predation, particularly with regard to data being collected in the 1991 stomach program;
 - c) conduct medium- and long-term stochastic simulations incorporating multispecies effects, with emphasis on functional feeding relationships and stock/recruitment relationships;
 - d) explore the utility of various population attributes for comparing underlying trophic mechanisms among fishery ecosystems;
 - e) conduct any additional evaluation of the multispecies implications of fishery management scenarios, as requested by ACFM.
- 7) The Multispecies Working Group acknowledges the generous support of the Secretariat in accommodating its needs for substantial mainframe and micro-computer resources. However, the Working Group's activities have significantly disrupted normal computer functions at the Secretariat, when it has met at the Headquarters. The problem of computer access is particularly acute when other working groups have met coincident with the Multispecies Working Group. Given its projected intensive needs for higher-level computing resources (in accordance with the suggested terms of reference), the Multispecies Working Group recommends that the next meeting be convened in Woods Hole, USA.

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Table 2.8.1a. Output from MSVPA key run for cod.

FISHING MORTALITY		COD							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0842	.1441	.0582	.2295	.1165	.1871	.1521	.1645	.2489
2	.8210	.7608	.9762	.8605	1.0628	.8369	.9014	1.0101	.9501
3	.7202	.8032	.8500	.7245	.9499	.9278	.9323	.9701	1.2315
4	.7090	.6647	.8004	.5628	.8109	.5376	.7314	.7204	.7851
5	.7119	.7908	.6128	.5707	.9616	.7341	.5716	.6391	.7777
6	.7030	.6803	.9125	.4547	.7490	.5437	.6006	.6426	.8429
7	.6959	.7473	.8659	.5549	.7347	.6595	.7195	.7286	.6895
8	.7221	.5414	.4969	.6117	.8708	.5083	.7091	.6326	.7229
9	1.1287	.9462	.4604	.5342	1.0076	.7728	.6285	.6881	.6889
10	.6956	.9239	.9486	.3930	.7991	.7382	.7010	.6972	.5803
11	.6000	.6002	.6002	.6002	.8013	.6334	1.1465	.2155	.9520
MEAN F (UNWEIGHTED) FOR AGES 2 TO 8									
	.7204	.7126	.7893	.6229	.8771	.6783	.7380	.7691	.8571
AGE	1983	1984	1985	1986	1987	1988			
0	.0000	.0000	.0000	.0000	.0000	.0000			
1	.1659	.2315	.1544	.2200	.1565	.2029			
2	1.0733	.9774	.9738	.8822	.8854	.8075			
3	1.1457	.9774	.9118	1.0926	.8602	1.1234			
4	.8577	.7266	.8276	.8936	.8214	1.4653			
5	.7820	.7182	.6985	.8217	.6861	.6663			
6	.7773	.7644	.7062	.8849	.8357	.7993			
7	.7147	.7478	.7598	.9250	.8195	.6753			
8	.7248	.8125	.8228	1.0539	1.0177	.6683			
9	.5950	.8319	.6580	.8749	1.4702	.7553			
10	.5203	.9318	.4289	1.1788	1.1538	1.9262			
11	.5592	.9567	.9504	.2490	.7490	2.2243			
MEAN F (UNWEIGHTED) FOR AGES 2 TO 8									
	.8679	.8177	.8143	.9363	.8466	.8865			
STOCK NUMBERS		COD							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	313150.	478314.	226159.	856885.	523735.	540494.	1095753.	415661.	673549.
2	122761.	111269.	179035.	91543.	289699.	180389.	176010.	358126.	118035.
3	24179.	34764.	35486.	46876.	26575.	68439.	53446.	48727.	86409.
4	32031.	8405.	11887.	11535.	17321.	7775.	20766.	15856.	13775.
5	9434.	12907.	3540.	4371.	5273.	6303.	3718.	8182.	6317.
6	1993.	3790.	4792.	1570.	2022.	1650.	2477.	1719.	3397.
7	948.	808.	1572.	1575.	816.	783.	785.	1112.	740.
8	793.	403.	313.	541.	740.	320.	331.	313.	439.
9	514.	316.	192.	156.	240.	254.	158.	134.	136.
10	164.	136.	100.	99.	75.	72.	96.	69.	55.
11	433.	121.	80.	58.	87.	49.	38.	115.	41.
TOTAL STOCK BIOMASS ON 1. JANUARY									
	327850.	287949.	286530.	266181.	356341.	323398.	361382.	429281.	354093.
SPAWNING STOCK BIOMASS ON 1. JANUARY									
	169107.	141678.	118075.	99757.	114265.	102785.	117749.	129176.	132334.
AGE	1983	1984	1985	1986	1987	1988			
0	0.	0.	0.	0.	0.	0.			
1	344752.	624458.	132538.	587913.	280769.	197061.			
2	215961.	111392.	220650.	46596.	207091.	101136.			
3	30337.	49805.	29102.	58160.	13470.	60761.			
4	19095.	7244.	14542.	9007.	15181.	4411.			
5	5144.	6631.	2868.	5204.	3017.	5467.			
6	2376.	1927.	2648.	1168.	1873.	1244.			
7	1197.	894.	734.	1070.	395.	685.			
8	304.	480.	347.	281.	347.	142.			
9	175.	121.	174.	125.	80.	103.			
10	56.	79.	43.	74.	52.	15.			
11	47.	40.	37.	63.	30.	15.			
TOTAL STOCK BIOMASS ON 1. JANUARY									
	314698.	263130.	275694.	229418.	244714.	223433.			
SPAWNING STOCK BIOMASS ON 1. JANUARY									
	116181.	98040.	93884.	89825.	79966.	77617.			

Table 2.8.1a. (continued).

AGE	PREDATION MORTALITY			COD					
	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.8264	.9751	.8126	.6840	.7498	.6583	.7171	.5253	.5005
1	.4705	.3586	.3663	.3750	.4693	.4549	.4862	.6144	.4086
2	.1706	.1120	.0938	.1063	.1101	.1096	.1130	.1417	.1385
3	.1266	.0599	.0538	.0611	.0692	.0548	.0728	.0833	.0682
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

AGE	1983	1984	1985	1986	1987	1988
0	.4257	.5231	.4485	.5104	.7359	.8076
1	.6545	.3288	.4110	.3434	.3844	.4025
2	.1236	.0949	.0896	.0888	.0708	.0745
3	.0765	.0437	.0510	.0406	.0463	.0294
4	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000

Mortality of 0-group is for 3rd and 4th quarter only
 NORTH SEA DATA 1974-1988 (MULTISPECIES WORKING GROUP 1989)
 WITH SIMMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.8.1b. Output from MSVPA key run for haddock.

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FISHING MORTALITY		HADDOCK							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.0158	.0163	.0258	.0206	.0289	.0469	.0498	.0613	.0353
1	.3696	.3577	.3397	.3268	.3408	.1687	.2292	.1929	.2236
2	.9222	1.0301	.8438	.9893	.8241	1.0069	.8036	.4631	.4544
3	.9450	1.2958	1.4220	1.0448	1.0657	1.4368	1.2139	.9251	.8217
4	.9951	1.1344	.8063	1.2886	1.1223	1.0030	1.1066	.9948	.8813
5	.7066	1.0292	1.3840	1.0605	1.1203	.9785	.7142	.6365	.6028
6	.9456	.6719	1.1574	1.0559	1.0425	1.0525	.9547	.3063	.4952
7	1.1369	1.3393	.3565	.9248	1.1366	.5699	1.0123	.8919	.3858
8	.7418	1.1622	.6443	.4003	.6845	1.0224	.6238	.6712	.9329
9	.2758	.8873	1.2244	.4800	.6746	.5594	1.5070	.9143	.2543
10	1.1548	2.5651	3.0570	1.0046	.2421	.3850	.8787	.9085	.5853
11	.9000	.9000	.9000	.9000	1.0643	.9522	1.0033	.8952	.8874
MEAN F (UNWEIGHTED) FOR AGES 2 TO 6	.9029	1.0323	1.1227	1.0878	1.0350	1.0956	.9586	.6651	.6511

AGE	1983	1984	1985	1986	1987	1988
0	.0336	.0072	.0127	.0025	.0017	.0029
1	.7067	.1663	.3383	.1951	.1386	.1038
2	.6573	.6634	.6435	1.1097	.7914	.7685
3	1.0487	.9338	.9644	1.2987	.9906	1.0204
4	1.1486	1.0913	1.0983	1.3647	.9913	1.0284
5	1.2328	1.1554	.9939	1.0236	.9515	1.0299
6	.7892	1.0150	.9815	.7383	1.0774	1.0494
7	.3685	.6849	.8238	.9663	.8636	.7433
8	.1402	.1700	.5408	.7566	1.2410	.6703
9	.5377	.0945	.1727	.5822	.7172	.8693
10	.9710	.6036	.0849	.4241	.5476	.8722
11	.9354	.9522	.9343	.9713	1.0653	1.6004
MEAN F (UNWEIGHTED) FOR AGES 2 TO 6	.9753	.9718	.9363	1.1070	.9604	.9793

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

STOCK NUMBERS		HADDOCK							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	11961008.	20419052.	2094080.	2424492.	4567558.	5375107.	8503892.	2931557.	4034617.
2	350513.	1281466.	2220637.	199325.	309644.	452322.	836982.	1404574.	297930.
3	596587.	91072.	306740.	642932.	49517.	90803.	110394.	251539.	579673.
4	92051.	176755.	19018.	56535.	171184.	13115.	16254.	24940.	75406.
5	3933.	27520.	46091.	6886.	12636.	45234.	3904.	4361.	7479.
6	2343.	1584.	8033.	9434.	1948.	3367.	13897.	1562.	1885.
7	16911.	745.	662.	2067.	2687.	562.	962.	4380.	941.
8	491.	4442.	160.	380.	671.	705.	280.	286.	1470.
9	99.	192.	1138.	69.	208.	277.	208.	114.	120.
10	51.	62.	65.	274.	35.	87.	130.	38.	37.
11	15.	20.	6.	4.	114.	33.	69.	66.	19.
TOTAL STOCK BIOMASS ON 1. JANUARY	1020593.	1528262.	708064.	456419.	438675.	462532.	695767.	546356.	543940.
SPAWNING STOCK BIOMASS ON 1. JANUARY	253590.	226686.	269886.	225803.	131802.	98688.	110985.	175595.	218212.

AGE	1983	1984	1985	1986	1987	1988
0	0.	0.	0.	0.	0.	0.
1	2657675.	10339860.	5011716.	6762546.	8417080.	2655677.
2	695122.	405862.	1534101.	370152.	522773.	1258028.
3	124906.	209538.	142483.	547526.	82787.	163792.
4	191470.	33388.	62890.	41701.	113839.	23965.
5	25288.	49229.	9108.	17037.	8662.	34405.
6	3344.	6021.	12674.	2755.	5006.	2735.
7	940.	1243.	1787.	3889.	1078.	1395.
8	524.	533.	513.	642.	121.	372.
9	473.	373.	368.	245.	247.	287.
10	76.	226.	278.	253.	112.	99.
11	25.	34.	149.	303.	189.	63.
TOTAL STOCK BIOMASS ON 1. JANUARY	47621.	787834.	679037.	689147.	671100.	411245.
SPAWNING STOCK BIOMASS ON 1. JANUARY	186073.	145579.	186912.	210964.	127645.	162614.

Table 2.8.1b. (continued).

PREDATION MORTALITY		HADDOCK							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.7552	.9212	.9528	.9329	.9838	.8844	1.0818	1.2139	1.0548
1	1.1443	1.1413	1.2924	1.0112	1.0498	.9713	.8516	1.3736	.9536
2	.1156	.0897	.0857	.0913	.0927	.0955	.0886	.1120	.1082
3	.0415	.0405	.0391	.0485	.0349	.0526	.0437	.0496	.0560
4	.0123	.0097	.0096	.0098	.0086	.0088	.0091	.0096	.0113
5	.0030	.0022	.0024	.0023	.0021	.0017	.0022	.0023	.0022
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

PREDATION MORTALITY		HADDOCK					
AGE	1983	1984	1985	1986	1987	1988	
0	.7498	.9295	1.0548	1.1269	1.2101	1.6974	
1	.9527	1.0218	1.5474	1.6449	1.0421	1.8197	
2	.0832	.0734	.0768	.0779	.0582	.0820	
3	.0374	.0397	.0343	.0419	.0191	.0408	
4	.0096	.0078	.0077	.0069	.0053	.0057	
5	.0022	.0016	.0019	.0012	.0014	.0010	
6	.0000	.0000	.0000	.0000	.0000	.0000	
7	.0000	.0000	.0000	.0000	.0000	.0000	
8	.0000	.0000	.0000	.0000	.0000	.0000	
9	.0000	.0000	.0000	.0000	.0000	.0000	
10	.0000	.0000	.0000	.0000	.0000	.0000	
11	.0000	.0000	.0000	.0000	.0000	.0000	

Mortality of 0-group is for 3rd and 4th quarter only
 NORTHERN SEA DATA 1974 - 1988 (MULTISPECIES WORKING GROUP 1989)
 WITH SIMILAR CONTENT DATA FOR COO, WHITING, MACKEREL, SAITHE, AND HADDOCK

Table 2.8.1c. Output from MSVPA key run for whiting.

FISHING MORTALITY		WHITING							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.0539	.0568	.0716	.0852	.0567	.0409	.0627	.1129	.0311
1	.4362	.2473	.2253	.4763	.1790	.2895	.1258	.1979	.2427
2	.9136	.7935	1.0083	.5588	.4272	.5331	.4450	.3320	.3370
3	1.0830	1.0786	1.2691	.9287	.7230	.8251	.8237	.7668	.5232
4	.9715	1.0763	1.1309	1.0307	.8847	.7495	1.0311	1.0032	.7292
5	1.0628	1.0576	.8264	.8665	.7548	.9570	1.1849	1.0609	.9393
6	1.9985	.9721	1.2721	1.0494	1.1821	1.0286	1.4540	1.4086	1.2135
7	1.1648	1.0853	.7455	.8360	1.6045	.9029	1.1571	1.3727	.9564
8	.8891	1.2307	.6574	2.2173	1.7511	1.0945	1.9675	1.0598	1.3312
9	2.3431	1.4816	.7125	.3927	.7077	.5364	.7599	.7375	.7571
10	1.2000	1.2013	1.2000	1.2000	1.3731	1.0093	1.3711	1.1593	.9852
MEAN F (UNWEIGHTED) FOR AGES 2 TO 6	1.2059	.9956	1.1014	.8868	.7944	.8186	.9877	.9143	.7484

AGE	1981	1984	1985	1986	1987	1988
0	.1579	.0562	.0328	.0319	.0171	.0481
1	.2930	.3185	.2618	.3341	.1025	.3041
2	.4746	.5140	.3246	.3965	.3922	.2672
3	.7314	.8634	.6398	.6386	.7459	.5952
4	.7648	1.0829	.9396	1.2800	1.2004	.8107
5	.9483	1.0691	1.0376	1.1341	1.4243	.8075
6	1.0243	1.3475	1.1821	1.5100	2.0540	1.6371
7	1.2792	1.2323	1.3219	1.6051	1.9011	1.5004
8	1.3788	1.4108	2.4062	1.5693	2.0002	.9003
9	1.2543	2.2000	2.9464	1.8968	1.0138	1.2002
10	1.0352	1.1693	1.4022	1.1711	1.2521	2.7003
MEAN F (UNWEIGHTED) FOR AGES 2 TO 6	.7893	.9754	.8247	.9918	1.1634	.8175

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

STOCK NUMBERS		WHITING							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	3536671.	7096443.	4522211.	4549234.	5007275.	5462344.	5209377.	2423264.	2080773.
2	2034981.	908421.	2207438.	1373919.	1070188.	1444794.	1382303.	1564493.	539929.
3	415023.	520469.	271077.	529178.	515870.	451185.	546982.	574493.	697367.
4	59313.	96668.	124892.	53981.	147567.	176605.	139188.	169241.	185462.
5	8343.	16825.	25153.	30824.	14682.	46370.	63341.	37712.	46662.
6	1589.	2265.	4633.	8730.	10267.	5467.	14077.	15329.	10277.
7	9253.	170.	688.	1043.	2455.	2532.	1570.	2643.	3001.
8	654.	2364.	47.	267.	370.	404.	840.	404.	548.
9	63.	220.	565.	20.	24.	53.	121.	96.	115.
10	29.	7.	54.	301.	14.	14.	32.	62.	54.
TOTAL STOCK BIOMASS ON 1. JANUARY	506491.	537989.	559629.	493256.	493893.	563725.	564906.	485033.	375770.
SPAWNING STOCK BIOMASS ON 1. JANUARY	363383.	282587.	380589.	321612.	309389.	359679.	370265.	385276.	298148.

AGE	1983	1984	1985	1986	1987	1988
0	0.	0.	0.	0.	0.	0.
1	1806743.	2530599.	2184504.	4127746.	4902677.	3621642.
2	567382.	493605.	713627.	605979.	1125987.	1695801.
3	244661.	226467.	195074.	336600.	271594.	511540.
4	236179.	82144.	68016.	73228.	126969.	93316.
5	67277.	101013.	21326.	20355.	15601.	29562.
6	14338.	20601.	27561.	6005.	5205.	3001.
7	2439.	4131.	4310.	6812.	1069.	541.
8	944.	556.	986.	941.	1120.	131.
9	119.	195.	111.	73.	160.	124.
10	62.	37.	22.	6.	12.	50.
TOTAL STOCK BIOMASS ON 1. JANUARY	317573.	283144.	259264.	344142.	437136.	502079.
SPAWNING STOCK BIOMASS ON 1. JANUARY	245716.	190371.	176304.	194808.	255704.	359414.

Table 2.8.1c. (continued).

PREDATION MORTALITY		WHITING							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.5841	.9670	.8771	.8599	.9485	.9970	1.3107	.9047	.8363
1	.3630	.3605	.4060	.4108	.5040	.5248	.5171	.7435	.4968
2	.1300	.0958	.1000	.1008	.1165	.1182	.1131	.1560	.1346
3	.0940	.0687	.0647	.0684	.0689	.0710	.0694	.0838	.0875
4	.0584	.0400	.0382	.0413	.0429	.0459	.0448	.0552	.0548
5	.0308	.0222	.0218	.0229	.0231	.0252	.0239	.0291	.0308
6	.0252	.0196	.0185	.0192	.0177	.0192	.0187	.0222	.0250
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

AGE	1983	1984	1985	1986	1987	1988
0	.6002	.7679	.6236	.7984	1.2201	1.0613
1	.4984	.3873	.4605	.4050	.3992	.6353
2	.1239	.0944	.1069	.0861	.0768	.0911
3	.0770	.0595	.0600	.0564	.0424	.0532
4	.0465	.0357	.0369	.0362	.0270	.0341
5	.0252	.0197	.0198	.0196	.0141	.0181
6	.0202	.0168	.0157	.0156	.0107	.0139
7	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000

Mortality of 0-group is for 3rd and 4th quarter only
 NORTH SEA DATA 1974 - 1988 (MULTISPECIES WORKING GROUP 1989)
 WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITH AND HADDOCK

Table 2.8.1d. Output from MSVPA key run for saithe.

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AGE	FISHING MORTALITY		SAITHE						
	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0084	.0004	.0025	.0058	.0040	.0046	.0103	.0296	.0050
2	.0628	.1570	.1851	.1565	.1469	.2491	.1349	.1625	.1897
3	.4493	.3820	.7373	.1822	.2661	.2064	.2787	.1512	.3595
4	.5093	.7734	.8045	.5541	.5440	.4079	.2946	.3104	.4611
5	.3654	.6987	.9158	.9566	.5684	.4806	.5777	.3258	.7220
6	.5892	.5340	.6586	.6970	.4310	.3764	.5900	.5773	.5652
7	.6762	.5344	.5773	.3690	.2859	.4490	.5299	.5799	.5327
8	.5064	.5327	.5992	.4659	.2787	.3928	.3757	.8200	.5445
9	.4223	.2889	.3977	.3519	.2679	.2262	.4527	.4476	.6676
10	.3670	.2679	.4258	.2796	.2582	.1808	.3467	.4449	.3792
11	.3462	.2054	.4350	.2193	.2693	.2438	.3525	.5492	.3173
12	.3604	.3720	.5041	.4843	.2676	.2673	.2451	.7133	.3771
13	.6820	.4149	.4618	.3713	.5597	.1554	.2913	.5458	.4700
14	.3096	.4015	.6969	.6188	.3972	.2768	.2316	.6813	.6040
15	.2823	.3001	.3000	.3001	.3572	.2401	.3432	.6202	.4982

AGE	MEAN F (UNWEIGHTED) FOR AGES 3 TO 6								
	.4806	.5970	.7890	.5975	.4524	.3678	.4352	.3412	.5270

AGE	1983	1984	1985	1986	1987	1988
0	.0000	.0000	.0000	.0000	.0000	.0000
1	.0004	.0002	.0023	.0004	.0028	.0010
2	.1382	.0997	.0122	.0501	.1481	.0050
3	.2356	.5737	.5584	.1844	.3358	.1100
4	.4959	.7833	1.0329	1.3080	.5070	.2801
5	.7269	.6665	.7236	.9061	.7206	.3402
6	.7902	.9473	.5959	.7366	.3315	.3001
7	.9860	.5416	.4710	.4133	.4503	.2001
8	.8600	.6770	.3352	.3371	.4447	.2001
9	.8340	.4237	.2866	.3375	.5163	.2001
10	.4230	.4121	.2193	.2527	.5918	.2001
11	.4409	.2438	.2800	.4453	.4794	.3002
12	.3427	.2797	.2410	.5050	.4185	.2001
13	.4688	.2107	.1328	.1964	.4230	.4002
14	.3429	.4298	.2649	.2712	.3231	.4002
15	.5233	.3352	.1951	.3772	.3652	.4002

AGE	MEAN F (UNWEIGHTED) FOR AGES 3 TO 6					
	.5772	.7427	.7277	.7838	.4737	.2576

AGE	STOCK NUMBERS								
	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	480217.	190004.	120657.	129007.	117228.	260585.	163729.	200963.	348368.
2	266144.	389869.	155497.	98534.	96936.	95598.	212365.	132675.	159742.
3	184041.	204639.	272831.	105800.	68986.	68522.	61009.	151935.	92337.
4	87464.	96146.	114351.	106862.	72195.	43284.	45637.	37802.	105940.
5	44580.	43030.	36324.	41879.	50272.	34308.	23568.	27831.	22691.
6	50205.	25327.	17517.	11901.	13173.	23314.	17370.	10829.	16450.
7	32388.	22598.	12156.	7133.	4853.	7008.	13100.	7684.	4978.
8	13889.	13485.	10842.	5587.	4038.	2985.	3662.	6314.	3614.
9	4547.	6853.	6481.	4875.	2871.	2502.	1550.	2099.	2277.
10	2891.	2441.	4203.	3565.	2808.	1798.	1634.	859.	1078.
11	1546.	1640.	1529.	2248.	2707.	1775.	1229.	946.	451.
12	805.	895.	1093.	810.	1478.	1380.	1139.	707.	447.
13	293.	460.	505.	541.	409.	926.	865.	730.	284.
14	124.	121.	249.	261.	305.	191.	649.	529.	346.
15	121.	189.	169.	258.	269.	472.	283.	753.	436.

AGE	TOTAL STOCK BIONASS ON 1. JANUARY								
	796562.	745713.	702194.	493712.	410892.	368449.	365093.	389222.	415622.
AGE	SPAWNING STOCK BIONASS ON 1. JANUARY								
	445529.	359001.	295398.	237388.	218640.	212537.	199508.	174746.	161859.

AGE	1983	1984	1985	1986	1987	1988
0	0.	0.	0.	0.	0.	0.
1	491147.	484696.	162915.	242194.	921662.	16684.
2	283793.	401861.	396769.	133081.	198215.	752500.
3	108182.	202387.	297865.	320892.	103636.	139941.
4	57669.	65908.	93354.	139531.	218474.	60645.
5	51208.	26312.	24655.	27208.	30887.	107732.
6	9025.	21850.	11062.	9790.	9002.	12302.
7	7054.	3353.	6937.	4991.	3837.	5291.
8	2392.	2338.	1597.	3546.	2703.	2003.
9	1717.	879.	973.	935.	2072.	1416.
10	956.	610.	444.	598.	546.	1012.
11	604.	513.	331.	292.	380.	248.
12	209.	318.	329.	205.	153.	193.
13	251.	156.	197.	212.	101.	83.
14	145.	129.	104.	141.	142.	54.
15	301.	204.	710.	148.	204.	187.

AGE	TOTAL STOCK BIONASS ON 1. JANUARY					
	423756.	493961.	572604.	604616.	571352.	633972.
AGE	SPAWNING STOCK BIONASS ON 1. JANUARY					
	173722.	144009.	129086.	139781.	156270.	236908.

Table 2.8.1d. (continued).

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

AGE	1983	1984	1985	1986	1987	1988
0	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000
13	.0000	.0000	.0000	.0000	.0000	.0000
14	.0000	.0000	.0000	.0000	.0000	.0000
15	.0000	.0000	.0000	.0000	.0000	.0000

Mortality of 0-group is for 3rd and 4th quarter only
 NORTH SEA DATA 1974 - 1988 (MULTISPECIES WORKING GROUP 1989)
 WITH 1/4MATH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.0.1e. Output from MSVPA key run for mackerel.

FISHING MORTALITY		MACKEREL							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0067	.0240	.0093	.0067	.0000	.0216	.0193	.0210	.0146
2	.1097	.0277	.1897	.0798	.0573	.0143	.0643	.0501	.0956
3	.0773	.1253	.2519	.2147	.1900	.0994	.0766	.1710	.1718
4	.1822	.1855	.1414	.2084	.2134	.1611	.1687	.0439	.2017
5	.2353	.1784	.2069	.1326	.2319	.2561	.2581	.2033	.0974
6	.2200	.2870	.1715	.2347	.1056	.1692	.3101	.2875	.1771
7	.1028	.1759	.2677	.4314	.0290	.0951	.2634	.3393	.1863
8	.2421	.4299	.3154	.4726	.3831	.1357	.2670	.2705	.2470
9	.0901	.3785	.2713	.5571	.2931	.0699	.3009	.2555	.2023
10	.0457	.1914	.3590	.4699	.5174	.2668	.1614	.2426	.2091
11	.0395	.0593	.2143	.6721	.0867	.3302	.2967	.1346	.1670
12	.1426	.0620	.0764	.3752	.1338	.2360	.4097	.5412	.1839
13	.1780	.1005	.0324	.1536	.0520	.4075	.2347	.3196	.4367
14	.0280	.0890	.0895	.0337	.1582	.2897	.6391	.7945	.5504
15	.6790	.3602	.2535	.4059	.5713	.2927	.2914	1.4402	.4108
MEAN F (UNWEIGHTED) FOR AGES 4 TO 8									
AGE	1983	1984	1985	1986	1987	1988			
0	.0001	.0000	.0001	.0000	.0000	.0001			
1	.0046	.0023	.1395	.4919	.0322	.0266			
2	.1019	.0978	.0926	1.4130	.1156	.0310			
3	.2643	.6154	.3346	.4047	.0659	.1216			
4	.2666	.6168	.9735	.4248	.0469	.0658			
5	.7016	.5484	.8766	.5191	.0470	.0576			
6	.0050	.4643	.8303	.3845	.0529	.0443			
7	.1760	.2257	.5313	.3496	.0520	.0613			
8	.2283	.2548	.2264	.2323	.0602	.0493			
9	.2144	.2685	.4773	.7520	.1637	.1430			
10	.2385	.3500	.3386	.3754	.0238	.2212			
11	.1771	.2581	.4335	.2476	.0393	.0312			
12	.2091	.2605	.4625	.6462	.0171	.0478			
13	.1318	.1753	.5666	.5158	.0770	.0222			
14	.8826	.1255	.2706	.9047	.0402	.0978			
15	.7472	.6811	2.0661	.3660	.7412	.0685			
MEAN F (UNWEIGHTED) FOR AGES 4 TO 8									
AGE	1983	1984	1985	1986	1987	1988			
0	.0001	.0000	.0001	.0000	.0000	.0001			
1	.0046	.0023	.1395	.4919	.0322	.0266			
2	.1019	.0978	.0926	1.4130	.1156	.0310			
3	.2643	.6154	.3346	.4047	.0659	.1216			
4	.2666	.6168	.9735	.4248	.0469	.0658			
5	.7016	.5484	.8766	.5191	.0470	.0576			
6	.0050	.4643	.8303	.3845	.0529	.0443			
7	.1760	.2257	.5313	.3496	.0520	.0613			
8	.2283	.2548	.2264	.2323	.0602	.0493			
9	.2144	.2685	.4773	.7520	.1637	.1430			
10	.2385	.3500	.3386	.3754	.0238	.2212			
11	.1771	.2581	.4335	.2476	.0393	.0312			
12	.2091	.2605	.4625	.6462	.0171	.0478			
13	.1318	.1753	.5666	.5158	.0770	.0222			
14	.8826	.1255	.2706	.9047	.0402	.0978			
15	.7472	.6811	2.0661	.3660	.7412	.0685			
MEAN F (UNWEIGHTED) FOR AGES 4 TO 8									
AGE	1983	1984	1985	1986	1987	1988			
0	.0001	.0000	.0001	.0000	.0000	.0001			
1	.0046	.0023	.1395	.4919	.0322	.0266			
2	.1019	.0978	.0926	1.4130	.1156	.0310			
3	.2643	.6154	.3346	.4047	.0659	.1216			
4	.2666	.6168	.9735	.4248	.0469	.0658			
5	.7016	.5484	.8766	.5191	.0470	.0576			
6	.0050	.4643	.8303	.3845	.0529	.0443			
7	.1760	.2257	.5313	.3496	.0520	.0613			
8	.2283	.2548	.2264	.2323	.0602	.0493			
9	.2144	.2685	.4773	.7520	.1637	.1430			
10	.2385	.3500	.3386	.3754	.0238	.2212			
11	.1771	.2581	.4335	.2476	.0393	.0312			
12	.2091	.2605	.4625	.6462	.0171	.0478			
13	.1318	.1753	.5666	.5158	.0770	.0222			
14	.8826	.1255	.2706	.9047	.0402	.0978			
15	.7472	.6811	2.0661	.3660	.7412	.0685			

STOCK NUMBERS		MACKEREL							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	483203.	560248.	324404.	188795.	49341.	118427.	156453.	204794.	227224.
2	198957.	413135.	470780.	276629.	161410.	42468.	99757.	132082.	172598.
3	350778.	153458.	345889.	335200.	219827.	131190.	36033.	80516.	108930.
4	264678.	279468.	115255.	231427.	232754.	156463.	102230.	28727.	58464.
5	1269717.	189865.	199822.	87071.	147800.	161832.	114626.	74331.	23663.
6	256380.	863747.	136722.	139840.	65638.	100886.	107818.	76215.	52206.
7	84956.	177094.	557940.	99131.	95183.	50836.	73318.	68060.	49210.
8	82761.	65976.	127838.	367441.	55427.	79582.	39785.	48492.	41724.
9	40921.	55917.	37202.	80265.	197154.	32523.	59803.	26221.	31847.
10	12335.	32186.	32961.	24411.	39576.	126584.	26103.	38096.	17479.
11	8908.	10143.	22876.	19814.	13133.	20305.	83439.	19119.	25727.
12	7752.	7371.	8228.	15892.	8708.	10365.	12561.	53380.	14383.
13	8578.	5786.	5962.	6561.	9399.	6557.	7032.	7178.	26741.
14	37346.	6496.	4503.	4968.	4843.	5358.	3755.	4786.	4488.
15	48613.	78213.	15406.	8312.	8045.	9948.	9672.	2142.	4336.

TOTAL STOCK BIOMASS ON 1. JANUARY	983430.	892110.	750793.	621102.	461255.	373486.	319349.	267607.	242308.
SPANNING STOCK BIOMASS ON 1. JANUARY	810129.	715375.	533035.	458735.	365032.	320522.	275948.	201739.	158729.

AGE	1983	1984	1985	1986	1987	1988
0	0.	0.	0.	0.	0.	0.
1	41470.	12429.	56233.	9786.	17769.	17221.
2	192733.	35529.	10673.	42097.	5150.	14810.
3	135010.	149822.	27731.	8374.	8820.	3949.
4	78302.	89214.	69692.	17081.	4809.	7107.
5	41130.	51521.	41441.	22660.	3614.	3940.
6	18476.	28938.	25677.	14845.	11606.	7895.
7	37642.	14902.	15656.	9634.	8698.	9474.
8	35158.	27171.	10235.	7922.	5845.	7107.
9	28053.	24085.	18127.	7024.	5405.	4737.
10	22391.	19486.	15849.	9680.	4699.	3950.
11	12206.	15183.	11819.	9724.	5724.	3949.
12	18737.	8800.	10095.	6594.	6533.	4737.
13	10300.	13085.	5837.	5472.	2974.	5528.
14	14873.	7770.	9451.	2851.	2812.	2370.
15	3761.	9383.	6621.	15397.	1683.	11845.
TOTAL STOCK BIOMASS ON 1. JANUARY	222199.	181108.	116531.	72663.	37813.	42087.
SPANNING STOCK BIOMASS ON 1. JANUARY	142905.	111236.	102475.	60636.	32974.	36491.

Table 2.8.1e. (continued).

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

AGE	1983	1984	1985	1986	1987	1988
0	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000
13	.0000	.0000	.0000	.0000	.0000	.0000
14	.0000	.0000	.0000	.0000	.0000	.0000
15	.0000	.0000	.0000	.0000	.0000	.0000

Mortality of 0-group is for 3rd and 4th quarter only
 NORTH SEA DATA 1974 - 1988 (MULTISPECIES WORKING GROUP 1989)
 WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.8.1f. Output from MSVPA key run for herring.

FISHING MORTALITY		HERRING							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.0690	.0886	.0878	.0661	.0314	.0555	.0596	.3609	.3097
1	.4339	.5113	.1900	.1540	.1123	.0968	.0458	.1366	.1930
2	.9637	1.2222	1.2415	.1368	.0180	.0789	.2668	.2834	.2081
3	.8930	1.4280	1.3634	.9916	.0310	.0571	.3615	.2606	.4636
4	.9560	1.2599	1.6091	.3667	.0684	.0715	.2513	.2643	.2294
5	1.1232	1.8062	1.2860	.9374	.0157	.0347	.2003	.3502	.1297
6	.9964	1.2115	1.0677	.4006	.0554	.0117	.0468	.3334	.1200
7	.7642	2.0489	1.5734	.7310	.0300	.3154	.1052	.6210	.1675
8	.7802	2.8001	2.3972	.0	.0	.1151	.2301	.6489	.1946
9	1.0001	1.0603	.3602	.0010	.0003	.0120	.0022	.3000	.0235
MEAN F (UNWEIGHTED) FOR AGES 3 TO 6	.9921	1.4264	1.3316	.6741	.0426	.0438	.2150	.3021	.2357
AGE	1983	1984	1985	1986	1987	1988			
0	.3705	.1024	.0368	.0136	.0613	.0447			
1	1.1382	.0665	.1929	.1608	.2625	.2349			
2	.2745	.2466	.3454	.3891	.4386	.4781			
3	.3112	.3843	.6103	.4668	.4925	.6152			
4	.4178	.4792	.6845	.5189	.5502	.5986			
5	.2609	.5619	.5998	.5027	.5516	.6048			
6	.2905	.3265	.6562	.6194	.5874	.5818			
7	.3191	.5380	.5187	.7064	.5013	.6061			
8	.3449	.4217	.5396	.7030	.5924	.5938			
9	.3302	.2089	.4608	.4702	.1864	.5794			
MEAN F (UNWEIGHTED) FOR AGES 3 TO 6	.3201	.4380	.6377	.5270	.5454	.6001			

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

STOCK NUMBERS		HERRING							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	5381212.	9265296.	1770746.	1617870.	2605974.	2742669.	7089592.	8219432.	10943634.
2	1655100.	986799.	1721482.	435770.	413591.	692785.	746248.	1672103.	1996453.
3	756496.	407238.	190280.	309626.	232968.	241558.	388896.	337320.	762075.
4	226781.	215339.	70994.	96318.	84773.	166892.	164281.	198248.	183209.
5	89275.	72558.	51095.	11981.	21310.	66666.	130981.	107985.	127256.
6	39079.	25607.	10491.	12413.	4130.	18424.	56574.	94436.	66644.
7	10024.	10928.	5861.	2924.	6858.	3216.	15081.	44038.	54179.
8	3687.	4224.	1274.	1099.	1274.	6022.	2123.	12283.	21415.
9	1678.	2291.	1402.	1092.	3639.	9150.	50000.	4629.	50000.
TOTAL STOCK BIOMASS ON 1. JANUARY	332771.	283054.	194120.	98388.	107867.	154056.	253814.	350742.	452242.
SPAWNING STOCK BIOMASS ON 1. JANUARY	722267.	144210.	125100.	66881.	65118.	101919.	148031.	200158.	265517.
AGE	1983	1984	1985	1986	1987	1988			
0	0.	0.	0.	0.	0.	0.			
1	17187476.	15372518.	13567242.	21503812.	26422524.	20711789.			
2	3216242.	5940240.	6051339.	4710393.	7930754.	7702451.			
3	1000778.	1534487.	2952875.	2603264.	2003869.	3183985.			
4	343174.	547907.	795098.	1221943.	1226348.	963837.			
5	173234.	192007.	289811.	341046.	620420.	605857.			
6	40482.	83952.	96907.	140594.	162811.	316523.			
7	49502.	61925.	51601.	41946.	63867.	87024.			
8	41465.	32554.	32981.	27795.	18727.	35007.			
9	45626.	100808.	45010.	40033.	50004.	19005.			
TOTAL STOCK BIOMASS ON 1. JANUARY	675946.	979581.	1162024.	1187454.	1474266.	1510239.			
SPAWNING STOCK BIOMASS ON 1. JANUARY	780446.	621189.	831292.	798695.	937117.	1047955.			

Table 2.8.1f. (continued).

PREDATION MORTALITY		HERRING							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.3972	.4395	.4207	.3589	.3991	.3923	.4889	.3959	.3309
1	.9323	.8520	.8921	.8900	.8924	.8846	.9657	.9586	.7116
2	.2286	.2240	.2641	.2794	.3099	.2886	.3173	.4054	.2725
3	.2136	.1690	.1428	.1538	.1527	.1785	.1624	.1998	.1836
4	.0537	.0487	.0401	.0364	.0419	.0409	.0383	.0490	.0372
5	.0156	.0177	.0189	.0178	.0198	.0194	.0168	.0225	.0166
6	.1779	.1634	.1098	.0927	.0947	.0886	.1038	.1222	.0774
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
AGE	1983	1984	1985	1986	1987	1988			
0	.2557	.3036	.2348	.2711	.4306	.4569			
1	.6043	.5459	.5449	.5167	.6501	.8407			
2	.2595	.2424	.2881	.2556	.2640	.3286			
3	.1412	.1732	.1220	.1359	.0894	.1817			
4	.0334	.0276	.0320	.0289	.0250	.0475			
5	.0130	.0119	.0136	.0108	.0114	.0137			
6	.0734	.0602	.0812	.0697	.0549	.1159			
7	.0000	.0000	.0000	.0000	.0000	.0000			
8	.0000	.0000	.0000	.0000	.0000	.0000			
9	.0000	.0000	.0000	.0000	.0000	.0000			

Mortality of 0-group is for 3rd and 4th quarter only
 NORTH SEA DATA 1974 - 1988 (MULTISPECIES WORKING GROUP 1989)
 WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.8.1g. Output from MSVPA key run for sprat.

FISHING MORTALITY			SPRAT						
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.0060	.0020	.0154	.0065	.0021	.0037	.0072	.0085	.0028
1	.1021	.2203	.2645	.1673	.5027	.3372	.4269	.4689	.6913
2	.4538	.6101	.5471	.5560	.5249	.6933	.6062	1.2843	1.0877
3	.8167	1.5149	3.0643	.4843	2.1055	1.7113	1.5375	.5599	1.7042
4	2.8320	1.8733	2.5201	4.2896	1.3802	1.6868	1.8312	.3783	.4436
MEAN F (UNWEIGHTED) FOR AGES 1 TO 3									
	.4575	.7817	1.2920	.4026	1.0444	.9139	.8568	.7710	1.1611
AGE			1983	1984	1985	1986	1987	1988	
0	.0024	.0022	.0000	.0000	.0000	.0000	.0000		
1	.9324	.2757	.0955	.0093	.0625	1.2372			
2	1.0332	1.2322	.4366	.0774	.0652	.3369			
3	1.0909	2.0437	.5994	.3612	.1273	.2380			
4	1.8537	2.0649	1.0116	.6341	.3468	.5790			
MEAN F (UNWEIGHTED) FOR AGES 1 TO 3									
	1.1885	1.1839	.3772	.1493	.0850	.6041			
Mortality of 0-group is for 3rd and 4th quarter only									
STOCK NUMBERS			SPRAT						
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	373253568.	235517632.	308295104.	164927968.	153536992.	277227008.	105861120.	65367712.	33205864.
2	48539800.	108322736.	55077248.	73344720.	42034104.	28567540.	61959976.	20018592.	13351022.
3	3215537.	8233252.	11621018.	6360689.	8949712.	4496118.	2572255.	4405659.	922079.
4	426560.	537016.	697090.	178207.	1440714.	370620.	252727.	175736.	723338.
TOTAL STOCK BIOMASS ON 1. JANUARY									
	1459775.	1651811.	1472683.	1141237.	924259.	1057230.	832591.	410322.	227768.
SPAWNING STOCK BIOMASS ON 1. JANUARY									
	451991.	1015913.	640286.	695932.	509709.	308717.	546767.	233829.	138112.
AGE			1983	1984	1985	1986	1987	1988	
0	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	16450408.	52936624.	37097296.	38957872.	86680160.	12585006.			
2	6024338.	2450121.	14828840.	13063674.	13789914.	27555604.			
3	960896.	542527.	145397.	2244625.	2240442.	1692610.			
4	60680.	73619.	30270.	33455.	695113.	707308.			
TOTAL STOCK BIOMASS ON 1. JANUARY									
	109442.	172735.	223175.	246299.	395391.	298668.			
SPAWNING STOCK BIOMASS ON 1. JANUARY									
	64919.	29806.	123013.	141112.	161355.	264686.			
PREDATION MORTALITY			SPRAT						
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.1128	.1258	.1155	.1236	.1206	.1108	.1238	.0897	.0830
1	.5251	.6230	.5615	.5897	.5690	.5512	.6287	.5095	.4056
2	.7605	1.0625	1.0519	.9876	1.1506	1.1604	1.4777	1.2335	.9838
3	.5241	.4771	.6170	.5633	.6175	.6959	.7525	.8755	.5598
4	.6200	.6267	.7725	.8402	.9231	1.0823	1.2446	1.3656	1.1710
AGE			1983	1984	1985	1986	1987	1988	
0	.0643	.0703	.0546	.0629	.0838	.0839			
1	.3647	.3868	.3382	.4193	.4735	.5197			
2	.8141	1.0322	.8914	1.1258	1.4725	1.4441			
3	.5034	.4546	.5196	.4912	.6152	.8479			
4	.8116	.8232	.7316	.8389	.9560	1.3793			
Mortality of 0-group is for 3rd and 4th quarter only									
MURKIN SEA DATA 1974 - 1988 (MULTISPECIES WORKING GROUP 1989)									
WITH STOMACH CONTENT DATA FOR COD, WHITING, HACKEREL, SAITHE AND HADDOCK									

Table 2.8.1h. Output from MSVPA key run for Norway pout.

FISHING MORTALITY		NORWAY POUT							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.0318	.0366	.0299	.0167	.0103	.0100	.0087	.1730	.0074
1	.8031	.5701	.4056	.4052	.3458	.3912	.4851	.4073	.4102
2	2.6575	1.1314	1.5991	.5769	.9480	1.5072	1.9250	.9557	1.4776
3	2.0927	.8693	.7727	1.5693	.6434	.7459	1.2381	4.0663	.7203
MEAN F (UNWEIGHTED) FOR AGES 1 TO 2									
	1.7303	.8508	1.0024	.4911	.6469	.9492	1.2051	.6815	.9439
AGE	1983	1984	1985	1986	1987	1988			
0	.0219	.0186	.0054	.0261	.0046	.0271			
1	.4546	.6512	.6743	.4766	.2153	.6610			
2	1.1508	2.1105	1.8794	2.2271	1.9767	1.0801			
3	1.0237	1.0542	3.6482	1.2846	1.2106	.7570			
MEAN F (UNWEIGHTED) FOR AGES 1 TO 2									
	.8027	1.3808	1.2768	1.3519	1.0960	.8705			

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
0	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	247616800.	166949824.	240421664.	172392736.	864711168.	118086016.	134578576.	64634496.	162808096.
2	3135440.	8597140.	6040281.	11603282.	10898526.	5525571.	10394862.	12358726.	3063946.
3	684182.	48630.	636417.	285977.	1627893.	366555.	310893.	407282.	1064130.
TOTAL STOCK BIOMASS ON 1. JANUARY									
	1985247.	1475473.	1997693.	1598354.	984937.	1069558.	1283237.	802466.	1354957.
SPAWNING STOCK BIOMASS ON 1. JANUARY									
	1044303.	841064.	1084091.	943261.	656347.	620831.	771846.	556855.	736286.
AGE	1983	1984	1985	1986	1987	1988			
0	0.	0.	0.	0.	0.	0.			
1	133568560.	110911648.	101174240.	104517312.	173903776.	41081544.			
2	12835694.	11547024.	5677956.	2698449.	2403449.	9327752.			
3	181438.	1127124.	366952.	197274.	59878.	68914.			
TOTAL STOCK BIOMASS ON 1. JANUARY									
	1378211.	1165239.	919472.	866840.	1381386.	537115.			
SPAWNING STOCK BIOMASS ON 1. JANUARY									
	820671.	743699.	535009.	469674.	720551.	381005.			

PREDATION MORTALITY		NORWAY POUT							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.2570	.3008	.2874	.2660	.2545	.2055	.2339	.2696	.2437
1	1.8078	2.0001	1.8762	1.6063	1.6553	1.2896	1.1531	1.8918	1.3802
2	.9426	.9201	.8497	.8331	.9270	.7933	.6774	.9533	.7918
3	1.1455	1.1370	1.0665	1.0740	1.2145	1.0476	.9263	1.2723	1.0231
AGE	1983	1984	1985	1986	1987	1988			
0	.1835	.2486	.2913	.3251	.3317	.4543			
1	1.2436	1.5711	2.1999	2.5458	1.9602	3.5445			
2	.7287	.7032	.8845	.9951	.9640	1.7645			
3	.8578	.7912	1.0753	1.2185	1.0935	2.1615			

Mortality of 0-group is for 3rd and 4th quarter only
 NORTH SEA DATA 1974 - 1988 (MULTISPECIES WORKING GROUP 1989)
 WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.8.1i. Output from MSVPA key run for sandeel

FISHING MORTALITY		SANDEEL							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.0106	.0142	.0172	.0332	.1081	.0943	.0600	.1009	.1432
1	.1678	.1217	.2006	.3080	.4277	.2266	.4403	.3418	.3307
2	.1429	.2731	.4856	.4328	.7035	.8989	.7618	.8616	.8835
3	.0489	.3848	.3155	.7617	.3771	.6895	.9642	.5411	1.2406
4	.2689	.1423	.4011	.3837	.4806	.5974	.5177	.8151	1.2456
5	.2727	.3548	.1037	.7711	.2341	.8608	.4629	.9675	.8037
6	.5369	.3237	.4910	.8092	.8717	.8844	1.0470	.8195	.8028

MEAN F (UNWEIGHTED) FOR AGES 1 TO 2		SANDEEL							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	.1554	.1974	.3431	.3704	.5656	.5628	.6011	.6017	.6071

AGC		SANDEEL							
AGE	1983	1984	1985	1986	1987	1988			
0	.0377	.0261	.0243	.0196	.0105	.0465			
1	.2110	.4870	.2415	.1483	.2846	.4314			
2	.7846	.2637	1.2418	.4041	.5449	.9411			
3	.7213	1.6029	1.0562	.3060	.2163	1.1360			
4	.3920	.5956	.5305	.1889	.0758	.6581			
5	.5486	.5782	1.7590	.0901	.0951	.3107			
6	.8321	1.1136	1.2912	.3297	.0211	.3254			

MEAN F (UNWEIGHTED) FOR AGES 1 TO 2		SANDEEL							
AGE	1983	1984	1985	1986	1987	1988			
1	.4978	.3754	.7417	.2767	.4148	.6863			

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

STOCK NUMBERS		SANDEEL							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	499945344.	620558720.	383346112.	400757824.	422055296.	310958400.	326572032.	164502880.	423359680.
2	65956648.	55656200.	80657824.	42093216.	58690008.	64294704.	58786104.	48720248.	22933256.
3	25074056.	17906604.	14471122.	16212586.	10392034.	12263226.	11403658.	11556720.	7983780.
4	13342452.	12113118.	6318643.	5400524.	4122631.	4068222.	3572733.	2471080.	3665958.
5	1624311.	2902614.	2905341.	1215415.	1312481.	1064802.	1002106.	882336.	420343.
6	345954.	465117.	760672.	977095.	271377.	588836.	260649.	360089.	175580.

TOTAL STOCK B10MASS ON 1. JANUARY		SANDEEL							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	3293952.	3559634.	2717810.	2377974.	2501055.	2150621.	2126521.	1373814.	2085220.

SPAWNING STOCK B10MASS ON 1. JANUARY		SANDEEL							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	1343565.	1139456.	1222760.	815019.	855040.	937883.	852889.	732252.	434117.

AGC		SANDEEL							
AGE	1983	1984	1985	1986	1987	1988			
0	0.	0.	0.	0.	0.	0.			
1	122680980.	384840832.	122880576.	417295680.	291418944.	75985232.			
2	101049728.	29094220.	84235456.	29890040.	124954688.	75742544.			
3	4403178.	21374184.	11685148.	12353108.	10667170.	38455032.			
4	1344300.	1265510.	2646328.	2478411.	5666914.	5390982.			
5	443253.	427181.	369788.	829770.	1147002.	3006283.			
6	111944.	158887.	163043.	63320.	1176635.	1097421.			

TOTAL STOCK B10MASS ON 1. JANUARY		SANDEEL							
AGE	1983	1984	1985	1986	1987	1988			
0	1584214.	2153661.	1553614.	2178880.	2696314.	1819736.			

SPAWNING STOCK B10MASS ON 1. JANUARY		SANDEEL							
AGE	1983	1984	1985	1986	1987	1988			
1	1105731.	652782.	1074380.	551427.	1559781.	1523393.			

PREDATION MORTALITY		SANDEEL							
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982
0	.5467	.5376	.4642	.3922	.3962	.3892	.4152	.3153	.2940
1	1.5376	1.4288	1.5186	1.1232	.9641	.9496	.9724	1.1385	.6119
2	.7110	.6240	.6689	.5162	.4122	.3809	.4149	.4971	.3168
3	.2877	.2659	.2802	.2177	1.708	.1539	.1751	.2171	1.509
4	.8987	.9259	.8874	.6710	.5131	.4439	.5209	.5963	.5071
5	.7992	.6003	.7697	.5702	.4293	.3613	.4082	.4947	.4003
6	1.1219	1.2403	1.1067	.8067	.5822	.4752	.5558	.6063	.6222

AGC		SANDEEL							
AGE	1983	1984	1985	1986	1987	1988			
0	.2776	.3073	.2863	.3346	.3675	.3144			
1	.7177	.5422	.6821	.5676	.5729	.9119			
2	.3188	.2189	.2271	.1763	.1835	.3088			
3	.1355	.0961	.1045	.0841	.0762	.1419			
4	.3944	.2747	.2693	.2215	.1981	.3598			
5	.3331	.2138	.2190	.1655	.1281	.2532			
6	.4463	.2736	.2307	.1860	.1311	.2388			

Mortality of 0-group is for 3rd and 4th quarter only
 NORTH SEA DATA 1974 - 1988 (MULTISPECIES WORKING GROUP 1989)
 WITH STOMACH CONTENT DATA FOR COD, WHITING, MACKEREL, SAITHE AND HADDOCK

Table 2.8.2a Values of M1 and mean values (1981-1986) of M2, total natural mortality, fishing mortality, and stock in numbers ('000) at age. Last age is a + group. Stock numbers on 1 January (0-group 1 July).

Age	M1		M2	Total natural mortality	Fishing mortality	Numbers
	Residual mortality	"Other" predators				
<u>Cod</u>						
0 ¹	0.1	0.36	0.489	0.949	-	1,124,451
1	0.2	0.28	0.427	0.907	0.198	461,479
2	0.2	0.07	0.113	0.383	0.978	178,460
3	0.2	-	0.061	0.261	1.055	50,423
4	0.2	-	-	0.200	0.802	13,253
5	0.2	-	-	0.200	0.746	5,724
6	0.2	-	-	0.200	0.770	2,206
7	0.2	-	-	0.200	0.761	958
8	0.2	-	-	0.200	0.795	361
9	0.2	-	-	0.200	0.689	144
10	0.2	-	-	0.200	0.723	63
11	0.2	-	-	0.200	0.647	57
<u>Saithe</u>						
0 ¹	0.1	-	-	0.100	-	488,297
1	0.2	-	-	0.200	0.006	321,713
2	0.2	-	-	0.200	0.109	251,337
3	0.2	-	-	0.200	0.354	195,596
4	0.2	-	-	0.200	0.732	82,717
5	0.2	-	-	0.200	0.678	30,651
6	0.2	-	-	0.200	0.702	13,168
7	0.2	-	-	0.200	0.587	5,966
8	0.2	-	-	0.200	0.596	3,300
9	0.2	-	-	0.200	0.500	1,465
10	0.2	-	-	0.200	0.355	758
11	0.2	-	-	0.200	0.379	523
12	0.2	-	-	0.200	0.410	379
13	0.2	-	-	0.200	0.337	305
14	0.2	-	-	0.200	0.432	232
15	0.2	-	-	0.200	0.425	342

¹ Mortality rates per half year.

Table 2.8.2b Values of M1 and mean values (1981-1986) of M2, total natural mortality, fishing mortality, and stock in numbers ('000) at age. Last age is a + group. Stock numbers on 1 January (0-group 1 July).

Age	M1		M2	Total natural mortality	Fishing mortality	Numbers
	Residual mortality	"Other" predators				
Whiting						
0 ¹	0.1	0.28	0.755	1.135	0.070	9,719,488
1	0.2	0.36	0.499	1,059	0.275	2,542,271
2	0.2	0.12	0.117	0.437	0.396	747,503
3	0.2	0.08	0.071	0.351	0.694	379,110
4	0.2	0.03	0.044	0.274	0.967	144,045
5	0.2	0.01	0.024	0.234	1.032	49,058
6	0.2	-	0.019	0.219	1.281	15,685
7	0.2	-	-	0.200	1.295	3,889
8	0.2	-	-	0.200	1.526	730
9	0.2	-	-	0.200	1.632	118
10	0.2	-	-	0.200	1.154	41
Haddock						
0 ¹	0.1	0.52	1,022	1.642	0.025	32,059,552
1	0.2	0.52	1,249	1.559	0.220	5,289,662
2	0.2	0.11	0.090	0.400	0.665	769,623
3	0.2	0.03	0.043	0.273	0.999	309,211
4	0.2	-	0.009	0.209	1,096	71,633
5	0.2	-	0.002	0.202	0.941	18,750
6	0.2	-	-	0.200	0.721	4,707
7	0.2	-	-	0.200	0.687	2,197
8	0.2	-	-	0.200	0.535	661
9	0.2	-	-	0.200	0.426	282
10	0.2	-	-	0.200	0.596	151
11	0.2	-	-	0.200	0.929	99

¹ Mortality rates per half year.

Table 2.8.2c Values of M1 and mean values (1981-1986), of M2, total natural mortality, fishing mortality, and stock in numbers ('000) at age. Last age is a + group. Stock numbers on 1 January (0-group 1 July).

Age	M1		M2	Total natural mortality	Fishing mortality	Numbers
	Residual mortality	"Other" predators				
Mackerel						
0 ¹	0.08	-	-	0.08	0.000	488,297
1	0.15	-	-	0.15	0.006	321,713
2	0.15	-	-	0.15	0.109	251,337
3	0.15	-	-	0.15	0.354	195,596
4	0.15	-	-	0.15	0.732	82,717
5	0.15	-	-	0.15	0.678	30,651
6	0.15	-	-	0.15	0.702	13,168
7	0.15	-	-	0.15	0.587	5,966
8	0.15	-	-	0.15	0.596	3,300
9	0.15	-	-	0.15	0.500	1,465
10	0.15	-	-	0.15	0.355	758
11	0.15	-	-	0.15	0.379	523
12	0.15	-	-	0.15	0.410	379
13	0.15	-	-	0.15	0.337	305
14	0.15	-	-	0.15	0.432	232
15	0.15	-	-	0.15	0.425	342
Herring						
0 ¹	0.05	0.17	0.299	0.519	0.199	34,973,408
1	0.10	0.22	0.647	0.967	0.148	14,465,684
2	0.10	0.11	0.287	0.497	0.291	3,964,461
3	0.10	0.05	0.151	0.301	0.416	1,531,800
4	0.10	0.03	0.035	0.165	0.432	548,297
5	0.10	0.01	0.015	0.125	0.401	196,890
6	0.10	-	0.081	0.181	0.391	96,836
7	0.10	-	-	0.100	0.477	50,532
8	0.10	-	-	0.100	0.475	28,082
9	0.10	-	-	0.100	0.299	47,511

¹ Mortality rates per half year.

Table 2.8.2d Values of M1 and mean values (1981-1986) of M2, total natural mortality, fishing mortality, and stock in numbers ('000) at age. Last age is a + group. Stock numbers on 1 January (0-group 1 July).

Age	M1		M2	Total natural mortality	Fishing mortality	Numbers
	Residual mortality	"Other" predators				
<u>Sprat</u>						
0 ¹	0.1	0.22	0.071	0.391	0.003	65,303,744
1	0.2	0.41	0.404	1.014	0.412	40,675,952
2	0.2	0.36	1.013	1.573	0.859	11,622,764
3	0.2	0.30	0.567	1.067	1.145	1,536,864
4	0.2	0.26	0.957	1.417	1.064	182,851
<u>Norway Pout</u>						
0 ¹	0.1	0.30	0.260	0.660	0.042	268,833,472
1	0.2	0.55	1.805	2.555	0.512	112,939,040
2	0.2	0.44	0.843	1.483	1.634	8,030,298
3	0.2	0.34	1.041	1.581	1.966	557,368
<u>Sandeel</u>						
0 ¹	0.1	0.16	0.303	0.563	0.059	543,721,344
1	0.2	0.29	0.710	1.200	0.293	272,594,560
2	0.2	0.25	0.293	0.743	0.740	52,753,824
3	0.2	0.19	0.131	0.521	0.911	11,561,016
4	0.2	0.16	0.377	0.737	0.628	2,311,898
5	0.2	0.14	0.304	0.644	0.791	562,112
6	0.2	0.11	0.394	0.704	0.865	172,144

¹Mortality rates per half year.

Table 2.8.3 The mean of the ratio between numbers on the MSVPA and the single species VPAs for the years 1981-1986.

Age	Cod ¹	Whiting ¹	Saithe ¹	Haddock ¹	Herring ²
1	1.26	1.16	0.97	1.66	1.27
2	1.10	1.00	0.96	1.07	1.25
3	1.06	1.00	0.95	1.03	1.16
4	1.05	1.01	0.93	0.99	1.09
5	1.01	1.01	0.90	1.04	1.04
6	1.01	1.04	0.86	1.54	1.04
7	0.99	1.02	0.85	1.32	1.00
8	0.99	1.01	0.87	1.88	0.93

¹ 1988 single species assessment.

² 1989 single species assessment.

Table 2.8.4 Natural mortalities used by the single species working groups in their most recent reports compared to total M from MSVPA key run averaged over the period 1981-1986.

Age	Cod ¹		Haddock ¹		Whiting ¹		Saithe ¹	
	SS	MS	SS	MS	SS	MS	SS	MS
0 ³	1.35	0.95	1.03	1.64	1.28	1.14	0.1	0.1
1	0.80	0.91	1.65	1.56	0.95	1.06	0.2	0.2
2	0.35	0.38	0.40	0.40	0.45	0.44	0.2	0.2
3	0.25	0.26	0.25	0.27	0.35	0.35	0.2	0.2
4	0.20	0.20	0.25	0.21	0.30	0.27	0.2	0.2
5	0.20	0.20	0.20	0.20	0.25	0.23	0.2	0.2
6	0.20	0.20	0.20	0.20	0.25	0.22	0.2	0.2
7	0.20	0.20	0.20	0.20	0.20	0.20	0.2	0.2
8	0.20	0.20	0.20	0.20	0.20	0.20	0.2	0.2
9	0.20	0.20	0.20	0.20	0.20	0.20	0.2	0.2
10	0.20	0.20	0.20	0.20	0.20	0.20	0.2	0.2
11	0.20	0.20	-	-	-	-	0.2	0.2

Age	Herring ²		Norway pout ²		Sandeel ²		Sprat	
	SS	MS	SS	MS	SS	MS	SS	MS
0 ³	0.5	0.52	0.8	0.66	0.8	0.56	-	0.39 ³
1	1.0	0.97	1.6	2.56	1.2	1.20	-	-
2	0.3	0.50	1.6	1.48	0.6	0.74	-	1.01
3	0.2	0.30	1.6	1.58	0.6	0.52	-	1.07
4	0.1	0.17	-	-	0.6	0.74	-	1.42
5	0.1	0.13	-	-	0.6	0.64	-	-
6	0.1	0.18	-	-	0.6	0.70	-	-
7	0.1	0.10	-	-	-	-	-	-
8	0.1	0.10	-	-	-	-	-	-
9	0.1	0.10	-	-	-	-	-	-

¹ 1988 single species assessment.

² 1989 single species assessment.

³ Mortality rates per half year.

Table 3.4.3 Value (ECU/kg) at age by species in human consumption landings.

Age	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat
1	0.276	0.256	0.197	0.194	0.376	0.115	0.12
2	0.374	0.256	0.197	0.194	0.376	0.115	0.12
3	0.374	0.352	0.197	0.194	0.383	0.184	0.12
4	0.492	0.352	0.197	0.194	0.383	0.195	0.12
5	0.64	0.384	0.358	0.194	0.496	0.195	0.12
6	0.64	0.384	0.358	0.194	0.496	0.195	
7	0.64	0.384	0.363	0.194	0.496	0.195	
8	0.64	0.384	0.363	0.194	0.496	0.195	
9	0.64	0.384	0.363	0.194	0.496	0.195	
10	0.64	0.384	0.363	0.194	0.496	0.195	
11	0.64	0.384	0.363	0.194	0.496		
12	0.64		0.363	0.194	0.496		
13			0.363	0.194			
14			0.363	0.194			
15			0.363	0.194			
16			0.363	0.194			

For industrial species and by-catches, all ages: 0.04 except Herring, mackerel, and sprat: 0.035.

Table 3.4.4.1. Results of long-term forecasts using the MSFOR model, assuming constant recruitment, with the current exploitation patterns, and including multispecies effects. Catches are in thousands of tonnes (W), value in millions of ECUs (V).

Case #1	Roundf. Land.	Roundf. Disc.	Ind. Dem.	Ind. Pel.	Herr.	Saithe	Mack.	Tot. Cat.	Tot. Land.	TSB	SSB
Cod W V	246.9 115.5		12.8 0.5					259.7 116.0	259.7 116.0	324.3	103.6
Whiting W V	84.1 30.6	62.8 0.0	42.8 1.7	7.8 0.3				197.6 32.6	134.8 32.6	451.3	306.6
Saithe W V	30.8 9.9		4.0 0.2			175.2 55.7		210.0 65.8	210.0 65.8	508.2	171.2
Mackerel W V							33.2 6.4	33.2 6.4	33.2 6.4	98.0	41.7
Haddock W V	121.4 50.8	76.5 0.0	38.7 1.5					236.6 52.3	160.1 52.3	628.4	175.0
Herring W V				181.0 6.3	159.9 29.8			340.9 36.1	340.9 36.1	837.6	621.0
Sprat W V				320.8 11.2				320.8 11.2	320.8 11.2	647.7	302.2
Norway Pout W V			387.8 15.5					387.8 15.5	387.8 15.5	1239.8	714.8
Sandeel W V			1047.2 41.9					1047.2 41.9	1047.2 41.9	2716.5	1298.9
Total W V	483.2 206.8	139.3 0.0	1533.4 61.3	509.6 17.9	159.9 29.8	175.2 55.7	33.2 6.4	3033.8 378.0	2896.5 378.0		

Table 3.4.4.2. Percent deviation from baseline run (Table 3.4.4.1), in long-term multi-species projections, assuming constant recruitment and 120 mm minimum mesh size when fishing for cod.

Case #2	Roundf. Land.	Roundf. Disc.	Ind. Dem.	Ind. Pel.	Herr.	Saithe	Mack.	Tot. Cat.	Tot. Land.	TSB	SSB
Cod	W -2.8 V +4.3		-4.4 -4.5					-2.9	-2.9 +4.2	16.6	31.2
Whiting	W -18.5 V -16.2	-63.2	2.4 2.5	-5.9 -6.1				-27.7	-11.1 -15.1	14.9	26.9
Saithe	W -11.1 V -7.0		2.9 2.5			3.3 3.5		1.2	1.2 1.9	2.6	3.9
Mackerel	W V										
Haddock	W -16.4 V -9.5	-67.6	-14.1 -14.1					-32.5	-16.4 -9.6	-10.0	22.9
Herring	W V			-15.8 -15.8	-20.5 -20.8			-18.0	-18.0 -19.9	-16.8	-19.6
Sprat	W V			-1.4 -1.4				-1.4	-1.4 -1.4	-0.5	-0.8
Norway Pout	W V		-19.0 -19.0					-19.0	-19.0 -19.0	-7.0	-9.5
Sandeel	W V		-1.5 -1.5					-1.5	-1.5 -1.5	-0.6	-1.9
Total	W -9.5 V -2.7	-65.6	-6.2 -6.2	-6.6 -6.6	-20.5 -20.8	3.3 3.5		-9.6	-6.9 -3.9	-2.4	-1.4

Table 3.4.4.3. Results of long-term forecasts using MSFOR model, assuming constant recruitment, with current exploitation patterns, and only single-species effects. Catches are in thousands of tonnes (W), value in millions of ECUs (V).

Case #3	Roundf. Land.	Roundf. Disc.	Ind. Dem.	Ind. Pel.	Herr.	Saithe	Mack.	Tot. Cat.	Tot. Land.	TSB	SSB
Cod	W V	214.3 100.1	11.2 0.5					225.5 100.6	225.5 100.6	275.2	89.2
Whiting	W V	87.8 32.0	44.0 1.8	7.9 0.3				205.7 34.1	139.7 34.1	465.0	324.6
Saithe	W V	30.8 9.8	4.0 0.2			175.2 55.7		210.0 65.7	210.0 65.7	508.2	171.2
Mackerel	W V						33.2 6.4	33.2 6.4	33.2 6.4	98.0	41.7
Haddock	W V	136.4 57.1	43.4 1.7					265.9 58.8	179.8 58.8	625.2	196.6
Herring	W V			184.4 6.4	166.1 31.0			350.5 37.6	350.5 37.6	746.4	572.1
Sprat	W V			223.5 7.8				223.5 7.8	223.5 7.8	285.1	134.7
Norway Pout	W V		387.3 15.5					387.3 15.5	387.3 15.5	693.5	435.2
Sandeel	W V		735.4 29.4					735.4 29.4	735.4 29.4	1886.7	903.2
Total	W V	469.3 199.0	1225.3 49.0	415.8 14.6	166.1 31.0	175.2 55.7	33.2 6.4	2637.0 355.8	2484.9 355.8	5583.3	2868.6

Table 3.4.4.4. Percent deviation from baseline single-species run (Table 3.4.4.3), in long-term single-species projections, assuming constant recruitment and 120 mm minimum mesh size when fishing for cod.

Case #4	Roundf. Land.	Roundf. Disc.	Ind. Dem.	Ind. Pel.	Herr.	Saithe	Mack.	Tot. Cat.	Tot. Land.	TSB	SSB
Cod	W V	14.1 22.9	7.0					13.8 22.9	13.8 22.9	35.4	56.3
Whiting	W V	9.8 12.9	28.8 27.8	11.3 17.3				-6.1 13.5	15.8 13.5	47.7	67.7
Saithe	W V	-11.0 -6.5	2.5			3.2 3.6		1.2 2.0	1.2 2.0	2.6	3.9
Mackerel	W V										
Haddock	W V	34.9 46.1	21.3 23.5					4.6 45.6	31.6 45.6	36.9	97.5
Herring	W V										
Sprat	W V										
Norway Pout	W V										
Sandeel	W V										
Total	W V	17.7 26.5	-52.1	1.9 1.9	0.2	3.3 3.6		1.3 15.7	4.5 15.7	10.1	16.3

Table 3.4.4.5. Percent deviation from baseline multispecies run (Table 3.4.4.1), in long-term simulations assuming constant recruitment, current exploitation patterns, and a 10% increase in effort in all fleets.

Case #5	Roundf. Land.	Roundf. Disc.	Ind. Dem.	Ind. Pel.	Herr.	Saithe	Mack.	Tot. Cat.	Tot. Land.	TSB	SSB
Cod W V	2.6 0.3		14.8 14.8					3.2 0.3	3.2 0.3	-5.5	-16.5
Whiting W V	0.1	8.6	8.4 8.4	10.3				5.0 0.6	3.3 0.6	-2.3	-3.6
Saithe W V	-2.5 -0.4		5.0 5.0			-2.3 -3.6		-2.2 -3.6	-2.2 -3.6	-7.9	-17.3
Mackerel W V							1.2 1.4	1.2 1.4	1.2 1.4	-6.7	-13.2
Haddock W V	13.0 12.0	22.9	20.7 20.7					17.5 12.4	14.9 12.4	7.8	5.4
Herring W V				4.8 4.8	2.2 2.0			3.6 2.5	3.6 2.5	-5.1	-6.3
Sprat W V				4.9 4.9				4.9 4.9	4.9 4.9	-2.5	-5.4
Norway Pout W V			22.0 22.0					22.0 22.0	22.0 22.0	3.7	5.4
Sandeel W V			3.2 3.2					3.2 3.2	3.2 3.2	-3.6	-6.6
Total W V	4.4 2.9	16.4	8.6 8.6	4.9 4.9	2.2 2.0	-2.3 -3.6	1.2 1.4	6.6 2.8	6.2 2.8		

Table 3.4.4.6. Percent deviation from baseline multispecies run (Table 3.4.4.1), in long-term simulations assuming stochastic recruitment, multispecies effects, and 120 mm minimum mesh size when fishing for cod.

Case #6	Roundf. Land.	Roundf. Disc.	Ind. Dem.	Ind. Pel.	Herr.	Saithe	Mack.	Tot. Cat.	Tot. Land.	TSB	SSB
Cod W V	-6.0 0.8		-7.8 -5.6					-6.1 0.8	-6.1 0.8	12.5	26.7
Whiting W V	-18.3 -15.9	-63.4	2.2 2.9	-6.3 -2.7				-27.8 -14.8	-11.2 -14.8	14.6	26.9
Saithe W V	-10.1 -6.5		4.4 -16.5			4.4 4.6		2.3 2.9	2.3 2.9	3.7	5.1
Mackerel W V							8.5 9.2	8.5 9.2	8.5 9.2	8.6	8.6
Haddock W V	3.8 12.4	-61.3	-0.6 12.5					-18.0 12.2	2.7 12.2	4.1	52.0
Herring W V				-13.9 -13.5	-18.1 -18.3			-15.9 -17.4	-15.9 -17.4	-14.9	-17.3
Sprat W V				-0.4 -0.1				-0.4 -0.1	-0.4 -0.1	-0.4	0.5
Norway Pout W V			-2.8 -2.7					-2.8 -2.7	-2.8 -2.7	-3.8	-3.0
Sandeel W V			-4.3 -4.3					-4.3 -4.3	-4.3 -4.3	-3.4	-4.3
Total W V	-6.0 0.8	-62.2	-3.7 -3.6	-5.3 -5.4	-18.1 -18.2	4.4 4.6	8.5 9.2	-7.1 -1.0	-4.5 -1.0		

Table 3.4.4.7. Percent deviation from baseline multispecies run (Table 3.4.4.1), in long-term simulations assuming constant recruitment, multispecies effects, a 120 mm minimum mesh size when fishing for cod, and average cod recruitment halved as compared to baseline run.

Case #7	Roundf. Land.	Roundf. Disc.	Ind. Dem.	Ind. Pel.	Herr.	Saithe	Mack.	Tot. Cat.	Tot. Land.	TSB	SSB
Cod W V	-40.1 -35.5		-44.1 -42.8					-40.3 -35.5	-40.3 -35.5	-29.8	-18.0
Whiting W V	-9.7 -4.7	-61.1	7.7 8.5	-4.1 -0.3				-21.2 -3.9	-2.6 -3.9	21.7	38.3
Saithe W V	-11.0 -7.4		3.4 -17.5			3.3 3.5		1.2 1.8	1.2 1.8	2.6	3.9
Mackerel W V							0.1 0.6	0.1 0.6	0.1 0.6	0.0	0.0
Haddock W V	-5.6 2.2	-65.3	-9.7 -6.8					-25.7 2.0	-6.7 2.0	-5.4	37.1
Herring W V				-12.2 -11.7	-14.6 -14.6			-13.3 -14.1	-13.3 -14.1	-14.0	-15.2
Sprat W V				-17.1 11.3				-17.1 11.3	-17.1 11.3	-1.0	-1.4
Norway Pout W V			-19.6 -19.6					-19.6 -19.6	-19.6 -19.6	-7.5	-9.9
Sandeel W V			0.1					0.1	0.1	0.3	-0.1
Total W V	-24.0 -20.3	-63.4	-5.3 -5.3	-5.4 -5.5	-14.6 -14.6	3.3 3.5	0.1 0.6	-10.9 -12.9	-8.4 -12.9		

Table 3.4.4.8. Percent deviation from baseline multispecies run (Table 3.4.4.1), in long-term simulations assuming constant recruitment, multispecies effects, a 120 mm minimum mesh when fishing for cod, and a 10% increase in effort in the Roundfish-120 mm fishery.

Case #8	Roundf. Land.		Roundf. Disc.	Ind. Dem.		Ind. Pel.	Herr.	Saithe	Mack.	Tot. Cat.	Tot. Land.	TSB	SSB
	W	V		W	V								
Cod	W	-1.5		-2.5						-1.6	-1.6	13.1	19.5
	V	4.5								4.5	4.5		
Whiting	W	-18.7	-62.6	2.9	-5.7					-26.7	-10.0	15.3	27.7
	V	-14.3		3.6	-2.0					-13.2	-13.2		
Saithe	W	-6.5		3.1				2.4		1.1	1.1	1.9	2.3
	V	-2.7		-17.5				2.5		1.7	1.7		
Mackerel	W								-0.1	-0.1	-0.1	0.0	0.0
	V								0.6	0.6	0.6		
Haddock	W	-14.1	-66.5	-13.3						-30.9	-13.9	-9.8	22.3
	V	-7.1		-10.5						-7.2	-7.2		
Herring	W				-15.7	-20.2				-17.8	-17.8	-16.7	-19.4
	V				-15.2	-20.4				-19.5	-19.5		
Sprat	W				-1.5					-1.5	-1.5	-0.6	-0.9
	V				-1.2					-1.2	-1.2		
Norway Pout	W			-18.0						-18.0	-18.0	-6.7	-9.0
	V			-17.9						-17.9	-17.9		
Sandeel	W			-1.6						-1.6	-1.6	-0.7	-2.0
	V			-1.6						-1.6	-1.6		
Total	W	-7.6	-64.8	-5.9	-6.6	-20.2		2.4	-0.1	-9.2	-6.6		
	V	-1.5		-5.9	-6.7	-20.4		2.5	0.6	-3.3	-3.3		

Table 3.4.4.9. Percent deviation from baseline multispecies run (Table 3.4.4.1), in long-term simulations assuming constant recruitment, multispecies effects, a 120 mm minimum mesh size when fishing for cod, and effort on whiting increased 100% in Roundfish-85 mm and industrial fisheries.

Case #9	Roundf. Land.	Roundf. Disc.	Ind. Dem.	Ind. Pel.	Herr.	Saithe	Mack.	Tot. Cat.	Tot. Land.	TSB	SSB
Cod W V	0.9 8.3		-0.8					0.9 8.2	0.9 8.2	21.0	36.3
Whiting W V	-29.5 -27.3	-32.3	86.6 88.2	91.1 98.7				0.2 -20.1	15.3 -20.1	-6.2	-7.9
Saithe W V	-11.0 -7.4		3.4			3.3 3.6		1.2 1.8	1.2 1.8	2.6	3.9
Mackerel W V							-0.1	-0.1	-0.1	0.0	0.0
Haddock W V	17.8 27.7	-56.4	11.4 13.3					-7.2 27.3	16.3 27.3	21.6	72.8
Herring W V				0.6 1.6	-0.1 -0.3			0.3	0.3	1.5	0.9
Sprat W V				-13.4 2.7				-13.4 2.7	-13.4 2.7	1.7	3.1
Norway Pout W V			-10.2 -10.3					-10.2 -10.3	-10.2 -10.3	-3.5	-5.0
Sandeel W V			0.6 0.5					0.6 0.5	0.6 0.5	0.2	1.0
Total W V	-0.6 7.0	-45.6	0.5 0.7	3.4 3.4	-0.1 -0.3	3.3 3.6	-0.1	-1.2 4.6	1.0 4.6		

Table 3.4.4.10. Percent deviation from baseline multispecies run (Table 3.4.4.1), in long-term simulations assuming constant recruitment, multispecies effects, current exploitation patterns, and a 20% reduction in effort in the Roundfish and Saithe fisheries.

Case #10	Roundf. Land.	Roundf. Disc.	Ind. Dem.	Ind. Pel.	Herr.	Saithe	Mack.	Tot. Cat.	Tot. Land.	TSB	SSB
Cod W V	-10.7 -6.1		-11.7 -11.7					-10.7 -6.2	-10.7 -6.2	9.6	39.0
Whiting W V	-19.3 -9.2	-21.2	-0.9 -0.9	-1.3 -1.3				-11.2 -8.6	-6.6 -8.6	0.7	1.9
Saithe W V	5.5 8.1		12.5 12.5			4.2 7.0		4.5 7.1	4.5 7.1	21.7	51.4
Mackerel W V											
Haddock W V	-40.1 -38.8	-47.5	-28.4 -28.4					-40.5 -38.4	-37.2 -38.4	-25.7	-27.8
Herring W V				-7.5 -7.5	-10.6 -10.7			-9.0 -10.0	-9.0 -10.0	-7.4	-9.2
Sprat W V				-0.6 -0.6				-0.6 -0.6	-0.6 -0.6	-0.3	-0.6
Norway Pout W V			-37.1 -37.1					-37.1 -37.1	-37.1 -37.1	-13.5	-19.0
Sandeel W V			0.5 0.5					0.5 0.5	0.5 0.5	0.7	0.5
Total W V	-16.9 -13.9	-35.6	-9.9 -9.9	-3.0 -3.0	-10.6 -10.7	4.2 7.0		-10.2 -9.2	-8.9 -9.2	-3.1	-2.8

Table 3.4.4.11 Total consumption (TC) in tonnes and predation relative to average prey biomass (P/P; %) by individual predators, based on MSFOR baseline run (case 1).

Prey	Predators						Total
		Cod	Whiting	Saithe	Mackerel	Haddock	
Cod	TC	12,433	1,226	987	263	-	14,909
	P/P	4.6 ¹	0.5	0.4	0.1		5.5
Whiting	TC	40,574	43,842	6,025	-	209	90,650
	P/P	10.3	11.1	1.5	-	0.1	22.9
Saithe	TC	-	-	-	-	-	-
	P/P						
Mackerel	TC	-	-	-	-	-	-
	P/P						
Haddock	TC	46,617	44,958	97,164	-	817	189,556
	P/P	9.4	9.1	19.6	-	0.2	38.3
Herring	TC	35,367	51,858	15,562	14,623	84	117,503
	P/P	3.4	5.0	1.5	1.4	+	11.4
Sprat	TC	24,501	187,077	18,334	17,192	2,595	249,699
	P/P	3.5	26.5	2.6	2.4	0.4	35.4
Norway pout	TC	63,623	115,772	805,026	17,319	56,316	1,058,057
	P/P	5.1	9.3	64.7	1.4	4.5	85.0
Sandeel	TC	106,003	349,104	83,100	248,015	121,183	907,405
	P/P	3.9	12.8	3.0	9.1	4.4	33.3
Total	TC	329,118	793,837	1,026,198	297,421	181,205	2,627,778
	P/P	4.8	11.6	14.9	4.3	2.6	38.2

¹Predation/prey biomass as percentage.

Table 3.4.4.12 Percentage changes in total consumption (TC; as compared to baseline multispecies run case 1) and predation relative to average prey biomass (P/P; %) by individual predators when the MSFOR is run with 120 mm mesh size (case 2).

Prey		Predators					Total
		Cod	Whiting	Saithe	Mackerel	Haddock	
Cod	TC	33.0	35.7	12.1	1.0	-	31.3
	P/P	5.2	0.5	0.4	0.1	-	6.2
Whiting	TC	21.9	13.8	2.2	-	30.1	16.7
	P/P	10.7	10.8	1.3	-	0.1	22.9
Saithe	TC	-	-	-	-	-	-
	P/P	-	-	-	-	-	-
Mackerel	TC	-	-	-	-	-	-
	P/P	-	-	-	-	-	-
Haddock	TC	7.0	31.1	-7.2	-	14.2	5.4
	P/P	10.6	12.5	19.1	-	0.2	42.4
Herring	TC	8.7	20.2	-3.6	-8.9	51.3	10.0
	P/P	4.5	7.3	1.8	1.6	+	15.1
Sprat	TC	6.3	9.4	.7	0.8	-8.5	8.2
	P/P	3.7	29.2	2.8	2.5	0.3	38.6
Norway pout	TC	14.4	39.4	-0.4	-8.0	16.8	5.6
	P/P	6.4	14.1	70.2	1.4	5.7	97.9
Sandeel	TC	7.9	6.3	7.9	0.1	-2.7	3.7
	P/P	4.2	13.8	3.3	9.2	4.4	34.9
Total	TC	11.7	14.6	-0.3	-1.0	3.5	5.9
	P/P	5.1	12.6	14.1	4.1	2.6	38.4

+ - indicates <0.1%.

Table 4.1.1. Average catches (thousands of tons, W) and value (millions of ECUs, V) from medium-term stochastic forecasts with the MSFOR model, assuming multispecies effects, and 85-mm mesh when fishing for cod.

Fishery Group	W/V	1988	1989	1990	1991	1992	1993	1994	1995	1996
Cod H.C. landings	W	171.3	140.5	174.3	197.6	209.5	227.1	248.5	259.8	256.3
	V	82.5	70.5	79.0	89.1	96.2	104.2	113.6	119.8	120.0
(Total Biomass) (SSB)		223.6	193.0	225.6	248.5	266.5	291.4	319.9	335.9	335.0
		77.8	78.1	70.7	69.1	74.7	83.0	90.9	98.1	104.4
Human consumption and Saithe landings	W	615.0	643.2	654.3	545.7	556.4	611.0	668.1	692.0	691.7
	V	236.3	236.4	257.6	210.8	215.4	238.0	262.4	275.5	277.5
Roundfish discards	W	147.1	93.9	80.5	99.5	135.1	150.9	156.2	159.8	163.6
	V	-	-	-	-	-	-	-	-	-
Industrial demersal	W	1140.2	895.8	1071.1	1421.2	1721.1	1835.2	1785.0	1711.0	1647.8
	V	45.7	44.0	42.9	56.8	69.0	73.5	71.6	68.3	65.9
Industrial pelagic	W	428.6	487.7	528.8	541.8	583.2	538.9	496.4	522.0	521.6
	V	15.0	17.1	18.6	19.0	20.6	18.9	17.6	18.2	18.3
Herring and mackerel	W	275.3	277.4	251.3	229.8	217.6	213.9	208.8	200.2	198.9
	V	51.0	52.4	47.8	43.6	41.0	40.1	39.6	37.6	37.4
TOTAL	W	2606.2	2398.0	2586.0	2838.0	3213.4	3349.9	3314.5	3285.0	3223.6
	V	348.0	349.9	366.9	330.2	346.0	370.5	391.2	399.6	399.1

Table 4.1.2. Average catches (thousands of tons, W) and value (millions of ECUs, V) from medium-term stochastic forecasts with the MSFOR model, assuming multispecies effects, and 120-mm minimum mesh size when fishing for cod.

Fishery Group	W/V	1988	1989	1990	1991	1992	1993	1994	1995	1996
Cod H.C. landings	W	151.9	136.4	159.0	199.4	218.4	228.8	240.4	245.8	246.4
	V	75.1	70.8	76.6	95.4	107.2	113.7	119.1	122.8	123.4
(Total Biomass) (SSB)	W	223.6	214.8	255.7	303.3	335.8	357.5	378.2	384.8	388.1
	V	77.8	83.2	82.0	88.8	103.6	117.9	128.0	133.7	137.7
Human consumption and Saithe landings	W	498.5	585.4	663.9	579.7	569.1	578.6	611.3	632.9	634.1
	V	193.6	218.8	270.7	233.9	230.8	237.2	252.0	265.7	267.3
Roundfish discards	W	61.5	42.4	32.4	34.0	44.1	52.9	53.2	51.3	51.8
	V	-	-	-	-	-	-	-	-	-
Industrial demersal	W	1138.1	872.9	1077.4	1428.2	1615.0	1576.7	1481.5	1410.1	1407.8
	V	45.5	34.9	43.1	57.1	69.0	63.1	57.8	57.7	56.3
Industrial pelagic	W	416.7	460.1	528.9	522.1	496.7	474.5	447.2	495.0	480.9
	V	14.6	16.1	18.5	18.3	17.4	16.6	15.7	17.4	16.9
Herring and mackerel	W	273.7	266.7	229.2	205.9	194.1	184.4	174.0	167.9	167.8
	V	50.8	50.7	43.7	38.8	36.5	34.7	32.7	31.5	31.5
TOTAL	W	2388.5	2227.5	2531.8	2769.9	2919.0	2867.1	2767.2	2757.2	2742.4
	V	304.5	320.5	376.0	348.1	353.7	351.6	358.2	372.3	372.0

Table 4.1.3 Time trends in total stock biomass ('000 t) estimated in medium-term runs with MSFOR, assuming stochastic and constant recruitment, and the baseline and 120 mm mesh options when fishing for cod. Long-term means are also given (∞).

Year:	Stochastic recruitment ¹							
	Baseline fishery				120 mm option			
	1988	1992	1996	∞	1988	1992	1996	∞
Cod	224 (22.1)	267 (23.3)	335 (24.8)	315 (24.8)	224	336 (20.7)	388 (25.5)	365 (23.0)
Whiting	506 (18.4)	438 (14.6)	462 (16.2)	456 (16.2)	506	502 (14.1)	514 (14.3)	517 (14.1)
Saithe	634 (24.0)	530 (32.0)	487 (31.0)	540 (31.0)	634	578 (33.1)	507 (29.3)	527 (30.4)
Mackerel	36 (43.1)	82 (38.7)	94 (37.8)	96 (37.8)	36	82 (47.0)	98 (47.7)	106 (51.1)
Haddock	488 (47.3)	517 (53.0)	759 (55.6)	642 (55.6)	488	476 (46.2)	634 (49.3)	654 (55.5)
Herring	1,515 (25.8)	923 (30.3)	866 (29.9)	836 (29.9)	1,515	842 (28.1)	736 (27.3)	713 (36.0)
Sprat	299 (50.8)	741 (50.3)	649 (57.0)	657 (57.0)	299	630 (54.8)	640 (51.6)	645 (57.3)
Norway pout	538 (43.5)	1,296 (37.6)	1,346 (39.3)	1,252 (39.3)	538	1,229 (46.4)	1,172 (40.0)	1,192 (40.9)
Sandeel	1,825 (36.0)	3,012 (29.7)	2,636 (33.4)	2,690 (33.4)	1,825	2,895 (45.5)	2,466 (34.7)	2,624 (34.6)

¹ Coefficients of variation (CVs) given in parentheses.

Year:	Constant recruitment							
	Baseline fishery				120 mm option			
	1988	1992	1996	∞	1988	1992	1996	∞
Cod	224	288	326	324	224	338	382	378
Whiting	506	444	451	451	506	504	522	519
Saithe	634	533	511	508	634	546	523	521
Mackerel	36	78	93	98	36	78	93	98
Haddock	488	498	620	628	488	400	558	565
Herring	1,515	946	857	838	1,515	794	717	697
Sprat	299	659	651	648	299	659	645	644
Norway pout	538	1,210	1,239	1,240	538	1,119	1,152	1,153
Sandeel	1,825	2,890	2,733	2,716	1,825	2,877	2,706	2,700

Table 4.1.4 Time trends in spawning stock biomass ('000 t) estimated in medium-term runs with MSFOR, assuming stochastic and constant recruitment, and the baseline and 120 mm mesh options when fishing for cod. Long-term means are also given (∞).

Year:	Stochastic recruitment ¹							
	Baseline fishery				120 mm option			
	1988	1992	1996	∞	1988	1992	1996	∞
Cod	78	74 (16.8)	104 (20.4)	101 (20.8)	78	104 (21.8)	138 (20.0)	131 (20.6)
Whiting	362	284 (18.9)	312 (19.7)	309 (17.8)	362	366 (13.0)	386 (16.9)	389 (15.4)
Saithe	237	206 (4.9)	171 (30.3)	182 (31.8)	237	216 (6.9)	178 (28.7)	180 (31.4)
Mackerel	31	21 (70.2)	39 (49.5)	41 (43.2)	31	24 (62)	37 (54)	45 (57.3)
Haddock	162	84 (49.6)	216 (49.4)	187 (60.6)	162	113 (32.3)	250 (66.9)	266 (65.9)
Herring	1,054	714 (26.7)	645 (30.2)	619 (31.3)	1,054	629 (28.1)	539 (27.3)	513 (38.0)
Sprat	265	323 (58.4)	323 (67.1)	309 (77.8)	265	311 (59.1)	342 (77.8)	304 (79.3)
Norway pout	381	735 (46.3)	827 (42.0)	739 (43.3)	381	687 (46.4)	679 (40.0)	693 (44.4)
Sandeel	1,529	1,381 (46.5)	1,276 (42.8)	1,299 (45.6)	1,529	1,488 (45.5)	1,195 (34.7)	1,243 (47.4)

¹ Coefficients of variation (CVs) given in parentheses.

Year:	Constant recruitment							
	Baseline fishery				120 mm option			
	1988	1992	1996	∞	1988	1992	1996	∞
Cod	78	79	103	104	78	106	136	136
Whiting	362	294	306	307	362	371	394	389
Saithe	237	208	174	171	237	215	180	178
Mackerel	31	22	37	42	31	22	37	42
Haddock	162	80	171	175	162	103	211	215
Herring	1,054	721	640	621	1,054	592	521	500
Sprat	265	312	305	302	265	313	301	300
Norway pout	381	674	714	715	381	605	647	647
Sandeel	1,529	1,424	1,312	1,299	1,529	1,383	1,279	1,275

Table 4.1.5 Time trends in total catch ('000 t) estimated in medium-term runs with MSFOR, assuming stochastic and constant recruitment, and the baseline and 120 mm mesh options when fishing for cod. Long-term means are also given (∞).

Stochastic recruitment ¹								
Year:	Baseline fishery				120 mm option			
	1988	1992	1996	∞	1988	1992	1996	∞
Cod	176	221 (23.8)	268 (24.4)	253 (26.7)	157	230 (18.6)	258 (24.4)	244 (23.6)
Whiting	207	191 (13.5)	201 (13.0)	199 (13.1)	121	141 (12.4)	142 (13.8)	143 (11.3)
Saithe	255	217 (22.1)	201 (32.0)	223 (32.7)	249	235 (35.1)	202 (31.1)	215 (32.1)
Mackerel	12	28 (44.1)	32 (40.5)	33 (38.9)	12	28 (45.0)	33 (49.8)	36 (52.7)
Haddock	216	164 (47.4)	299 (48.6)	251 (54.9)	130	106 (41.4)	188 (47.5)	194 (57.9)
Herring	557	390 (22.5)	358 (26.5)	340 (26.6)	547	341 (24.3)	293 (24.8)	287 (31.4)
Sprat	127	375 (54.3)	322 (52.9)	327 (60.7)	124	314 (57.5)	315 (50.8)	320 (62.1)
Norway Pout	169	459 (72.3)	514 (57.1)	427 (64.3)	163	381 (39.9)	370 (33.9)	377 (65.9)
Sandeel	887	1,167 (34.3)	1,029 (29.4)	1,042 (34.1)	885	1,143 (29.8)	941 (26.3)	1,002 (35.1)

¹ Coefficients of variation (CVs) given in parentheses.

Constant recruitment								
Year:	Baseline fishery				120 mm option			
	1988	1992	1996	∞	1988	1992	1996	∞
Cod	176	239	262	260	157	232	256	252
Whiting	207	194	198	208	123	141	144	143
Saithe	255	222	210	210	249	224	212	212
Mackerel	12	27	32	33	12	27	32	33
Haddock	217	149	233	230	129	91	158	160
Herring	555	390	347	340	551	326	285	280
Sprat	127	328	323	321	124	328	317	316
Norway pout	167	374	387	388	165	302	311	314
Sandeel	895	1,133	1,055	1,047	890	1,120	1,034	1,031

Table 4.1.6. Percentage deviations in Human Consumption landings and SSB of cod from 1988 values, in medium-term predictions using MSFOR in single and multispecies modes with constant recruitment, and assuming adoption of the 120 mm mesh option when fishing for cod. Also presented are similar predictions supplied to ACFM by the Roundfish Working Group. Data are presented as percent deviations from 1988, since starting conditions were somewhat different between MSWG and RFWG runs.

Year	----- Predictions From MSFOR -----				- Roundfish WG ¹ -	
	Single-Species Mode Landings	SSB	Multispecies Mode Landings	SSB	Landings	SSB
1988	100	100	100	100	100	100
1989	-11	6	-10	6	-43	-7
1990	5	4	7	5	-25	-7
1991	33	13	36	15	5	13
1992	46	33	45	36	11	40
1993	53	54	49	54	16	58
1994	57	68	55	63	18	67
1995	59	74	60	69	19	70
1996	59	86	61	74	19	71

¹ Data submitted directly to ACFM, assumed recruitment: 1987(age 1; millions)=202, 1988(age 1)=414, 1989(age 0)=6,130

Table 6.3.2.1 Parameter estimates and standard errors of estimates for single slope model fit to G11 data set. Values are for the levels of PREDSPECIES.

Level	Parameter estimate	S.E. of estimate
Cod 1981	-1.493	.346
Cod 1985	-1.685	.347
Cod 1986	-1.529	.337
Cod 1987	+0.219	.333
Whiting 1981	-0.143	.334
Whiting 1985	+0.605	.333
Saithe 1981	+0.466	.331
Saithe 1986	-0.662	.335
Saithe 1987	+1.118	*** (aliased)

Table 6.3.2.2 Parameter estimates for predator + prey + predator * prey interaction summed, from same model as Table 6.3.2.1. Sand lance as prey are aliased in all estimates.

Predator	Prey					
	Cod	Whiting	Haddock	Herring	Sprat	Norway Pout
Cod 1981 \bar{x}	1.235	0.624	1.470	0.878	-1.597	-1.016
SE	.388	.341	.357	.321	.399	.327
Cod 1985 \bar{x}	1.330	1.253	0.521	0.544	-1.892	-0.673
SE	.413	.470	.356	.321	.397	.327
Cod 1986 \bar{x}	1.324	1.009	1.399	1.445	-1.964	0.328
\bar{x}	.407	.340	.356	.321	.398	.327
Cod 1987 \bar{x}	2.777	1.352	1.072	0.151	-3.291	-0.335
SE	.402	.335	.350	.316	.490	.321
Whiting 1981 \bar{x}	1.397	-1.484	1.912	2.389	0.497	-0.553
SE	.395	.333	.351	.311	.405	.317
Whiting 1985 \bar{x}	1.682	2.573	2.380	1.564	1.258	0.953
SE	.392	.334	.345	.399	.335	.274
Saithe 1981 \bar{x}	1.161	0.027	2.936	0.483	-0.950	3.063
SE	.382	.332	.348	.313	.392	.319
Saithe 1985 \bar{x}	2.243	0.806	1.345	0.750	-1.661	2.595
SE	.381	.334	.403	.314	.394	.320
Saithe 1987 \bar{x}	2.300	0.340	2.375	1.468	-0.822	3.175
SE	.444	.329	.354	.298	.444	.304
Mackerel 1981 \bar{x}	3.143	-	-	3.891	2.000	1.197
SE	.6404			.305	.417	.310
Haddock \bar{x}	-	0.602	2.638	3.612	0.056	3.213
SE		.347	.375	.323	.448	.334

Table 6.3.2.3

a. Parameter estimates of slopes of the log-weight-ratio term nested under each level of the predator for the G11 data set.

Level	Parameter estimate	S.E. of estimate
Cod 1981	0.817	0.155
Cod 1985	0.823	0.157
Cod 1986	0.788	0.159
Cod 1987	0.800	0.160
Whiting 1981	1.433	0.144
Whiting 1985	0.815	0.145
Saithe 1981	1.637	0.186
Saithe 1986	0.933	0.185
Saithe 1987	1.230	0.184
Mackerel 1981	1.436	0.170
Haddock 1981	1.524	0.180

b. Parameter estimates of slopes of the log-weight-ratio of same model, for level of prey species.

Level	Parameter estimate	S.E. of estimate
Cod	0.124	0.117
Whiting	0.269	0.079
Haddock 1981	0.201	0.075
Herring	0.160	0.082
Sprat	-0.371	0.079
Norway Pout	-0.175	0.078
Sand eel	aliased	

Table 6.3.2.4

a. Least Squares Means for the levels of the predator main effect, from the single slope model fit to the G11 data.

	Mean	S. E.
Cod 1981	-4.735	0.076
Cod 1985	-4.938	0.077
Cod 1986	-4.890	0.081
Cod 1987	-4.755	0.092
Whiting 1981	-4.215	0.116
Whiting 1985	-4.068	0.113
Saithe 1981	-4.236	0.103
Saithe 1986	-4.757	0.125
Saithe 1987	-4.504	0.145

b. Probabilities that various LS Means are the same.

Mean 1	Mean 2	Probability
Cod 1981	Cod 1985	0.058
Cod 1981	Cod 1986	0.157
Cod 1981	Cod 1987	0.864
Cod 1985	Cod 1986	0.663
Cod 1985	Cod 1987	0.126
Cod 1986	Cod 1987	0.267
Whiting 1981	Whiting 1985	0.344
Saithe 1981	Saithe 1986	0.001
Saithe 1981	Saithe 1986	0.122
Saithe 1986	Saithe 1987	0.174

Table 6.8.1 Indicators of model fit to the MSVPA produced suitabilities and M2 values, for different data sets and ways of including covariates.

Data Set	OBSERVED		RZ	
	Suit	M2	Suit	M2
Total sum of squares	23437.19	50644.86	38751.50	54993.87
Total df	5210	5210	5376	5376
Single slope - log weight ratio only (df = 43)				
Residual SS	13236.85	34450.32	23013.57	37115.17
Model SS	10200.34	16194.54	15737.96	17878.70
r ²	.4352	.3198	.4061	.3251
Single slope - log weight ratio + log Predator weight (df = 44)				
Residual SS	13088.24	24449.17	22678.44	26193.89
Model SS	10348.95	26195.69	16073.06	28799.98
r ²	.4416	.5172	.4148	.5237
Predator nesting - log weight ratio (df = 47)				
Residual SS	12678.64	33164.27	22230.82	36364.19
Model SS	10785.55	17480.59	16520.68	18629.68
r ²	.4590	.3452	.4263	.3388
Predator nesting - log weight ratio + log Predator weight (df = 52)				
Residual SS	12575.92	21388.38	21229.20	23826.24
Model SS	10861.27	29256.48	17522.30	31167.63
r ²	.4634	.5777	.4522	.5667
Predator + Predator nesting - log weight ratio (df = 53)				
Residual SS	12347.90	32564.30	21229.20	35627.58
Model SS	11089.29	18080.56	17522.30	19366.29
r ²	.4731	.3570	.4522	.3522
Predator + Prey nesting - log weight ratio + log Predator weight (df = 64)				
Residual SS	11648.94	20295.67	19019.15	22866.04
Model SS	11788.25	30349.19	19732.35	32127.83
r ²	.5030	.5993	.5092	.5842
Single slope - weight ratio (not logged; df = 43)				
Residual SS			23041.47	42920.26
Model SS			15710.03	12073.61
r ²			.4054	.2195
Single slope - weight ratio + log Pred wt. (df = 44)				
Residual SS			22576.40	26334.84
Model SS			16175.10	28659.03
r ²			.4174	.5211

(cont'd)

Table 6.8.1 (cont'd)

Data Set	OBSERVED		RZ	
	Suit	M2	Suit	M2
Predator nested slope weight ratio (df = 47)				
Residual SS			21930.16	38846.96
Model SS			16821.34	16146.91
r ²			.4341	.2936
Predator nested slope - weight ratio + log Predator weight (df = 52)				
Residual SS			21700.25	23562.28
Model SS			17051.21	31431.59
r ²			.4400	.5715
Predator + Prey nested slope - weight ratio (df = 53)				
Residual SS			21569.06	38590.47
Model SS			17182.44	16403.40
r ²			.4434	.2983
Predator + Prey nested slope - weight ratio + log Predator weight (df = 64)				
Residual SS			20310.91	23052.36
Model SS			18440.59	31941.51
r ²			.4759	.5808

Table 6.8.2 Estimates of slopes of covariate terms for the models fit to OBSERVED and LZ data sets. Sum of squares of the terms also presented where appropriate.

Data Set Variable fit	SUIT		M2	
	Parm.Est.	SSreg	Parm.Est.	SSreg
Single Slope - LWTR				
LWTR	-.0609		-1.5429	
LWTRSQ	-.002698	182.04	.0751	6471.51
Single Slope log weight ratio + log predator weight				
LWTR	+.1438	}	+ .1369	}
LWTRSQ	-.0139	} 330.65	-.0167	} 16472.65
LPDT	-.2065	}	-1.6943	}
Predator nested slope - log weight ratio				
(LWTR) Pred.		565.20		5772.01
Cod	+.0821		-.8745	
Whiting	+.5685		-.8211	
Saithe	+.6909		+.3275	
Mackerel	+.5072		+.0337	
Haddock	+.6666		-1.1292	
LWTRSQ	-.0437	153.25	-.0280	63.07
Predator nested slopes - log weight ratio + log predator weight				
(LWTR) Pred.		485.60		1007.57
Cod	.1743		.5110	
Whiting	.7129		.6734	
Saithe	.7730		1.6651	
Mackerel	.5257		.9207	
Haddock	.9879		1.2588	
LWTRSQ	-.0485	180.77	-.1002	772.61
(LPDW) Pred.		102.72		11775.85
Cod	-.0759		-1.1505	
Whiting	-.3310		-2.9658	
Saithe	+.0263		-2.5148	
Mackerel	+.3095		-2.1947	
Haddock	-.5517		-3.3982	
Predator and Prey nested slopes log weight ratio				
(LWTR) Pred.		662.76		4171.41
Cod	-.4133		-1.5150	
Whiting	.1383		-1.3862	
Saithe	.0413		-.5621	
Mackerel	.2286		-.3660	
Haddock	.2916		-1.6122	

(cont'd)

Table 6.8.2 (cont'd)

Data Set Variable fit	SUIT		M2	
	Parm.Est.	SSreg	Parm.Est.	SSreg
(LWTR) Prey		330.73		599.97
Cod	.5317		.5038	
Whiting	.5947		.7289	
Saithe	.3719		.3020	
Mackerel	.3374		.4481	
Haddock	.5470		.7025	
Herring	.4480		.6460	
LWTRSQ	-.0343	86.65	-.0124	11.19
Predator and Prey nested slopes - log weight ratio and log predator weight				
(LWTR) Pred.		419.68		946.58
Cod	-.6696		-.0247	
Whiting	-.0671		.1761	
Saithe	-.2753		1.1370	
Mackerel	-.0320		.5866	
Haddock	+.2564		.7922	
(LWTR) Prey		371.48		310.97
Cod	.6747		.4941	
Whiting	.9123		.6516	
Nor. Pout	.5829		.3674	
Sandeel	.8497		.6839	
Herring	.7889		.5916	
Sprat	.7366		.4395	
(LPDW) Pred.		74.40		2721.19
Cod	.4009		-.4474	
Whiting	.1607		-2.3218	
Saithe	.4928		-1.8603	
Mackerel	.5433		-1.8337	
Haddock	.0320		-2.7248	
(LPDW) Prey		638.77		345.71
Cod	.0069			
Whiting	-.5686			
Nor. Pout	-.1474			
Sandeel	-1.1170			
Herring	-.1661			
Sprat	-.3090			
LWTRSQ	-.0333	75.14	-.1004	684.14

Table 6.8.3 Estimates of slopes of covariate terms for the model with log weight ratio and log predator biomass both nested under predator, fit to the RZ data set.

	RZ			
	SUIT		M2	
	Parm.Est.	SSreg	Parm.Est.	SSreg
(LWTR) Pred.		651.17		735.24
Cod	+ .0501		+ .3187	
Whiting	+ .6766		+ .5523	
Saithe	+ .3452		+1.1597	
Mackerel	- .7852		-0.0837	
Haddock	- .0614		+ .6982	
(LPDW) Pred.		322.82		12537.95
Cod	- .2753		-1.1505	
Whiting	- .3006		-2.9658	
Saithe	+ .1870		-2.5148	
Mackerel	2.0790		-2.1947	
Haddock	.1985		-3.3982	
LWTRSQ	- .01985	33.38	-0.06949	409.27

Table 6.11.1 MSVPA runs, from which data were selected for regression analysis of observed versus predicted prey fractions in the food of cod. For all other predator species the total data base was used.

Stomach content data from year	Years included in the analysis			
	1981	1985	1986	1987
1981	-	+	+	+
1985	+	-	+	+
1986	+	+	-	+
1987	+	+	+	-
1981/1985	+	+	+	+
1981/1985/1986	+	+	+	+
1981/1985/1986/1987	+	+	+	+

Table 6.11.2 Results of regression analysis of observed and predicted stomach contents fractions in cod during 1st and 3rd quarters, based on individual sampling years (1981, 1985, 1986, 1987).

A) Observed fractions in individual years versus predicted, on the basis of observations in another year (1981, 1985, 1986, 1987).

Prey/Year	1981			1985			1986			1987			1981/1987	
	n	r ²	a	b	n	r ²	a	b	n	r ²	a	b	n	r ²
ALL	722	.26	.49	.04	732	.29	.55	.04	639	.33	.5	.05	657	.32
COD	66	.08	.36	.04	72	.04	.22	.06	51	.11	.37	.06	54	0
WHI	156	.41	.53	.03	150	.47	.85	.02	126	.48	.89	.04	117	.48
NOP	75	.21	.72	.09	93	.24	.37	.08	87	.3	.4	.06	90	.2
SAN	143	.32	.71	.01	120	.43	.76	.01	93	.48	.53	.03	120	.45
HAD	99	.67	.76	.02	93	.35	.74	.04	84	.45	.68	.07	99	.58
HER	90	.06	.16	.10	135	.24	.56	.04	144	.37	.61	.02	138	.41
SPR	93	.06	.11	.01	69	.05	.19	.03	54	.01	-.07	.05	39	.09
														2.30
														.04
														.04
														.30
														.02
														.19
														.40
														.50
														.21
														.00

B) Observed fractions in individual years versus observed fractions in another year (1981, 1985, 1986, 1987)

Prey/Year	1981			1985			1986			1987			1981/1987	
	n	r ²	a	b	n	r ²	a	b	n	r ²	a	b	n	r ²
ALL	722	.21	.49	.04	732	.27	.56	.04	639	.27	.48	.05	657	.30
COD	66	.04	.19	.04	72	.01	.14	.07	51	.00	.05	.08	54	.01
WHI	156	.42	.54	.03	150	.44	1.01	.02	126	.38	.76	.05	117	.45
NOP	75	.02	.16	.15	93	.21	.37	.08	87	.29	.47	.06	90	.29
SAN	143	.26	.67	.01	120	.39	.76	.02	93	.30	.36	.04	120	.34
HAD	99	.49	.68	.02	93	.32	.74	.03	84	.24	.48	.08	99	.49
HER	90	.01	.16	.11	135	.19	.48	.04	144	.30	.49	.03	138	.26
SPR	93	.11	.13	.01	69	.16	1.01	.01	54	.01	.14	.04	39	.02
														1.07
														.05
														.04
														.26
														.01
														.36
														.17
														.29
														.38
														.17
														.01

Table 6.11.3 Comparison of the gain obtained by including one more data year at each step in terms of r squared by prey species.

PREY	1981		1981/1985		1981/1985/1986/1987		1981/1985/1986/1987	
	n	r ²	n	r ²	n	r ²	0	r ²
ALL	963	.38	1124	.5	1148	.56	1176	.6
COD	88	.29	100	.33	100	.34	104	.33
WHI	208	.54	212	.63	212	.68	212	.72
NOP	100	.31	128	.54	128	.55	128	.56
SAN	191	.42	204	.55	204	.64	220	.67
HAD	132	.74	144	.75	148	.76	156	.79
HER	120	.11	212	.28	224	.39	224	.44
SPR	124	.28	124	.32	132	.3	132	.3

Table 6.11.4 Results of regression analysis of observed and predicted stomach contents fractions when all available data sets are included (1981/1987).

A) Based on individual observations by prey age group.

B) Based on total fractions by prey summed over age groups.

PRED	PREY	A) BY PREY AGE				B) BY PREY			
		n	r ²	a	b	n	r ²	a	n
ALL	ALL	2232	.68	.89	0	659	.72	.93	.01
COD	ALL	1176	.6	.82	.01	288	.58	.82	.03
	COD	104	.33	.81	.01	40	.3	.77	.03
	WHI	212	.72	.96	0	44	.6	.91	.03
	NOP	128	.56	.85	.02	40	.47	.87	.03
	SAN	220	.67	.83	0	44	.55	.73	.03
	HAD	156	.79	.95	0	40	.66	.85	.05
	HER	224	.44	.68	.02	40	.32	.51	.12
	SPR	132	.3	.5	.01	40	.41	.58	.01
WHI	ALL	630	.63	.99	0	225	.7	.96	0
	COD	30	.33	.96	0	30	.33	.96	0
	WHI	54	.68	.88	.01	30	.2	.58	.08
	NOP	99	.82	1.19	-.19	33	.76	1.14	-.04
	SAN	177	.84	.94	0	33	.56	.93	.01
	HAD	60	.71	.96	0	33	.42	.88	.02
	HER	87	.19	.55	.04	33	.46	.77	.05
	SPR	123	.41	.82	0	33	.39	.91	0
SAI	ALL	426	.79	.95	0	146	.82	.97	0
	COD	18	.68	1.31	-.02	18	.68	1.31	-.02
	WHI	56	.78	1.04	0	23	.95	1.06	0
	NOP	84	.81	.87	.03	24	.2	.59	.28
	SAN	92	.67	.8	0	24	.67	.84	0
	HAD	48	.82	.99	-.02	24	.6	.1	-.02
	HER	113	.55	1.57	-.03	24	.57	1.77	-.1
	SPR	15	.96	1.02	0	9	.96	1.04	0

Table 7.1 Total biomasses consumed by all predators, compared to total stock biomass, total predator biomass, total yield, and residual natural mortality in terms of biomass (1,000 t). Second figure refers to deviation of 1988 results in percent of 1988 results, negative values are in parentheses.

Year	Average biomass	Total yield	Total VPA species eaten (TVSE)	Total oth. food eaten (TOFE)	Average predator biomass (APDB)	Yield		TVSE		TOFE		TVSE	
						Av. biomass	Yield	Av. biomass	Yield	Av. biomass	Yield	Av. biomass	Yield
1974	10,350	1 3,030	0 6,114 (3)	9,131	3,381	0.29	(1)	0.59	(4)	0.88		1.81	
1975	9,870	2 3,159	0 5,628 (3)	7,471	3,206	0.32	(2)	0.57	(5)	0.76		1.76	(4)
1976	8,208	3 3,158	0 4,676 (2)	6,116	2,574	0.38	(3)	0.57	(5)	0.75		1.82	(2)
1977	6,837	3 2,506	0 3,601 (3)	5,637	2,114	0.37	(3)	0.53	(6)	0.82		1.70	(4)
1978	6,327	2 2,540	5 2,985 (6)	5,257	1,909	0.40	3	0.47	(8)	0.83		1.56	(7)
1979	6,481	2 2,419	0 2,854 (4)	5,512	1,931	0.37	(2)	0.44	(6)	0.85		1.48	(5)
1980	5,855	2 2,601	0 2,590 (3)	5,102	1,983	0.44	(2)	0.44	(5)	0.87		1.31	(4)
1981	5,291	1 2,419	0 2,314 (4)	4,720	1,832	0.46	(1)	0.44	(5)	0.89		1.26	(5)
1982	5,850	1 2,378	0 2,328 (3)	3,809	1,655	0.41	(1)	0.40	(4)	0.65		1.41	(3)
1983	5,796	1 2,349	0 2,062 (6)	4,365	1,625	0.41	(1)	0.36	(7)	0.75		1.27	(5)
1984	6,222	1 2,586	0 1,923 (7)	4,230	1,689	0.42	(1)	0.31	(8)	0.68		1.14	(6)
1985	5,850	(2) 2,512	3 1,964 (18)	4,282	1,679	0.43	5	0.34	(16)	0.73		1.17	(14)
1986	7,290	5 1,967 (16)	2,446 (21)	4,453	1,665	0.27	(20)	0.34	(24)	0.61		1.47	(15)
1987	7,576	25 2,440 (4)	2,368 (11)	3,542	1,654	0.32	(23)	0.31	(29)	0.47		1.43	(7)
Mean	6,996	2,576	3,132	5,259	2,064	0.38		0.44		0.75		1.47	
Coeff. var.	0.12	0.12	0.42	0.28	0.27	0.15		0.22		0.15		0.15	

Table 8.1.1 Yield and value calculations based on Multispecies logistic model, wherein effort is increased by 10% in each fleet individually.

Fleet	Effort change	New yield ('000 t)	Old yield ('000 t)	% Change
Roundfish	1.10	503.22	483.25	4.13
Indust. DE	1.10	1662.13	1533.39	8.40
Indust. PE	1.10	532.41	509.60	4.48
Herring	1.10	163.05	159.90	1.97
Saithe	1.10	168.79	175.20	-3.66
Mackerel	1.10	33.28	33.18	.30
Total		3062.88	2894.52	5.82

Fleet	Effort change	New value (000,000ecu)	Old value (000,000ecu)	Profit (000,000ecu)	% change
Roundfish	1.10	211.75	206.81	-15.74	2.39
Indust. DE	1.10	66.49	61.34	-.98	8.40
Indust. PE	1.10	18.68	17.88	-.99	4.49
Herring	1.10	30.32	29.82	-2.48	1.68
Saithe	1.10	52.88	55.73	-8.43	-5.12
Mackerel	1.10	6.46	6.44	-.62	.30

Table 8.1.2 Calculated bioeconomic reference points for the quadratic multispecies yield surface.

Effort change Fleet	MSY	Overall $F_{0.1}$	Fleet $F_{0.1}$	Status quo
Roundfish	1.89	1.76	1.04	1.00
Indust. DE	1.49	1.40	1.11	1.00
Indust. PE	1.08	.97	1.22	1.00
Herring	1.39	1.30	1.10	1.00
Saithe	1.75	*1.75	.87	1.00
Mackerel	*2.00	*2.00	.96	1.00
Total				
Yield k.tonnes	3949	3931	2821	2895
Value m.ecu	339	377	355	378
Profit m.ecu	-314	-240	-37	0

*Defined as a constraint in order to allow model solution.

Table 8.1.3 Calculated bioeconomic reference points for the quadratic multispecies yield surface.

Effort change Fleet	MSY	Overall $F_{0.1}$	Fleet $F_{0.1}$	MEY	Status quo
Roundfish	1.29	1.20	.92	.59	1.00
Indust. DE	.96	.92	1.10	.21	1.00
Indust. PE	* .10	* .10	1.22	*.10	1.00
Herring	*2.00	1.97	1.04	.92	1.00
Saithe	*1.75	1.79	.84	.98	1.00
Mackerel	*2.00	*2.00	.96	.98	1.00
<hr/>					
Total					
Yield k.tonnes	3349	3284	2744	1421	2895
Value m.ecu	469	468	349	319	378
Profit m.ecu	-28	-10	-13	94	0

*Defined as a constraint in order to allow model solution.

Table 8.2.1. Percentage change in long-term population size, by species and age, caused by a 10% decrease in effort on the following species/ages.

	age	cod0	cod1	cod2	cod3+	wh10	wh11	wh12	wh13+	sai0	sai1	sai2	sai3+	mac0	mac1	mac2	mac3+	had0	had1	had2	had3+	
COD	0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	-1	-1.1	.0	.0	-1	-5	.0	.0	.0	.0	
	1	.0	.6	-8	-8	-1	-2	.0	.0	.0	.0	-2	-1.9	.0	-1	-2	-9	.0	.0	.0	.0	
	2	.0	1.2	2.7	-2.3	-1	-2	.0	.0	.0	.0	-2	-1.6	.0	-1	-2	-7	.0	.0	.0	.0	
	3	.0	1.1	5.8	1.3	-1	-2	.0	.0	.0	.0	-2	-1.5	.0	-1	-2	-7	.0	.0	.0	.0	
	4	.0	1.1	6.2	9.4	-1	-2	.0	.0	.0	.0	-2	-1.4	.0	-1	-2	-7	.0	.0	.0	.0	
	5	.0	1.1	6.6	16.7	-1	-2	.0	.0	.0	.0	-2	-1.4	.0	-1	-2	-7	.0	.0	.0	.0	
	6	.0	1.1	6.6	23.9	-1	-2	.0	.0	.0	.0	-2	-1.4	.0	-1	-2	-7	.0	.0	.0	.0	
	7	.0	1.1	6.6	31.1	-1	-2	.0	.0	.0	.0	-2	-1.4	.0	-1	-2	-7	.0	.0	.0	.0	
	8	.0	1.1	6.6	38.3	-1	-2	.0	.0	.0	.0	-2	-1.4	.0	-1	-2	-7	.0	.0	.0	.0	
	9	.0	1.1	6.6	45.6	-1	-2	.0	.0	.0	.0	-2	-1.4	.0	-1	-2	-7	.0	.0	.0	.0	
	10	.0	1.1	6.6	52.9	-1	-2	.0	.0	.0	.0	-2	-1.4	.0	-1	-2	-7	.0	.0	.0	.0	
WHITING	0	.0	.0	.1	.2	.2	-1.4	-1.3	-2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	
	1	.0	.0	-1	.2	.4	.5	-1.6	-1.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	
	2	.0	-2	-7	-4	.3	1.7	1.6	-1.4	.0	.0	.0	.0	.0	.0	.0	.1	.2	.0	.0	.0	
	3	.0	-3	-1.2	-1.4	.3	1.7	4.3	2.5	.0	.0	.0	.0	.0	.0	.0	.2	.0	.0	.0	.0	
	4	.0	-3	-1.5	-2.0	.3	1.7	4.3	11.8	.0	.0	.0	.0	.0	.0	.1	.2	.0	.0	.0	.0	
	5	.0	-4	-1.7	-2.4	.3	1.7	4.3	21.7	.0	.0	.0	.0	.0	.0	.1	.2	.0	.0	.0	.0	
	6	.0	-4	-1.9	-2.7	.3	1.3	4.3	33.0	.0	.0	.0	.0	.0	.0	.1	.2	.0	.0	.0	.0	
	7	.0	-4	-1.9	-2.8	.3	1.8	4.3	45.5	.0	.0	.0	.0	.0	.0	.1	.2	.0	.0	.0	.0	
	8	.0	-4	-1.7	-2.8	.3	1.8	4.3	58.4	.0	.0	.0	.0	.0	.0	.1	.2	.0	.0	.0	.0	
	9	.0	-4	-1.9	-2.8	.3	1.2	4.3	72.1	.0	.0	.0	.0	.0	.0	.1	.2	.0	.0	.0	.0	
	10	.0	-4	-1.9	-2.2	.3	1.2	4.3	84.5	.0	.0	.0	.0	.0	.0	.1	.2	.0	.0	.0	.0	
HADDOCK	0	.0	.0	.0	.1	-1	-3	-5	-5	.0	.0	-3	-1.6	.0	.0	.0	.0	.1	.0	.0	.0	
	1	.0	-1	-4	-1	-2	-7	-1.1	-1.1	.0	-1	-1.1	-6.8	.0	.0	.0	.1	.3	1.4	.0	.0	
	2	.0	-3	-1.1	-8	-2	-7	-1.1	-1.3	.0	-1	-1.6	-10.6	.0	.0	.0	.2	.3	2.8	4.0	.0	
	3	.0	-3	-1.4	-1.5	-2	-7	-1.2	-1.3	.0	-1	-1.6	-10.7	.0	.0	.1	.2	.3	2.8	8.0	5.5	
	4	.0	-4	-1.6	-1.8	-2	-7	-1.2	-1.3	.0	-1	-1.6	-10.7	.0	.0	.1	.2	.3	2.8	8.0	16.5	
	5	.0	-4	-1.6	-1.9	-2	-7	-1.2	-1.3	.0	-1	-1.6	-10.7	.0	.0	.1	.2	.3	2.8	8.0	26.7	
	6	.0	-4	-1.6	-1.9	-2	-7	-1.2	-1.3	.0	-1	-1.6	-10.7	.0	.0	.1	.2	.3	2.8	8.0	35.9	
	7	.0	-4	-1.6	-1.9	-2	-7	-1.2	-1.3	.0	-1	-1.6	-10.7	.0	.0	.1	.2	.3	2.8	8.0	44.3	
	8	.0	-4	-1.6	-1.9	-2	-7	-1.2	-1.3	.0	-1	-1.6	-10.7	.0	.0	.1	.2	.3	2.8	8.0	51.6	
	9	.0	-4	-1.6	-1.9	-2	-7	-1.2	-1.3	.0	-1	-1.6	-10.7	.0	.0	.1	.2	.3	2.8	8.0	58.0	
	10	.0	-4	-1.6	-1.9	-2	-7	-1.2	-1.3	.0	-1	-1.6	-10.7	.0	.0	.1	.2	.3	2.8	8.0	65.1	
HERRING	0	.0	.0	.1	.0	.0	-2	-1	.0	.0	.0	.0	.0	.0	-1	-3	.0	.0	.0	.0	.0	
	1	.0	.0	.2	.3	.2	-1.6	-1.7	-1.5	.0	.0	.0	-2	.0	-1	-3	-1.1	.0	.0	.0	.0	
	2	.0	-1	.1	.5	-2	-1.0	-1.1	-1.9	.0	.0	.0	-3	.0	-1	-4	-1.8	.0	.0	.0	.0	
	3	.0	-2	-4	.9	-3	-1.9	-1.2	-1.9	.0	.0	-1	-7	.0	-1	-4	-1.8	.0	.0	.0	.0	
	4	.0	-2	-8	.5	-3	-1.0	-1.2	-1.9	.0	.0	-1	-1.2	.0	-1	-4	-1.8	.0	.0	.0	.0	
	5	.0	-3	-9	.6	-2	-1.0	-1.2	-1.9	.0	.0	-1	-1.5	.0	-1	-4	-1.8	.0	.0	.0	.0	
	6	.0	-3	-1.1	-2	-2	-1.0	-1.2	-1.9	.0	.0	-2	-2.2	.0	-1	-3	-1.7	.0	.0	.0	.0	
	7	.0	-3	-1.2	-1.0	-2	-1.0	-1.2	-1.9	.0	.0	-2	-2.9	.0	-1	-3	-1.7	.0	.0	.0	.0	
	8	.0	-3	-1.2	-1.0	-2	-1.0	-1.2	-1.9	.0	.0	-2	-2.9	.0	-1	-3	-1.7	.0	.0	.0	.0	
	9	.0	-3	-1.2	-1.0	-2	-1.0	-1.2	-1.9	.0	.0	-2	-2.9	.0	-1	-3	-1.7	.0	.0	.0	.0	
	10	.0	-3	-1.2	-1.0	-2	-1.0	-1.2	-1.9	.0	.0	-2	-2.9	.0	-1	-3	-1.7	.0	.0	.0	.0	
SPRAT	0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	
	1	.0	.0	.1	.0	-1	-2	-1	.0	.0	.0	.0	.0	.0	-1	-2	-1.9	.0	.0	.0	.0	
	2	.0	.0	.2	.1	-3	-7	-3	.2	.0	.0	.0	.0	.0	-1	-3	-1.7	.0	.0	.0	.0	
	3	.0	.1	.4	.4	-5	-1.5	-1.9	.0	.0	.0	-1	.0	.0	-1	-4	-2.0	.0	.0	.0	.0	
	4	.0	.0	.2	.7	-7	-2.3	-1.9	-1.0	.0	.0	-1	.2	.0	-1	-4	-2.0	.0	.0	.0	.0	
N. POUT	0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	-1	-5	.0	.0	.0	.0	.0	.0	.0	.0	
	1	.0	.0	.0	.1	.0	-1	-2	-2	.0	.0	-1	-2	-8.1	.0	.0	-1	-5	.0	-1	-2	-2
	2	.0	-1	-3	.0	.6	-2	-5	-8	.0	.0	-2	-2.6	-19.5	.0	.0	-1	-9	.0	-2	-3	-4
	3	.0	-1	-6	-2	-1	-5	-1.0	-1.6	.0	.0	-3	-3.5	-29.7	.0	.0	-1	-9	.0	-2	-4	-4
	4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SAI DEEL	0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	-1	-2	.0	.0	.0	.0	
	1	.0	.0	.1	.1	-1	-3	-1	.1	.0	.0	.0	.3	.0	-2	-4	-1.4	.0	-1	-1	-1	-1
	2	.0	.0	.1	.2	-2	-3	-3	.1	.0	.0	.0	.4	.0	-3	-8	-2.9	.0	-1	-1	-1	-1
	3	.0	.0	.1	.2	-2	-7	-5	.6	.0	.0	.0	.4	.0	-4	-1.0	-3.7	.0	-1	-1	-1	-1
	4	.0	.0	.2	.1	-3	-3	-7	-1	.0	.0	.0	.4	.0	-5	-1.3	-4.4	.0	-1	-1	-1	-1
	5	.0	-1	-1	-1	-3	-1.0	-1.9	-2	.0	.0	.0	.4	.0	-6	-1.6	-5.5	.0	-1	-1	-1	-1
6	.0	-1	-4	-4	-3	-1.0	-1.1	-3	.0	.0	-1	.3	.0	-8	-2.0	-6.7	.0	-1	-2	-2	-1	

TABLE 8.2.2. Expected change in steady state fishery yields (tons), contingent upon a 10% decrease in fishing mortality on the species/age group listed at the left of the table.

FISHERY	TOTAL	COD	WHITING	SAITHE	HACKRL	HADDOCK	HERRING	SPRAT	N. POUT	SANDEEL
cod0	0	0	0	0	0	0	0	0	0	0
cod1	141	1507	-403	0	0	-678	-207	121	-84	-115
cod2	-901	2961	-1646	0	0	-2854	-385	674	-348	697
cod3+	-3641	-1452	-1628	0	0	-2679	209	516	113	1281
wh10	-3195	-182	348	0	0	-420	-445	-860	-132	-1504
wh11	-11844	-404	-814	0	0	-1732	-1707	-2372	-581	-4235
wh12	-11774	-25	-2162	0	0	-2842	-2035	-1125	-1062	-2524
wh13+	-7135	21	-1934	0	0	-3159	-1533	194	-1468	744
sa10	0	0	0	0	0	0	0	0	0	0
sa11	-665	-30	-2	256	0	-337	-10	-12	-524	-7
sa12	-8237	-343	-23	2207	0	-3814	-115	-132	-5935	-82
sa13+	-62316	-2979	-44	6540	0	-24915	-1251	19	-42821	3135
mac0	0	0	0	0	0	0	0	0	0	0
mac1	-2695	-122	22	0	430	38	-212	-296	-136	-2419
mac2	-7413	-383	69	0	1034	120	-652	-887	-368	-6347
mac3+	-33952	-1379	250	0	-210	433	-3125	-5109	-2252	-22560
had0	134	0	-1	0	0	339	1	0	-49	-156
had1	630	4	-13	0	0	1893	6	-1	-445	-816
had2	2230	9	-29	0	0	4168	13	5	-853	-1082
had3+	682	7	-24	0	0	2323	6	13	-880	-762

Table 8.4.1 Percentage of mean weight of food items by taxonomic units and size class in stomachs of *Raja radiata*.

Taxonomic units	Predator size class (mm)						
	100	150	200	250	300	400	500
PISCES	3.39	5.71	18.92	36.00	39.11	51.31	65.40
Ammodytoidei	-	2.52	7.13	17.45	16.26	31.16	36.50
Ammodytidae A	-	2.52	7.13	17.45	16.26	31.16	36.50
Blennioidei	-	-	-	0.14	0.33	0.48	2.43
Lumpenus lampretaeformis	-	-	-	0.14	0.33	0.48	2.43
Callionymoidei	-	0.01	0.37	0.29	0.27	0.69	-
Callionymus lyra	-	0.01	0.37	0.29	0.27	0.69	-
Clupeoidei	-	-	-	0.35	1.40	2.80	2.22
Clupea sp.	-	-	-	0.35	0.05	1.03	2.11
Clupea harengus	-	-	-	-	1.35	1.77	0.11
Cottoidei	-	-	0.46	-	0.02	0.03	0.37
Agonus cataphractus	-	-	-	-	0.02	0.03	0.37
Liparis liparis	-	-	0.46	-	-	-	-
Gadoidei	-	-	3.88	12.28	7.26	7.47	12.01
Gadidae	-	-	1.17	-	-	1.66	1.02
Melanogrammus aeglefinus	-	-	-	5.73	1.21	-	-
Merlangius merlangus	-	-	1.91	4.91	0.33	2.70	10.99
Rhinonemus cimbricus	-	-	-	0.86	5.49	1.98	-
Trisopterus esmarki	-	-	0.80	0.78	0.23	1.13	-
Gobioidei	-	-	1.48	0.57	0.75	0.49	0.15
Aphia minuta	-	-	-	0.17	0.12	0.11	0.04
Gobiidae	-	-	-	0.09	0.23	0.02	0.11
Pamatochistus sp.	-	-	1.48	0.31	0.39	0.36	-
Pleuronectoidei	3.39	2.46	5.23	2.58	6.59	3.36	7.69
Arnoglossus lanterna	-	-	-	-	0.39	-	-
Hippoglossus platessoides	3.39	1.08	2.89	1.87	1.34	2.26	5.48
Limanda limanda	-	0.20	1.77	0.55	4.61	0.95	1.70
Pleuronectidae	-	1.18	0.57	0.16	0.24	0.15	0.51
Soleoidei	-	-	-	-	0.29	0.65	1.18
Buglossidium luteum	-	-	-	-	0.29	0.65	1.18
Squaloidei	-	-	-	-	-	0.21	-
Raja radiata	-	-	-	-	-	0.21	-
Unident. pisces	-	0.72	0.37	2.33	5.95	3.97	2.85

Table 8.4.2 Annual consumption by taxonomic units and size class by Raja radiata.

Consum. (10**6 kg) per taxonomic unit	Size class							Total
	100	150	200	250	300	400	500	
Polychaeta	0.4	4.1	4.6	7.8	24.0	9.2	1.0	51
Gammeridea	14.8	17.2	20.8	14.8	11.4	3.0	0.2	82
Natantia	4.9	8.0	4.7	8.1	16.9	10.3	2.7	55
Reptantia	0.1	2.4	12.4	9.4	54.1	51.9	7.8	138
Pisces	0.9	2.1	10.4	25.2	71.8	84.4	23.3	218
Other food	5.1	3.8	2.0	4.7	5.3	5.8	0.7	27
Total	26.3	37.6	54.9	70.1	183.5	164.5	35.6	573

Table 9.1 Percent changes in biomass, catch and value associated with three effort reduction strategies.

% Change from baseline with 50% reduction in all effort.

Species	Total biomass	Sp.stock biomass	Average biomass	Catch	Fleet*	Catch	Value
COD	26	128	35	-37	RF85L	-43	-38
WHI	9	14	9	-37	RF85D	-72	0
SAI	90	228	91	10	RF120L	0	0
MAC	60	127	56	-14	RF120D	0	0
HAD	-71	-80	-70	-89	Ind-Dem	-44	-44
HER	16	20	15	-42	Ind-Pel	-38	-38
SPR	16	35	16	-34	Her	-40	-39
NOR	-35	-43	-48	-88	Sai	10	17
SAN	27	50	36	-25	Mac	-14	-14
Total	10	28	14	-40	Total	-40	-30

% Change from baseline with 50% in industrial effort.

Species	Total biomass	Sp.stock biomass	Average biomass	Catch	Fleet*	Catch	Value
COD	8	9	8	6	RF85L	15	15
WHI	11	14	11	0	RF85D	15	0
SAI	1	2	1	0	RF120L	0	0
MAC	0	0	0	0	RF120D	0	0
HAD	16	27	17	14	Ind-Dem	-23	-23
HER	83	106	81	-2	Ind-Pel	-24	-24
SPR	21	44	20	-30	Her	9	11
NOR	15	22	15	-24	Sai	1	1
SAN	31	61	43	-21	Mac	0	0
Total	27	50	33	-12	Total	-6	-19

% Change from baseline with 50% reduction in human consumption effort.

Species	Total biomass	Sp.stock biomass	Average biomass	Catch	Fleet*	Catch	Value
COD	19	113	27	-39	RF85L	-48	-43
WHI	-2	0	-2	-34	RF85D	-75	0
SAI	87	222	89	10	RF120L	0	0
MAC	0	0	0	0	RF120D	0	0
HAD	-74	-85	-73	-89	Ind-Dem	-21	-21
HER	-24	-30	-24	-29	Ind-Pel	-9	-9
SPR	0	-1	0	-1	Her	-34	-35
NOR	-37	-45	-43	-78	Sai	8	15
SAN	2	1	2	1	Mac	0	0
Total	-8	-4	-8	-25	Total	-25	-28

*Fleet definitions are as in Sections 3 and 4.

Table 9.2.1 Predation parameters for all predators of the MSVPA stocks. Logarithms are to base 10.

Predator weight g	log (W)	Mean predation distance	Predation window width
		$\log \frac{W_{\text{prey}}}{W_{\text{pred}}}$	Std ($\log(\frac{W_{\text{prey}}}{W_{\text{pred}}})$)
7.5	0.875	-0.63	0.23
13.3	1.125	-0.66	-
23.7	1.375	-	-
42.2	1.625	-	-
75	1.875	-1.29	0.23
133	2.125	-1.40	0.29
237	2.375	-1.47	0.27
422	2.625	-1.68	0.32
750	2.875	-1.74	0.41
1,334	3.125	-2.04	0.17
2,371	3.375	-2.09	0.26
4,217	3.625	-2.26	0.38
7,499	3.875	-2.37	0.47
13,335	4.125	-2.08	0.43

Table 9.2.2 Predation parameters of single predators by age group.
Logarithms are to base 10.

Predator	Age	Weight (g)	Predation distance	Predation window width	
Cod	2	193.7	-1.39	0.21	
	3	801.7	-1.77	0.12	
	4	2,110.0	-1.76	0.44	
	5	4,227.5	-1.87	0.56	
	6	6,415.0	-1.94	0.52	
	7	8,262.5	-1.95	0.43	
	8	10,127.5	-2.03	0.43	
	9	11,400.0	-2.10	0.43	
	10	12,625.0	-2.14	0.43	
	11	13,625.0	-2.18	0.43	
	12	14,425.0	-2.17	0.42	
	Whiting	1	6.9	-0.63	0.23
2		71.4	-1.29	0.21	
3		159.5	-1.42	0.29	
4		243.3	-1.45	0.28	
5		334.5	-1.49	0.26	
6		410.2	-1.54	0.30	
7		464.2	-1.58	0.26	
8		532.2	-1.60	0.21	
9		592.7	-1.63	0.20	
10		715.0	-1.78	0.26	
11		825.0	-1.89	0.31	
Saithe	4	1,019.5	-2.05	0.19	
	5	1,565.0	-2.03	0.13	
	6	2,242.5	-2.11	0.13	
	7	3,070.0	-2.29	0.14	
	8	3,962.5	-2.32	0.18	
	9	4,785.0	-2.42	0.19	
	10	5,617.5	-2.48	0.19	
	11	6,475.0	-2.55	0.18	
	12	7,207.5	-2.61	0.19	
	13	7,792.5	-2.65	0.19	
	14	8,467.5	-2.69	0.18	
	15	8,937.5	-2.71	0.18	
	16	9,182.5	-2.72	0.18	
	Mackerel	2	177.5	-1.32	0.27
		3	282.5	-1.53	0.26
		4	340.0	-1.65	0.30
5		382.5	-1.70	0.30	
6		421.2	-1.73	0.31	
7		457.5	-1.78	0.30	
8		493.7	-1.82	0.30	
9		526.2	-1.58	0.41	
10		557.5	-1.59	0.41	
11		587.5	-1.62	0.41	
12		617.5	-1.64	0.41	
13		645.0	-1.66	0.41	
14		668.7	-1.67	0.41	
15		693.8	-1.69	0.40	
16		715.0	-1.71	0.40	

(cont'd)

Table 9.2.2 (cont'd)

Predator	Age	Weight (g)	Predation distance	Predation window width
Haddock	1	10.3	-0.66	0.00
	2	93.5	-1.14	0.46
	3	255.8	-1.50	0.27
	4	431.7	-1.60	0.15
	5	622.3	-1.72	0.18
	6	836.3	-1.75	0.15
	7	1,053.5	-1.99	0.27
	8	1,277.5	-2.07	0.27
	9	1,572.5	-2.17	0.28
	10	1,865.0	-2.24	0.27
	11	2,052.5	-2.30	0.29
	12	2,427.5	-2.35	0.26

COD STOCK SIZE

- +— TSB MSVPA
- SSB MSVPA
- x— TSB SSVPA
- ▽— SSB SSVPA

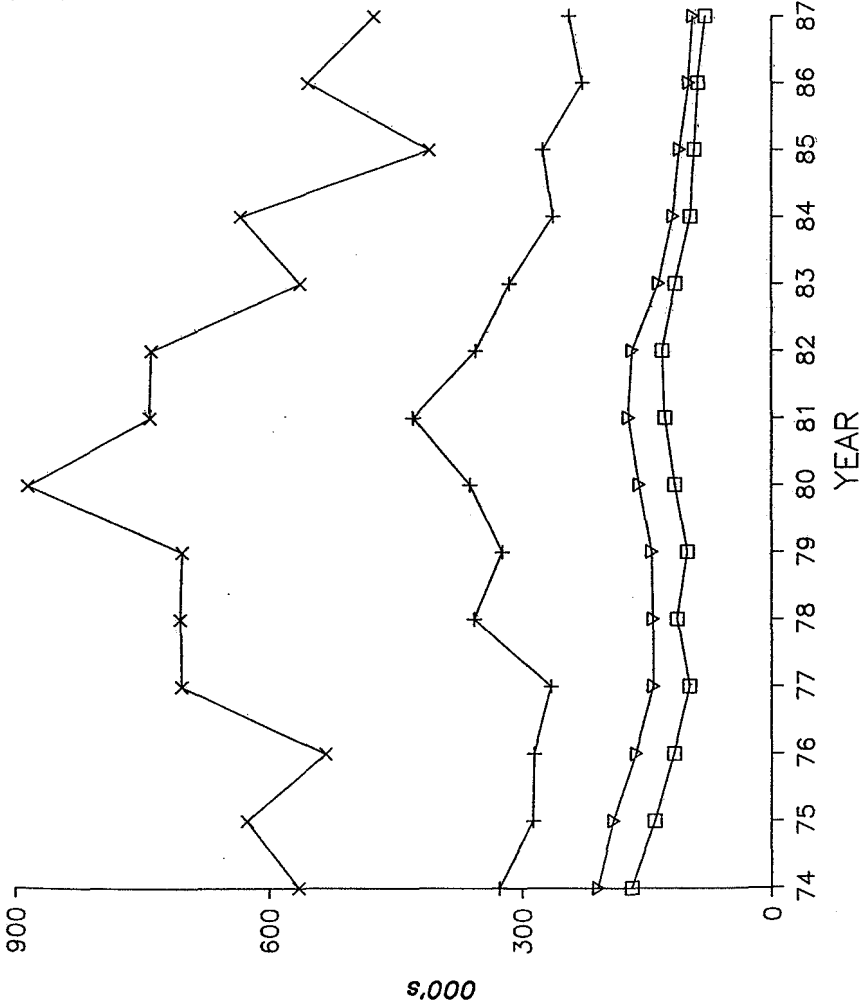


Figure 2.8.2a. The total stock biomass (TSB) and spawning stock biomass (SSB) of cod from the MSVPA and the single-species VPA (SSVPA).

HADDOCK STOCK SIZE

- +— TSB MSVPA
- SSB MSVPA
- x— TSB SSVPA
- ▽— SSB SSVPA

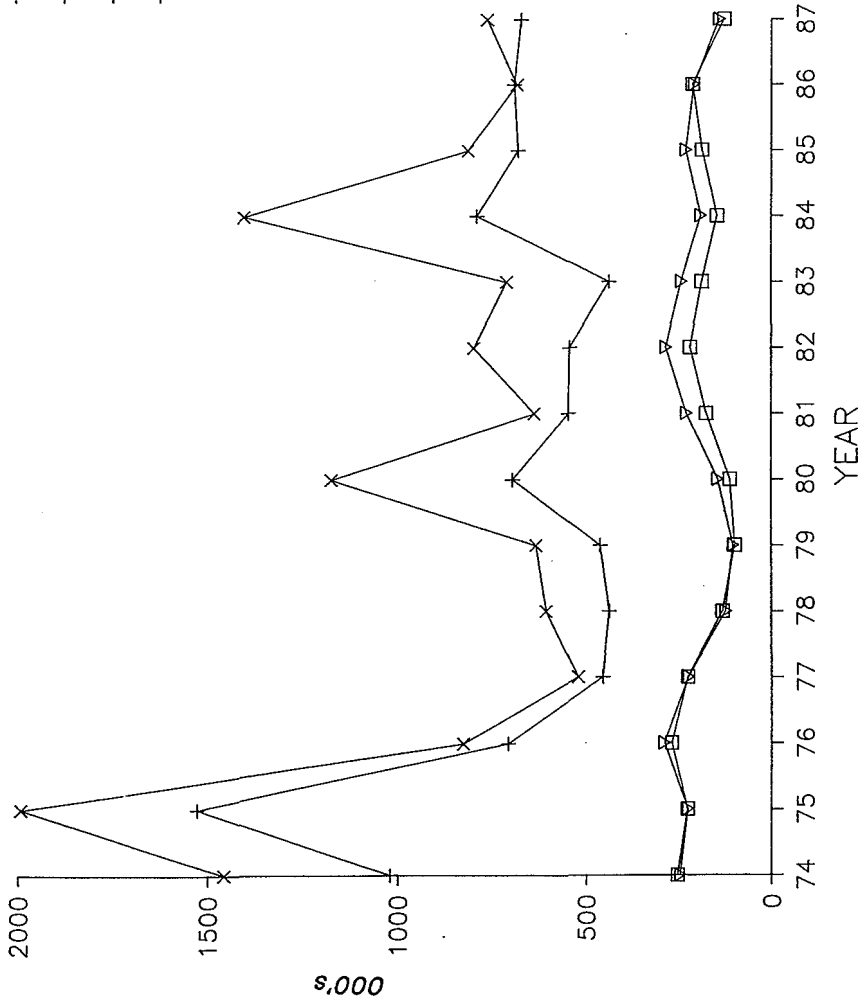


Figure 2.8.2b. The total stock biomass (TSB) and spawning stock biomass (SSB) of haddock from the MSVPA and the single species VPA (SSVPA).

WHITING STOCK SIZE

- +— TSB MSVPA
- SSB MSVPA
- x— TSB SSVPA
- ▽— SSB SSVPA

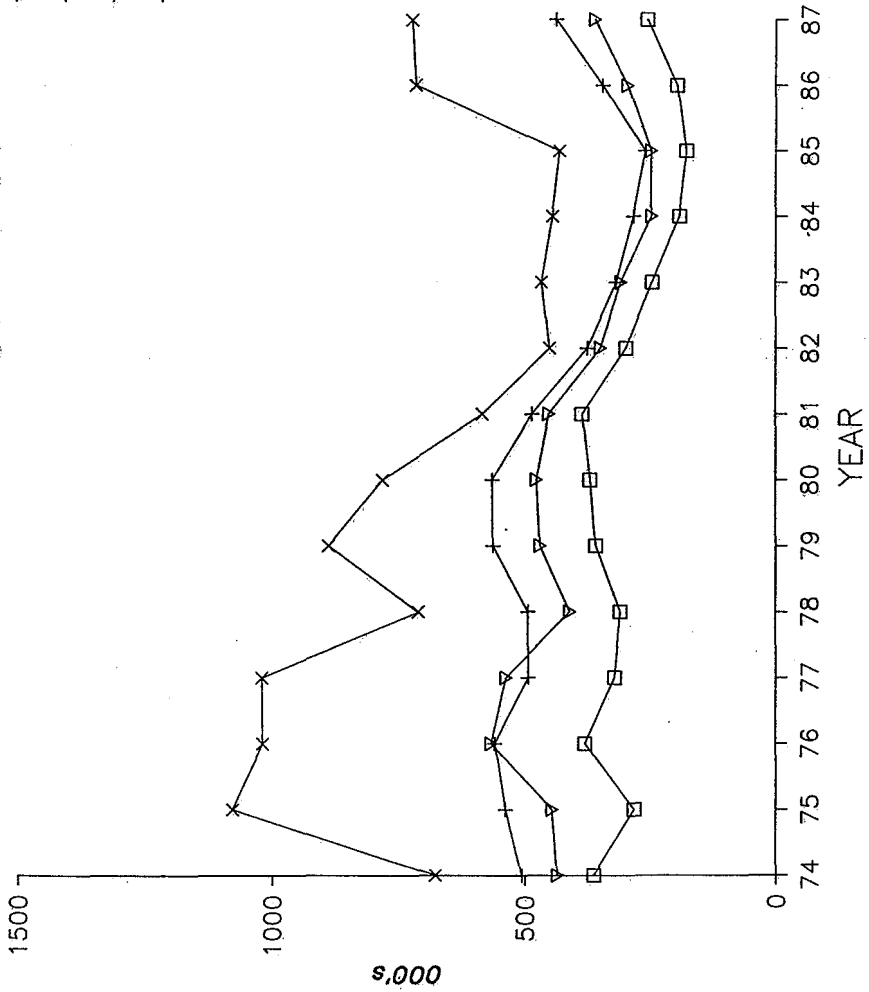


Figure 2.8.2c. The total stock biomass (TSB) and spawning stock biomass (SSB) of whiting from the MSVPA and the single-species VPA (SSVPA).

HERRING STOCK SIZE

- +— TSB MSVPA
- SSB MSVPA
- x— TSB SSVPA
- ▽— SSB SSVPA

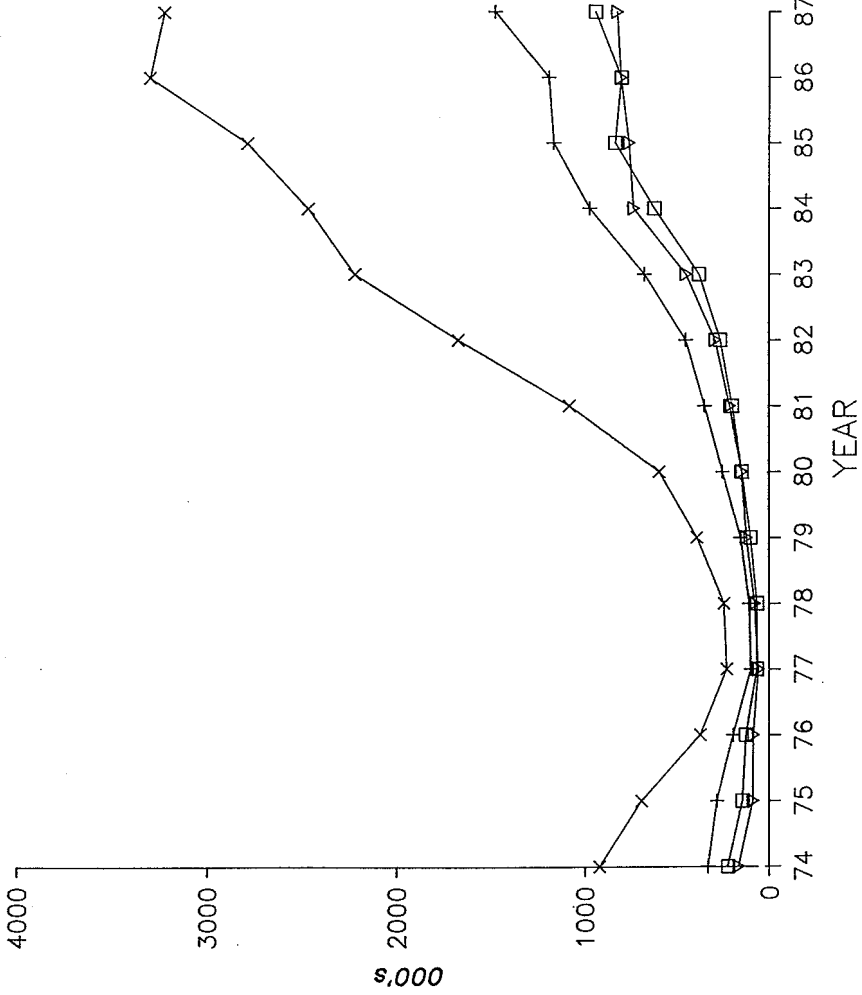


Figure 2.8.2d. The total stock biomass (TSB) and spawning stock biomass (SSB) of herring from the MSVPA and single-species VPA (SSVPA).

NORWAY POUT STOCK SIZE

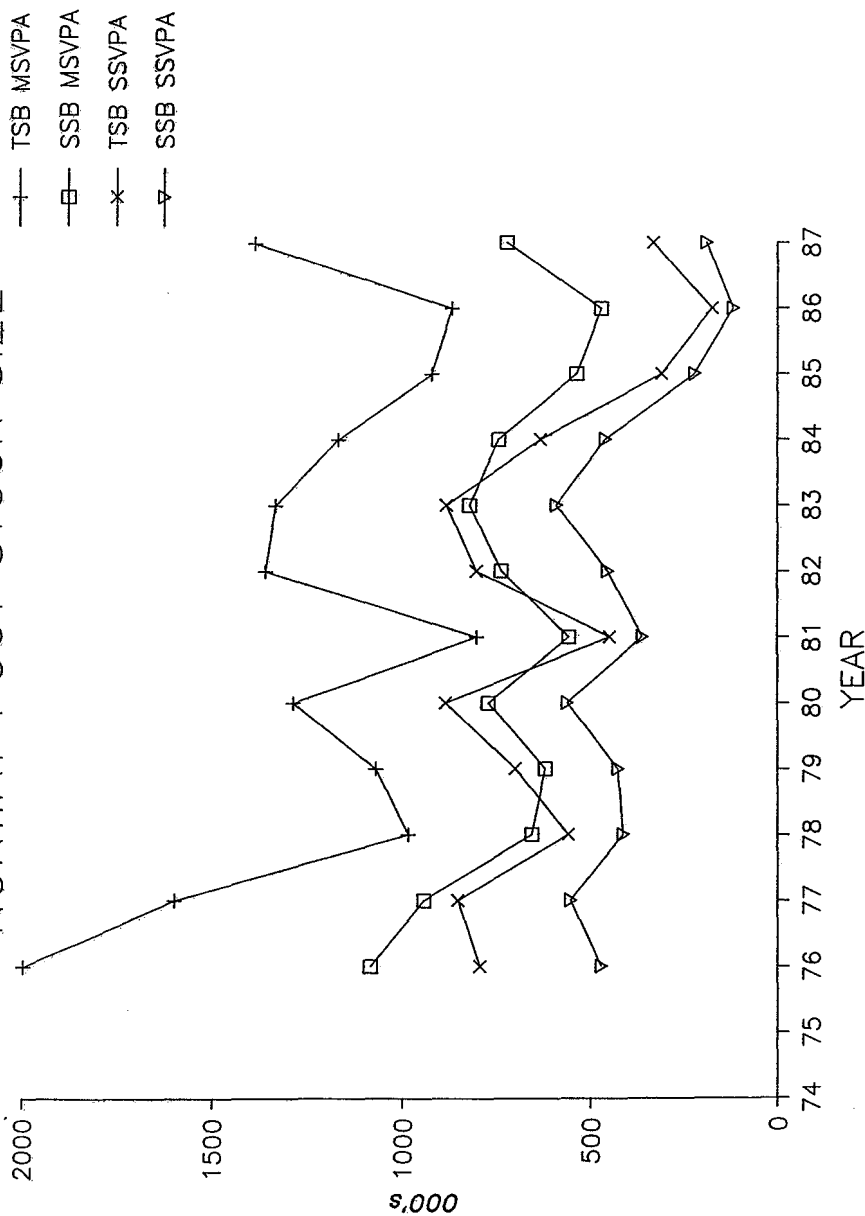


Figure 2.8.2e. The total stock biomass (TSB) and spawning stock biomass (SSB) of Norway pout from the MSVPA and single-species VPA (SSVPA).

SANDEEL STOCK SIZE

—+— TSB MSVPA
 —□— SSB MSVPA
 —x— TSB SSVPA
 —▽— SSB SSVPA

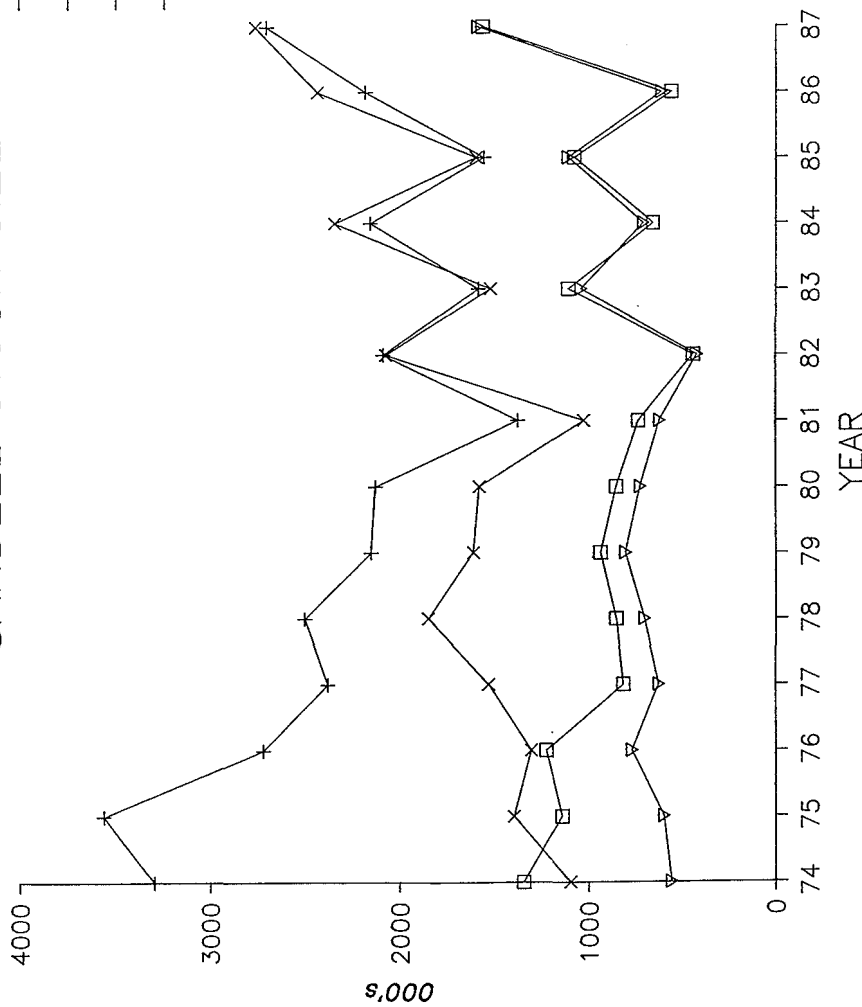


Figure 2.8.2f. The total stock biomass (TSB) and spawning stock biomass (SSB) of sandeel from the MSVPA and single-species VPA (SSVPA).

LONG-TERM PERCENT CHANGES WEIGHT



Figure 3.4.4.1a. Percent deviations in long-term projected catches (weight), by species and fleet, from baseline multispecies run (Table 3.4.4.1), assuming multispecies effects, constant recruitment, and 120 mm minimum mesh size when fishing for cod. Data for this figure given in Table 3.4.4.2 (case 2).

LONG-TERM PERCENT CHANGES VALUE

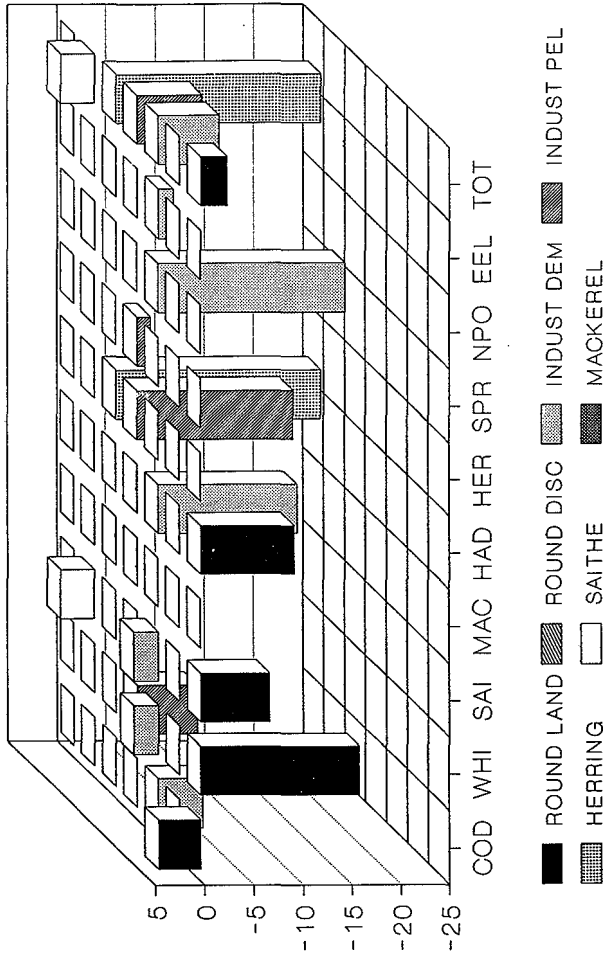


Figure 3.4.4.1b. Percent deviations in long-term projected landed value, by species and fleet, from baseline multispecies run (Table 3.4.4.1), assuming multispecies effects, constant recruitment, and 120 mm minimum mesh size when fishing for cod. Data for this figure given in Table 3.4.4.2 (Case 2).

LONG-TERM PERCENT CHANGES TOTAL BIOMASS AND SPAWNING STOCK BIOMASS

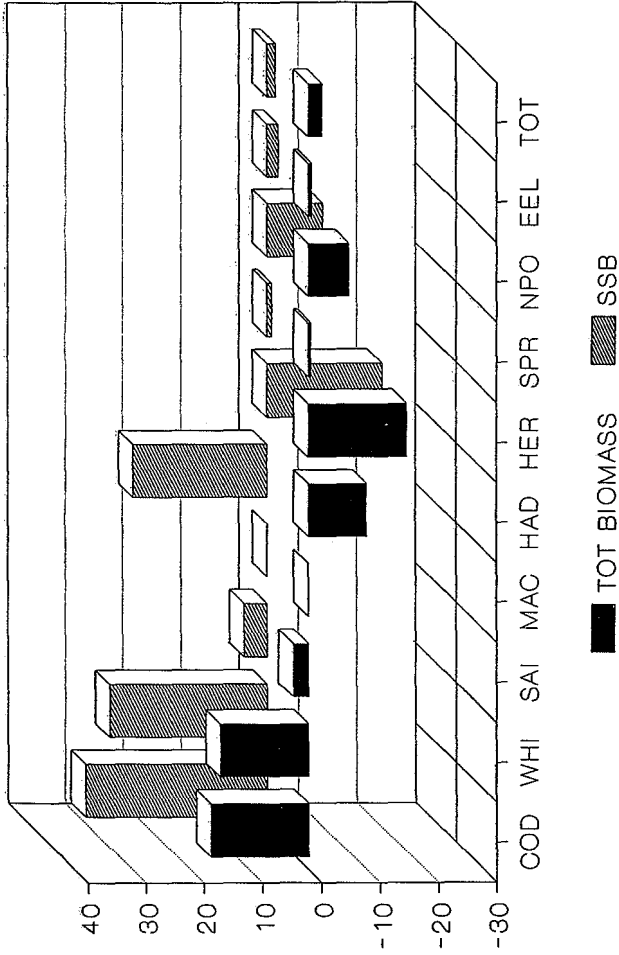
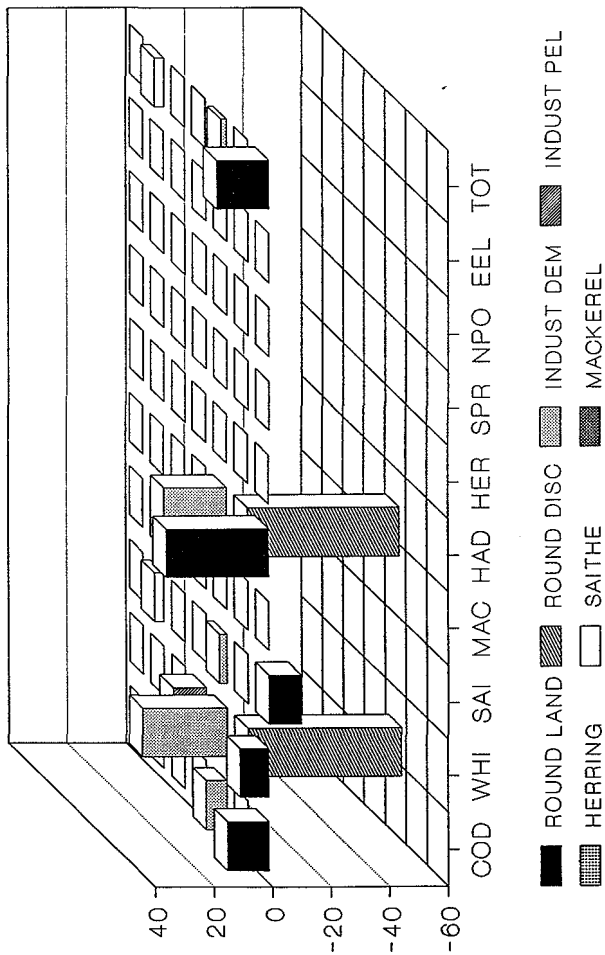


Figure 3.4.4.1c. Percent deviations in long-term projected total stock biomass (TSB) and spawning stock biomass (SSB), by species, from baseline multispecies run (Table 3.4.4.1), assuming multispecies effects, constant recruitment, and 120 mm minimum mesh size when fishing for cod. Data for this figure given in Table 3.4.4.2 (case 2).

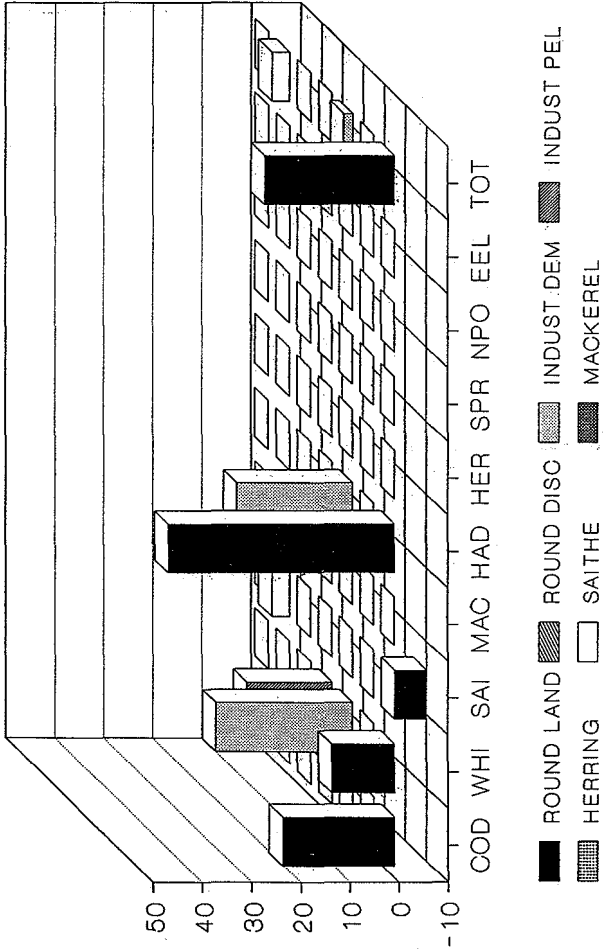
LONG-TERM PERCENT CHANGES WEIGHT



CASE 4

Figure 3.4.4.2a. Percent deviations in long-term projected catches (weight), by species and fleet, from baseline single-species run (Table 3.4.4.3), assuming single-species effects, constant recruitment, and 120 mm minimum mesh size when fishing for cod. Data for this figure given in Table 3.4.4.4 (case 4).

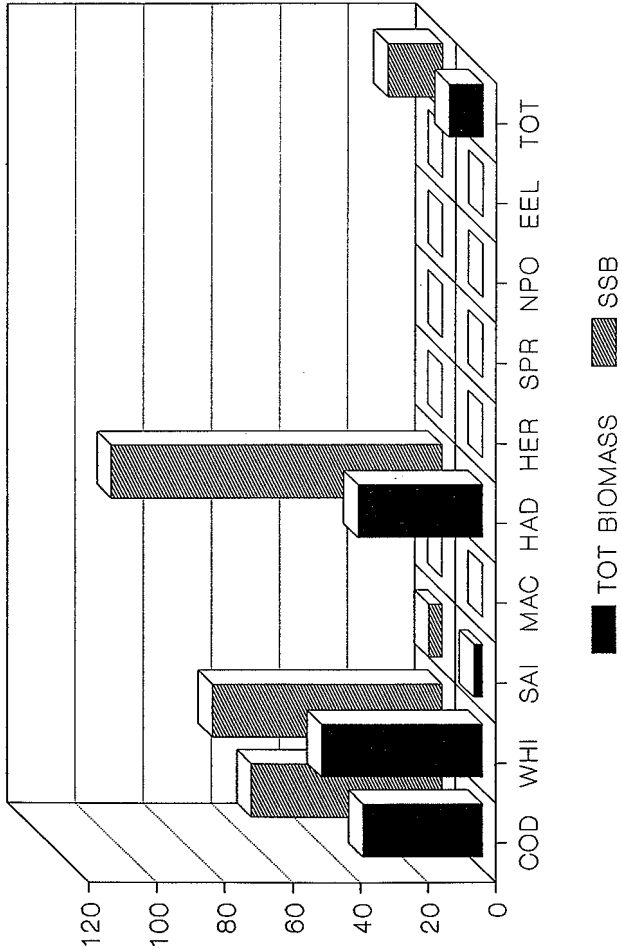
LONG-TERM PERCENT CHANGES
VALUE



CASE 4

Figure 3.4.4.2b. Percent deviations in long-term projected landed value, by species and fleet, from baseline single-species run (Table 3.4.4.3), assuming single-species effects, constant recruitment, and 120 mm minimum mesh size when fishing for cod. Data for this figure given in Table 3.4.4.4 (case 4).

LONG-TERM PERCENT CHANGES TOTAL BIOMASS AND SPAWNING STOCK BIOMASS



CASE 4

Figure 3.4.4.2c. Percent deviations in long-term projected total stock biomass (TSB) and spawning stock biomass (SSB), by species, from baseline single-species run (Table 3.4.4.3), assuming single-species effects, constant recruitment, and 120 mm minimum mesh size when fishing for cod. Data for this figure given in Table 3.4.4.4 (case 4).

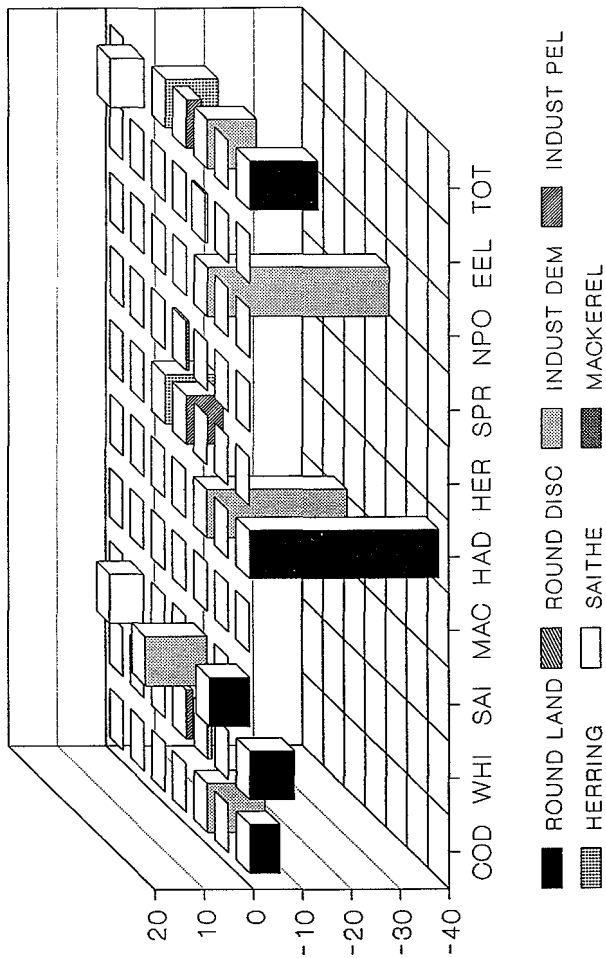
LONG-TERM PERCENT CHANGES WEIGHT



CASE 10

Figure 3.4.4.3a. Percent deviations in long-term projected catches (weight), by species and fleet, from baseline multispecies run (Table 3.4.4.1), assuming multispecies effects, constant recruitment, current exploitation patterns, and a 20% reduction in effort in the Roundfish and Saithe fisheries. Data for this figure given in Table 3.4.4.10 (case 10).

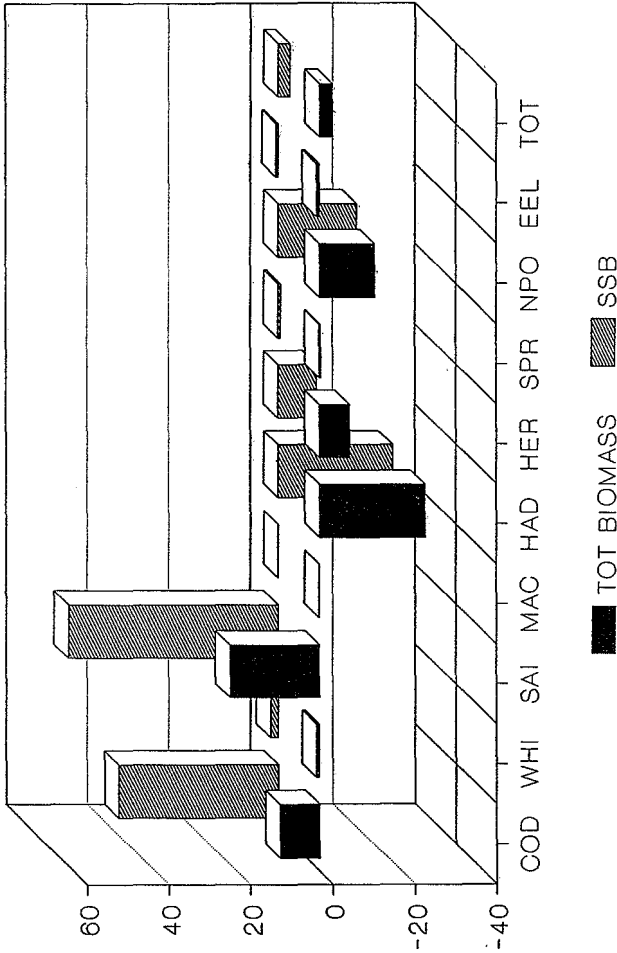
LONG-TERM PERCENT CHANGES VALUE



CASE 10

Figure 3.4.4.3b. Percent deviations in long-term projected landed value, by species and fleet, from baseline multispecies run (Table 3.4.4.1), assuming multispecies effects, constant recruitment, current exploitation patterns, and a 20% reduction in effort in the Roundfish and Saithe fisheries. Data for this figure given in Table 3.4.4.10 (case 10).

LONG-TERM PERCENT CHANGES TOTAL BIOMASS AND SPAWNING STOCK BIOMASS



CASE 10

Figure 3.4.4.3c. Percent deviations in long-term projected total stock biomass (TSB) and spawning stock biomass (SSB), by species, from baseline multispecies run (Table 3.4.4.1), assuming multispecies effects, constant recruitment, current exploitation patterns, and a 20% reduction in effort in the Roundfish and Saithe fisheries. Data for this figure given in Table 3.4.4.10 (case 10).

MEDIUM TERM MSFOR PREDICTIONS

COD in H.C. LANDINGS

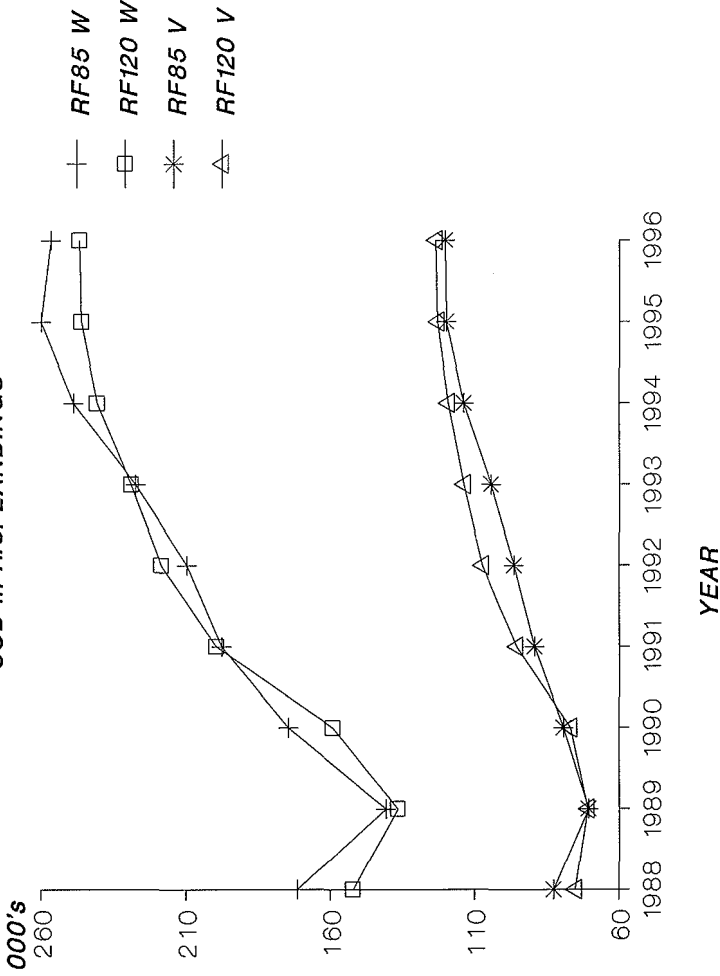


Figure 4.1.1. Projected cod catch in thousands of tonnes (W), and millions of ECUs (V) from medium-term stochastic simulations of MSFOR, assuming use of 85 mm mesh in the roundfish fishery (RF85), and the 120 mm minimum mesh option when fishing for cod (RF120).

MEDIUM TERM MSFOR PREDICTIONS COD BIOMASSES

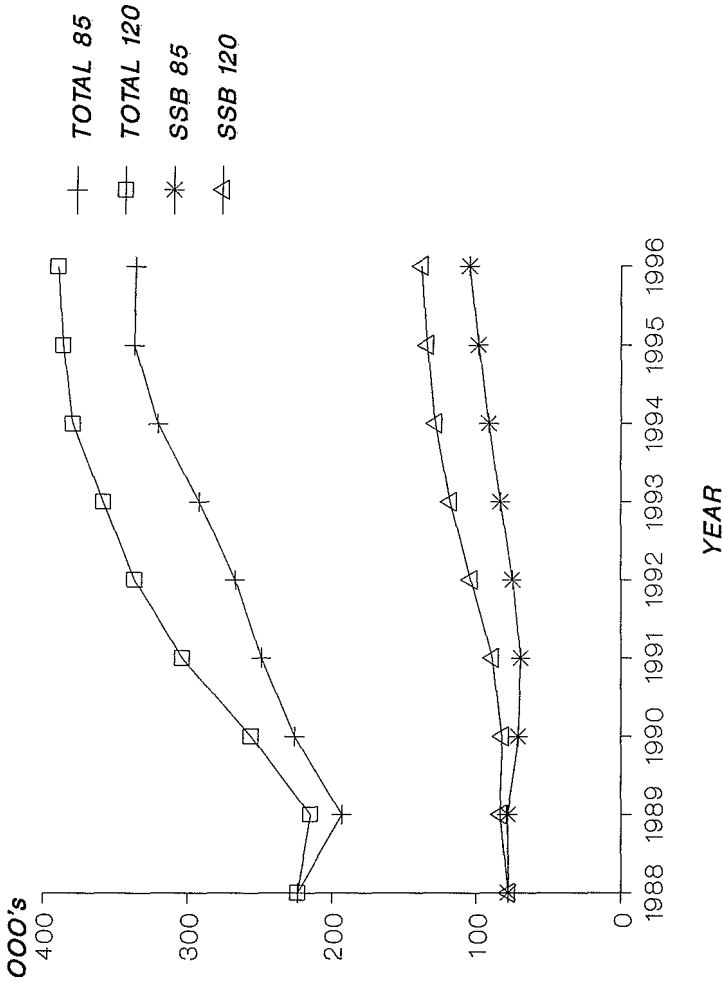


Figure 4.1.1.2. Projected total and spawning stock biomasses for cod from medium-term stochastic simulations of MSFOR, assuming use of 85 mm mesh in the roundfish fishery (85), and 120 mm minimum mesh option when fishing for cod (RF120).

MEDIUM TERM MSFOR PREDICTIONS ROUND FISH + SAITHE LANDINGS

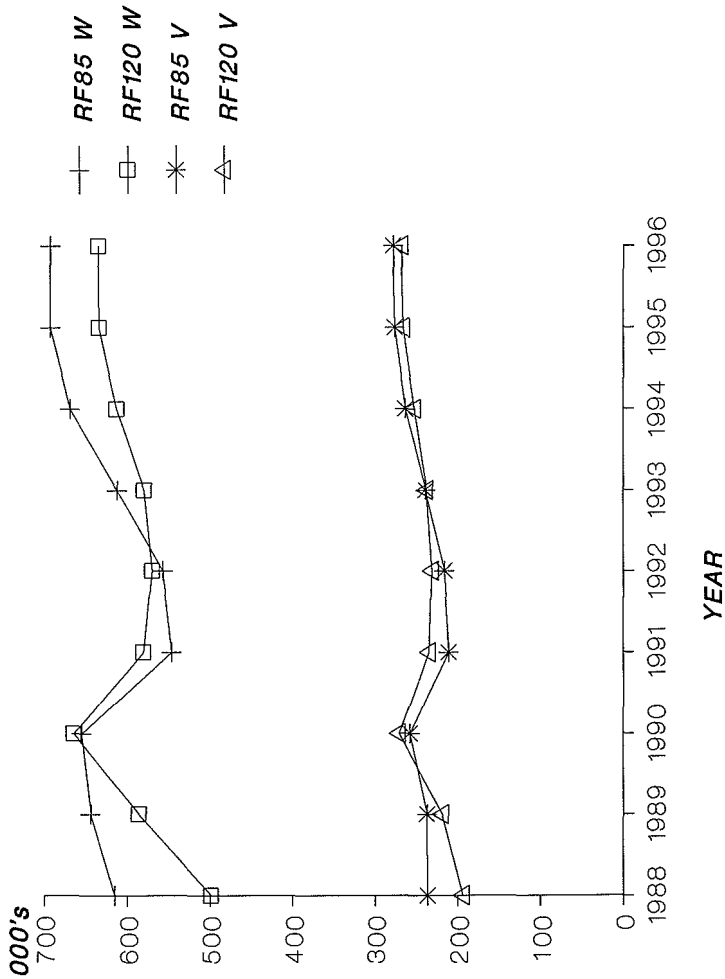


Figure 4.1.3. Projected aggregate species landings (thousands of tonnes, W; millions of ECUs, V) in the Roundfish and Saithe fisheries from medium-term stochastic simulations of MSFOR, assuming the use of 85 mm mesh in the Roundfish fishery (RF85), and the 120 mm minimum mesh option when fishing for cod (RF120).

MEDIUM TERM MSFOR PREDICTIONS INDUSTRIAL DEMERSAL

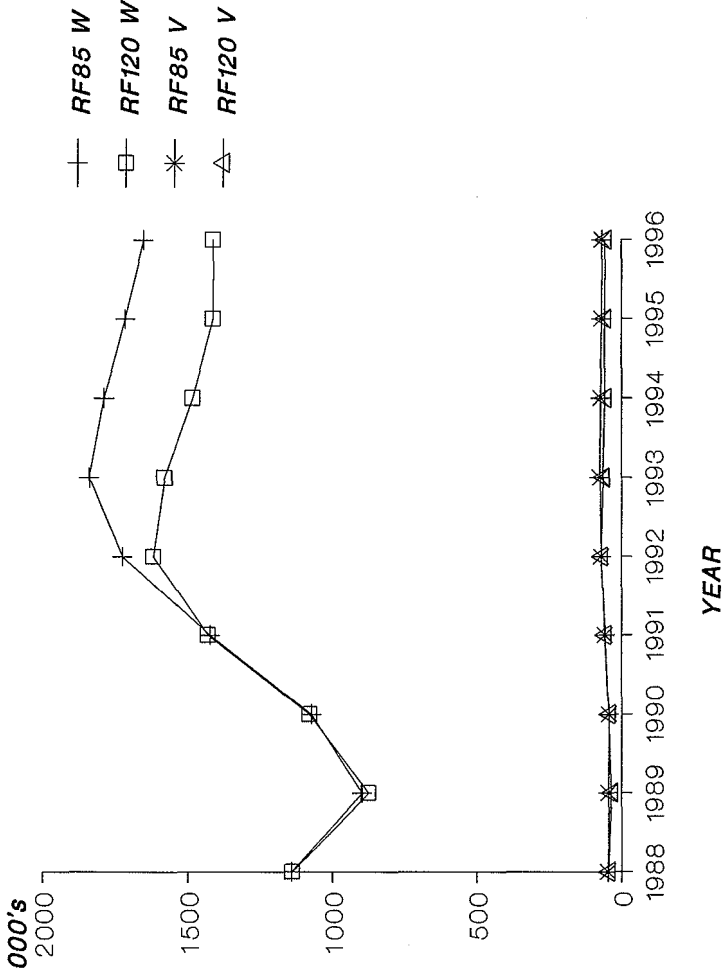


Figure 4.1.4. Projected aggregate species landings (thousands of tonnes, W; millions of ECUs, V) in the Industrial Demersal fishery from medium-term stochastic simulations of MSFOR, assuming the use of 85 mm mesh in the Roundfish fishery (RF85), and the 120 mm minimum mesh option when fishing for cod (RF120).

MEDIUM TERM MSFOR PREDICTIONS INDUSTRIAL PELAGIC

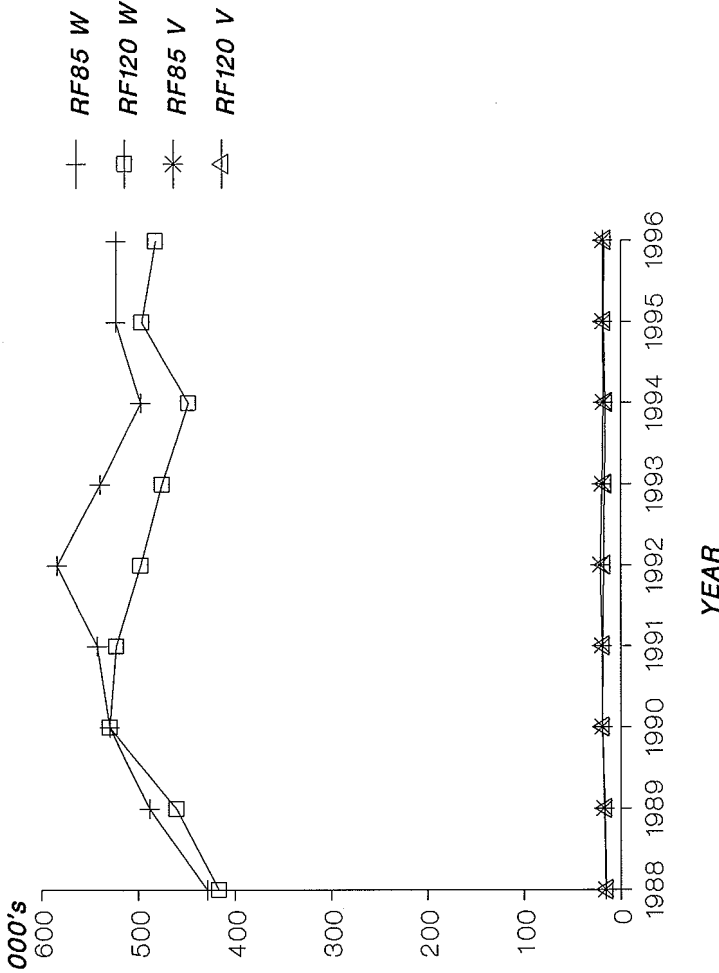


Figure 4.1.5. Projected aggregate species landings (thousands of tonnes, W; millions of ECU, V) in the Industrial Pelagic fishery from medium-term stochastic simulations of MSFOR, assuming the use of 85 mm mesh in the Roundfish Fishery (RF85) and the 120 mm minimum mesh option when fishing for cod (RF120).

MEDIUM TERM MSFOR PREDICTIONS HERRING + MACKEREL

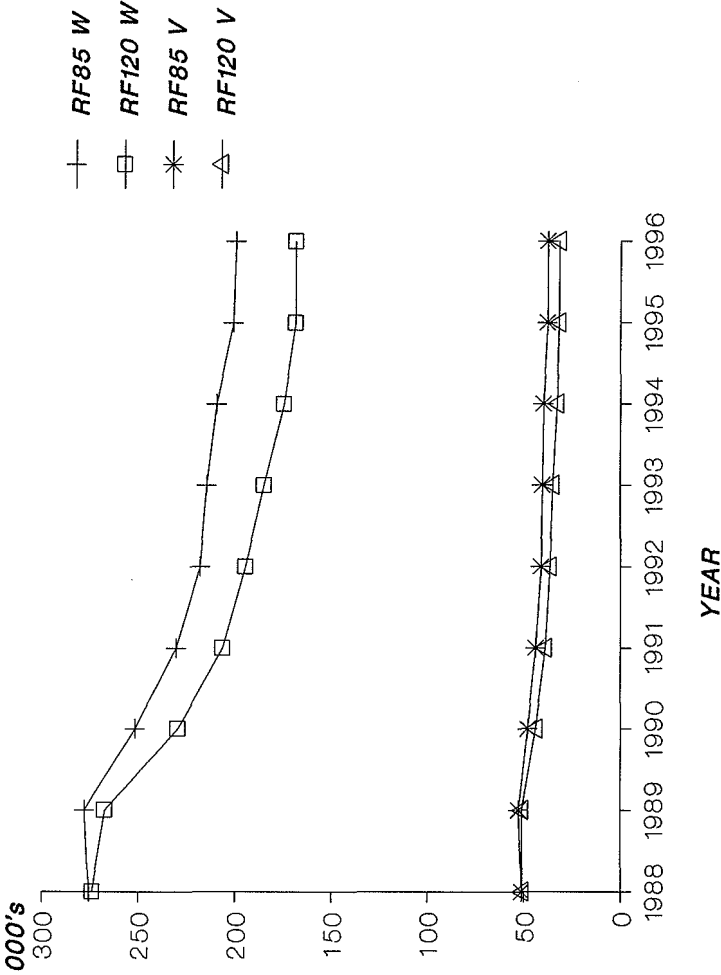


Figure 4.1.6. Projected aggregate species landings (thousands of tonnes, W; millions of ECUs, V) in the Herring and Mackerel Fisheries from medium-term stochastic simulations of MSFOR, assuming the use of 85 mm mesh in the Roundfish Fishery (RF85), and the 120 mm minimum mesh option when fishing for cod (RF120).

MEDIUM TERM MSFOR PREDICTIONS TOTAL NORTH SEA

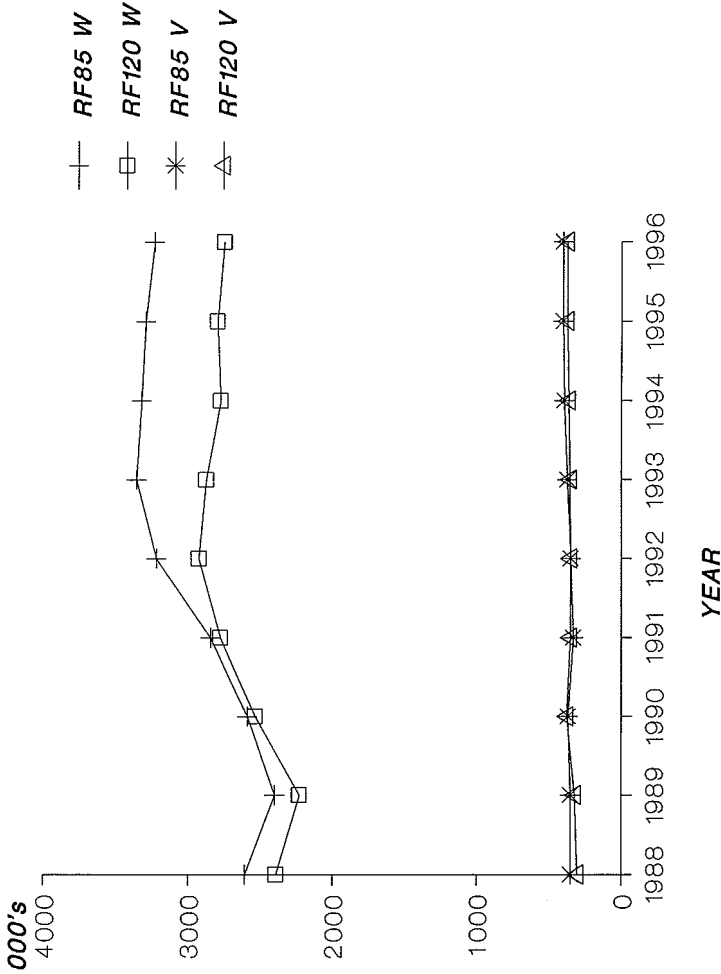
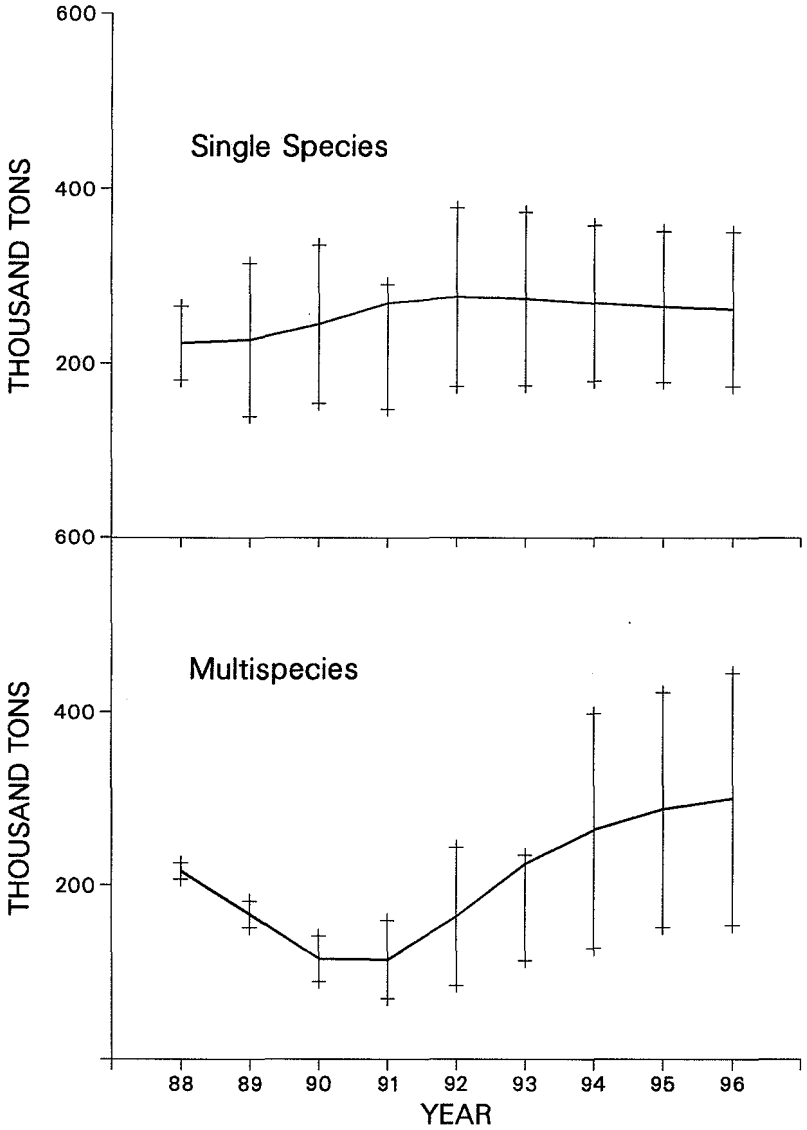


Figure 4.1.7. Projected aggregate species landings (thousands of tonnes, W; millions of ECUs, V) for all North Sea fisheries assessed in medium-term stochastic simulations with MSFOR, assuming the use of 85 mm mesh in the Roundfish Fishery (RF85), and the 120 mm minimum mesh option when fishing for cod (RF120).

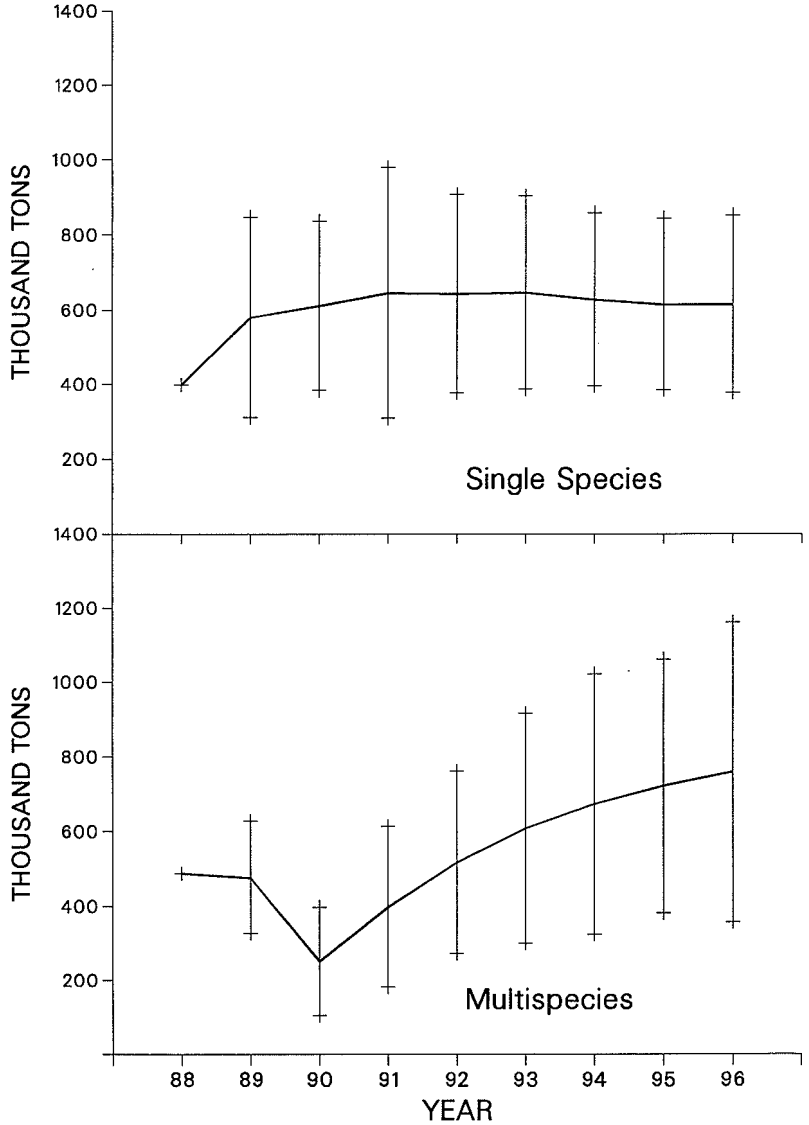
PREDICTED TOTAL CATCH HADDOCK

Figure 4.2.1. Predicted haddock catch (mean, ± 1 SD) under stochastic yield simulations with MSFOR, in single and multispecies modes. Simulations are based on lognormal recruitment distributions, using MSVPA results from 1974-1986. A total of 60 9-year simulations were run, assuming the current exploitation pattern (85 mm for cod).



PREDICTED TOTAL BIOMASS Haddock

Figure 4.2.2. Predicted haddock total stock biomass (mean, \pm 1 SD) under stochastic simulations with MSFOR, in single and multispecies modes. Simulations are based on lognormal recruitment distributions, using MSYPA results from 1974-1986. A total of 60 9-year simulations were run, assuming the current exploitation pattern (85 mm for cod).



PREDICTED SPAWNING STOCK BIOMASS HADDOCK

Figure 4.2.3. Predicted haddock spawning stock biomass (mean, \pm 1 SD) under stochastic simulations with MSFOR, in single and multispecies modes. Simulations are based on lognormal recruitment distributions, using MSVPA results from 1974-1986. A total of 60 9-year simulations were run, assuming the current exploitation pattern (85 mm for cod).

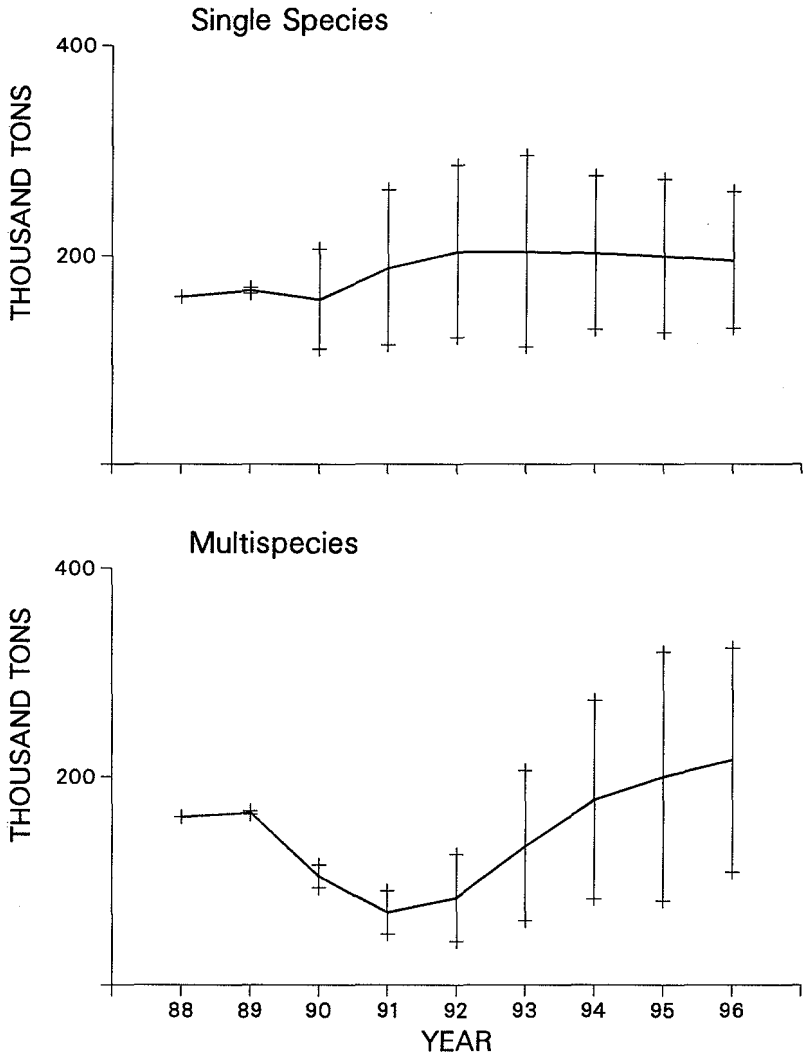


Figure 6.8.3a Parabolas of relative predation mortality inflicted by 0.5 kg cod (a), whiting (b) and saithe (c) on Norway pout for size ratios from small (predator slightly larger than prey) to large (predator much larger than prey) log weight ratios (LWTR). Similar parabolas for 2.0 kg predators preying on Norway pout are plotted below.

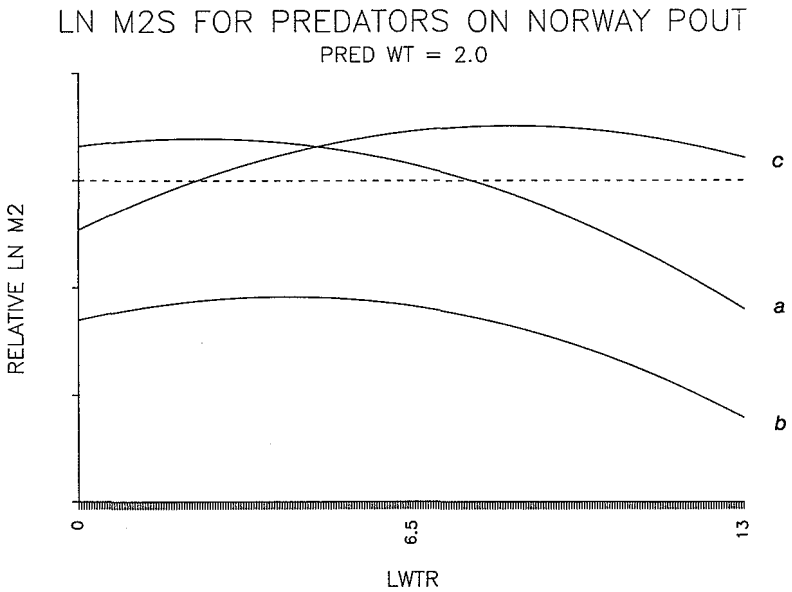
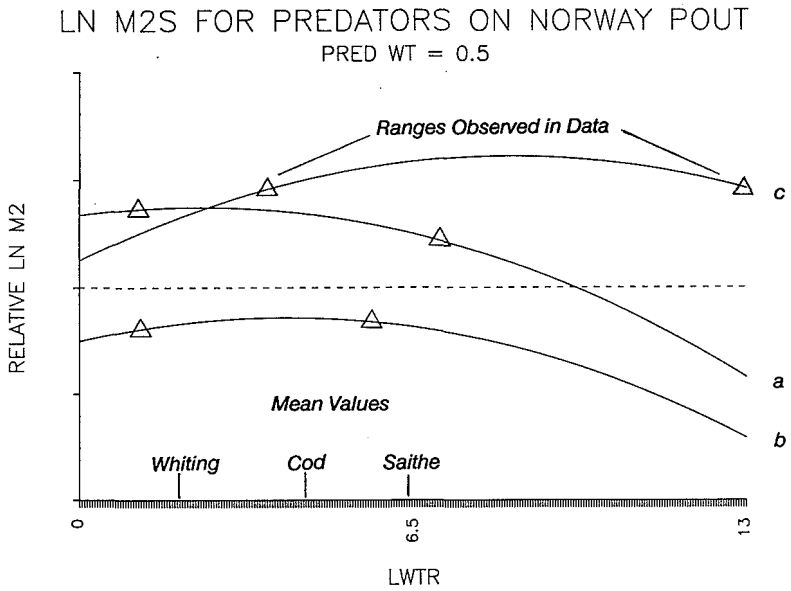
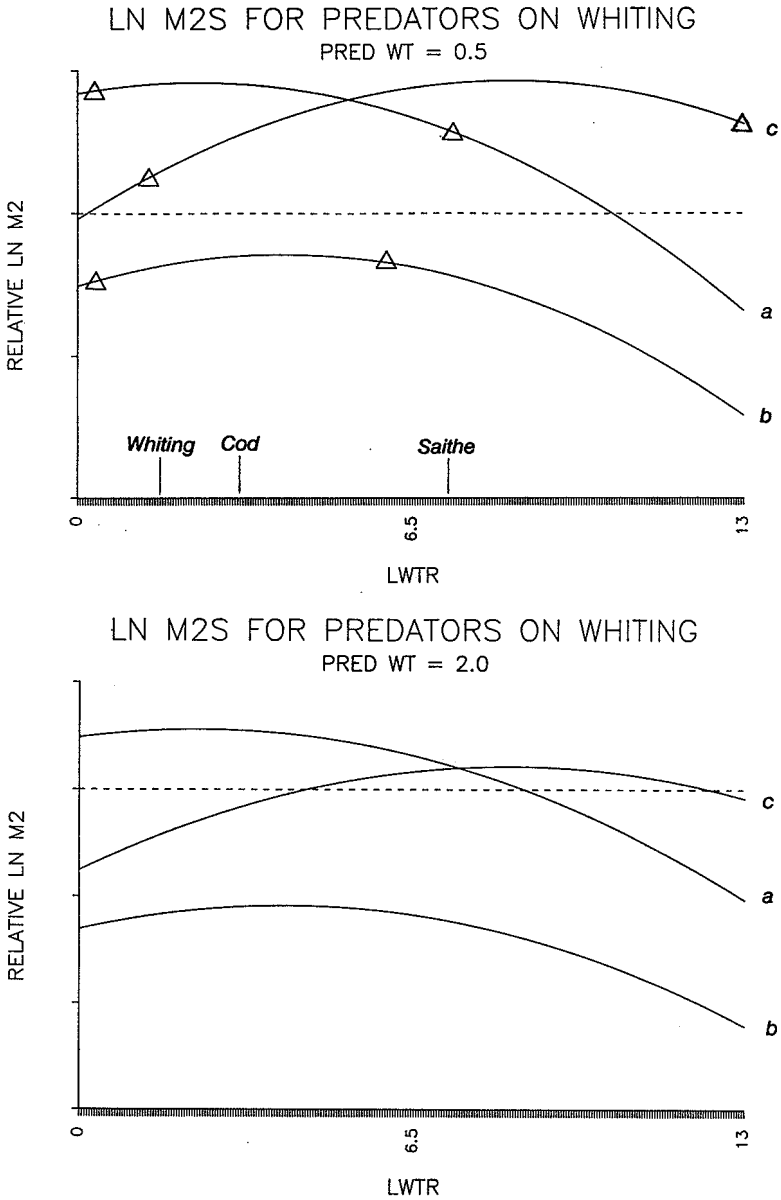
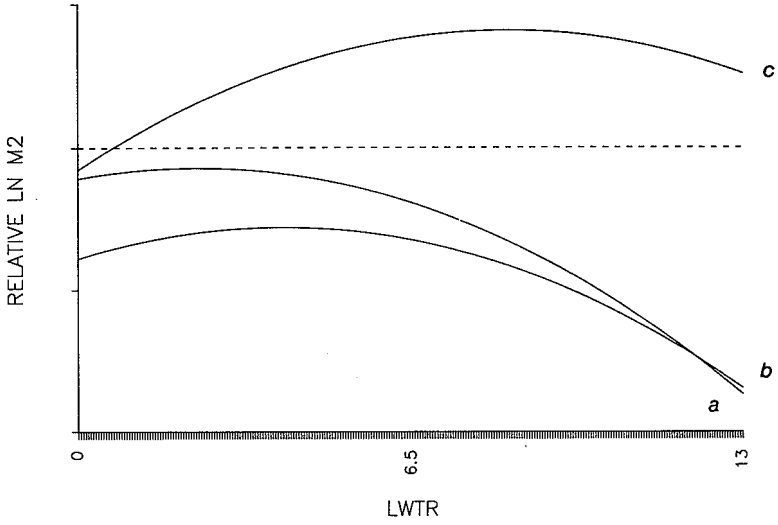


Figure 6.8.3b
Parabolas of relative predation mortality inflicted by 0.5 kg cod (a), whiting (b) and saithe (c; Above), on whiting for size ratios from small (predator slightly larger than prey) to large (predator much larger than prey) log weight ratios (LWTR). Similar parabolas for 2.0 kg predators preying on whiting are plotted below.



LN M2S FOR PREDATORS ON HERRING
 PRED WT = 0.5



LN M2S FOR PREDATORS ON HERRING
 PRED WT = 2.0

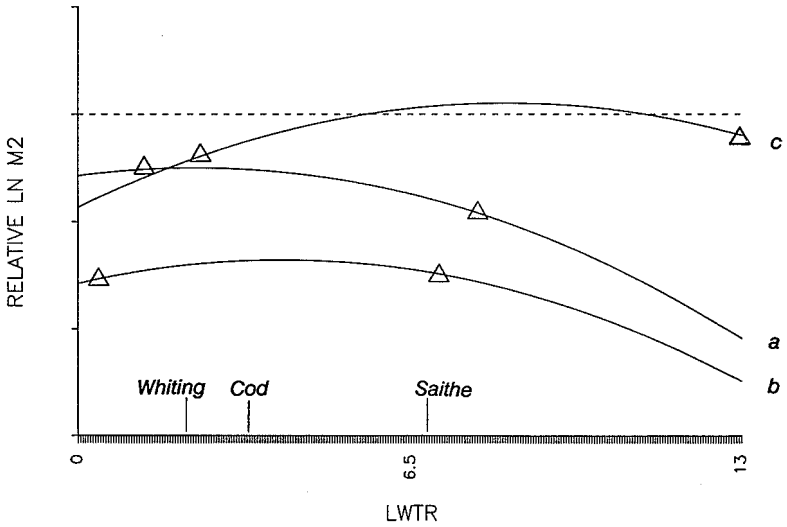


Figure 6.8.3c Parabolas of relative predation mortality inflicted by 0.5 kg cod (a), whiting (b) and saithe (c) on herring for size ratios from small (predator slightly larger than prey) to large (predator much larger than prey) log weight ratios (LWTR). Similar parabolas for 2.0 kg predators preying on herring are plotted below.

Figure 7.1 Trends in mean total biomass, yield, and predation (in thousands of tonnes) for all MSVPA species considered, 1974-1987.

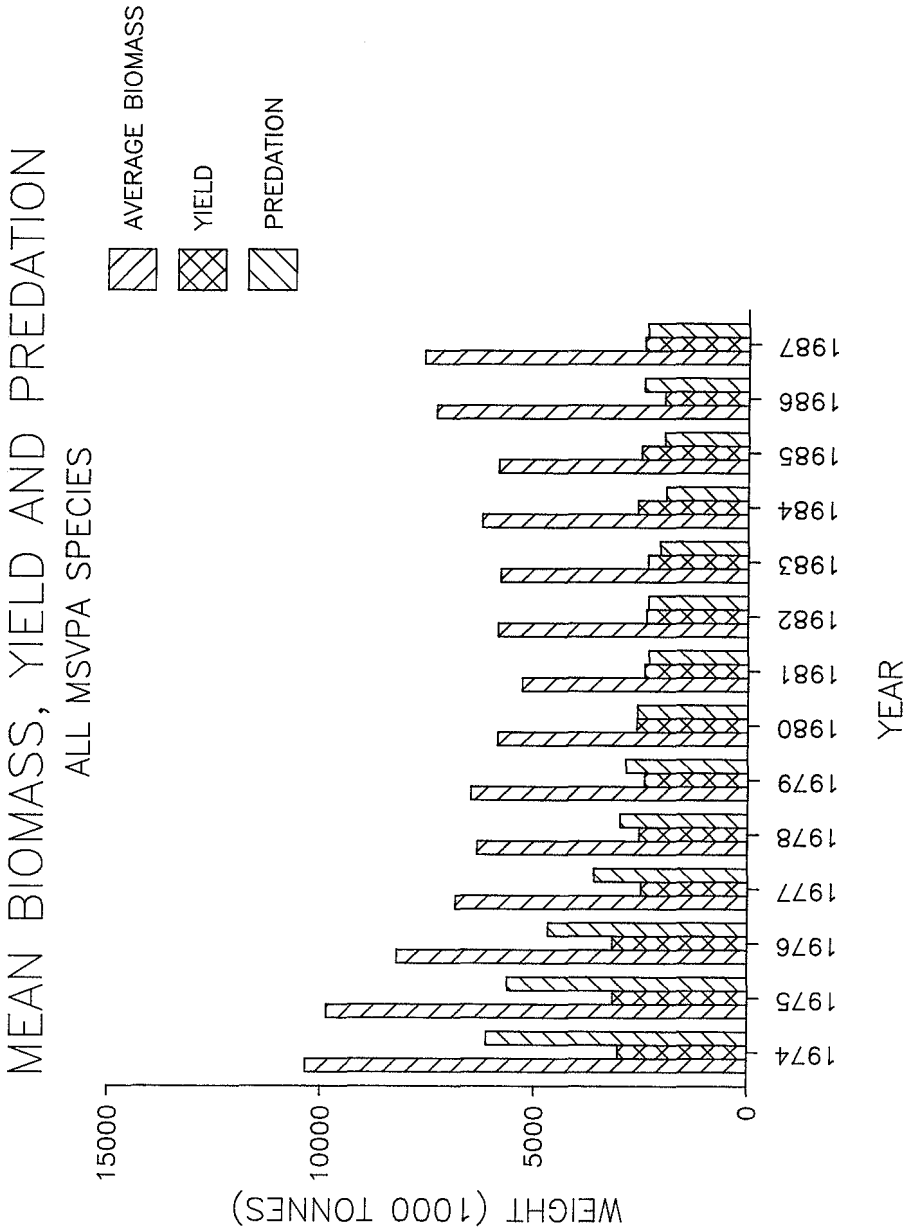


Figure 7.2. Trends in mean total biomass (thousands of tonnes) of MSVPA predator species, 1974-1987.

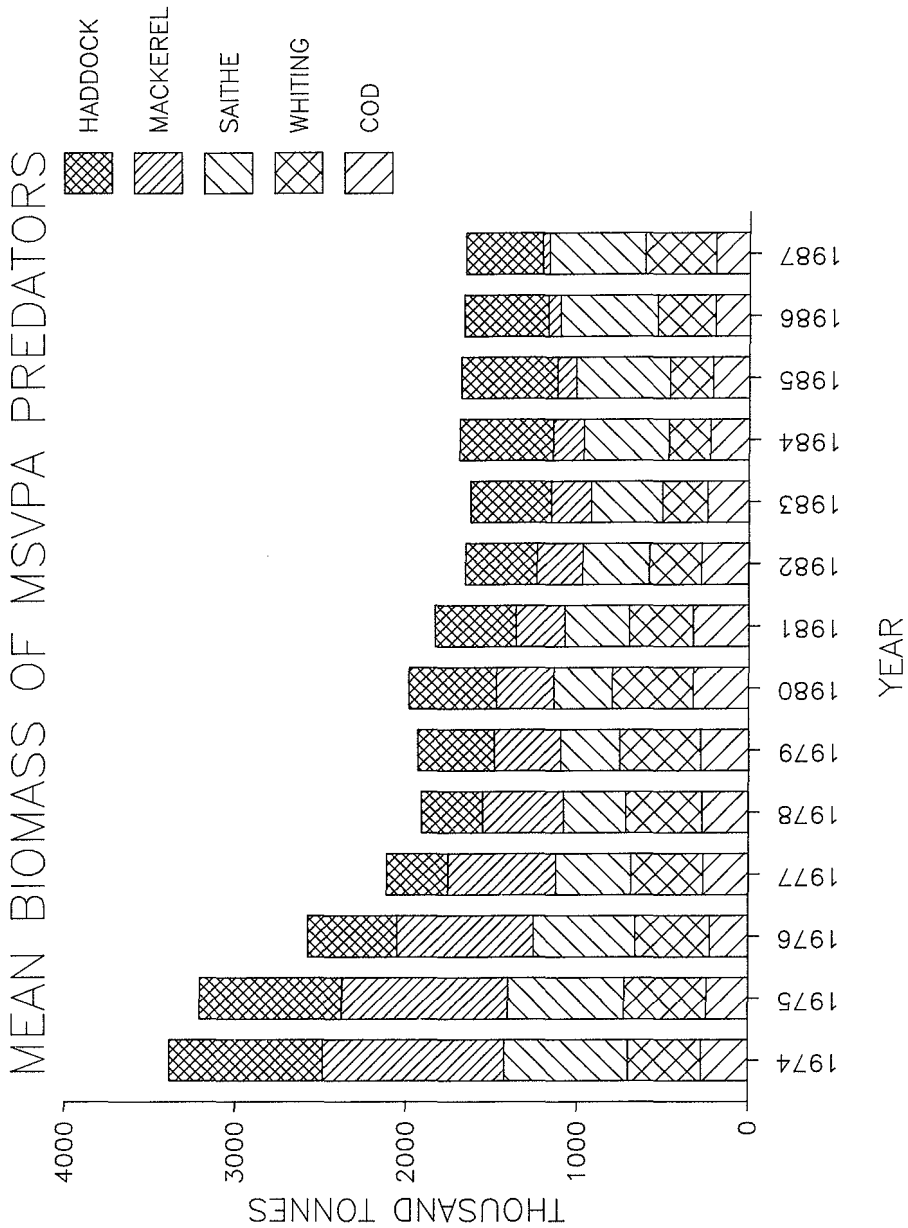


Figure 7.3. Trends in mean total biomass (thousands of tonnes) of MSVPA prey species, 1974-1987.

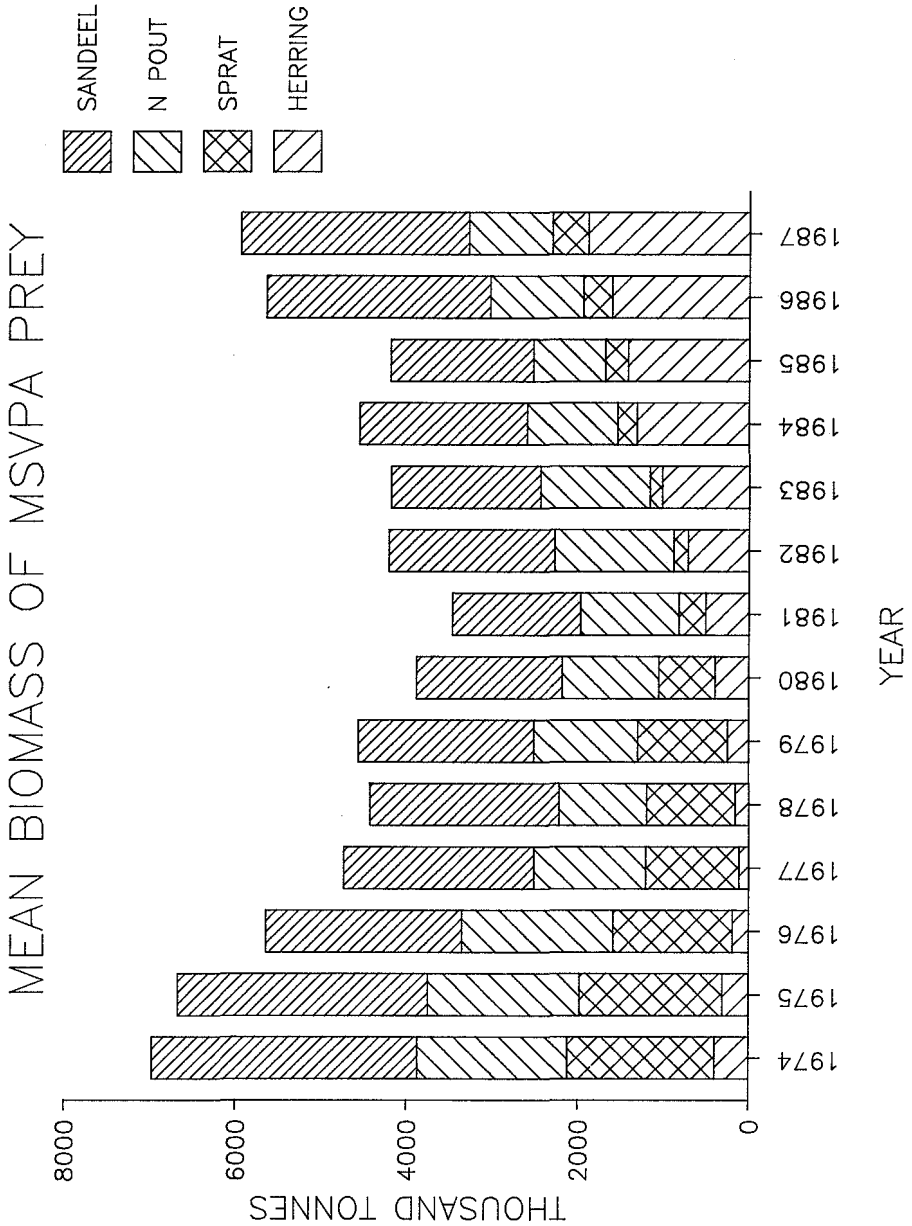


Figure 7.4. Food web of MSVPA species calculated from MSVPA results for 1974. Area of circles represents average biomass (also indicated by numbers in 1000 t), thickness of lines is proportional to the total annual predation (see legend), and annual yield to man (also indicated by numbers in 1000 t), respectively.

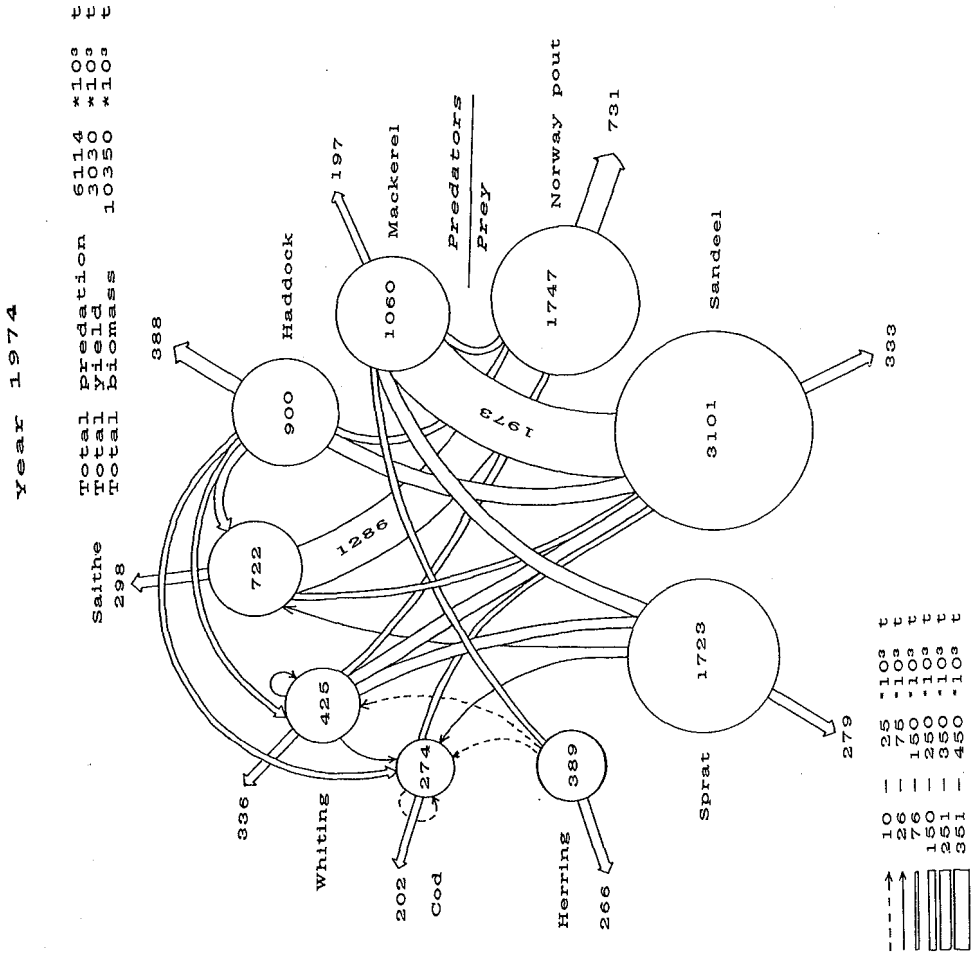


Figure 7.5. Food web of MSVPA species calculated from MSVPA results for 1985. Area of circles represents average biomass (also indicated by numbers in 1000 t), thickness of lines is proportional to the total annual predation (see legend), and annual yield to man (also indicated by numbers in 1000 t), respectively. Concentric circles represent the biomass during the current year (where lines begin or end), as compared with 1974.

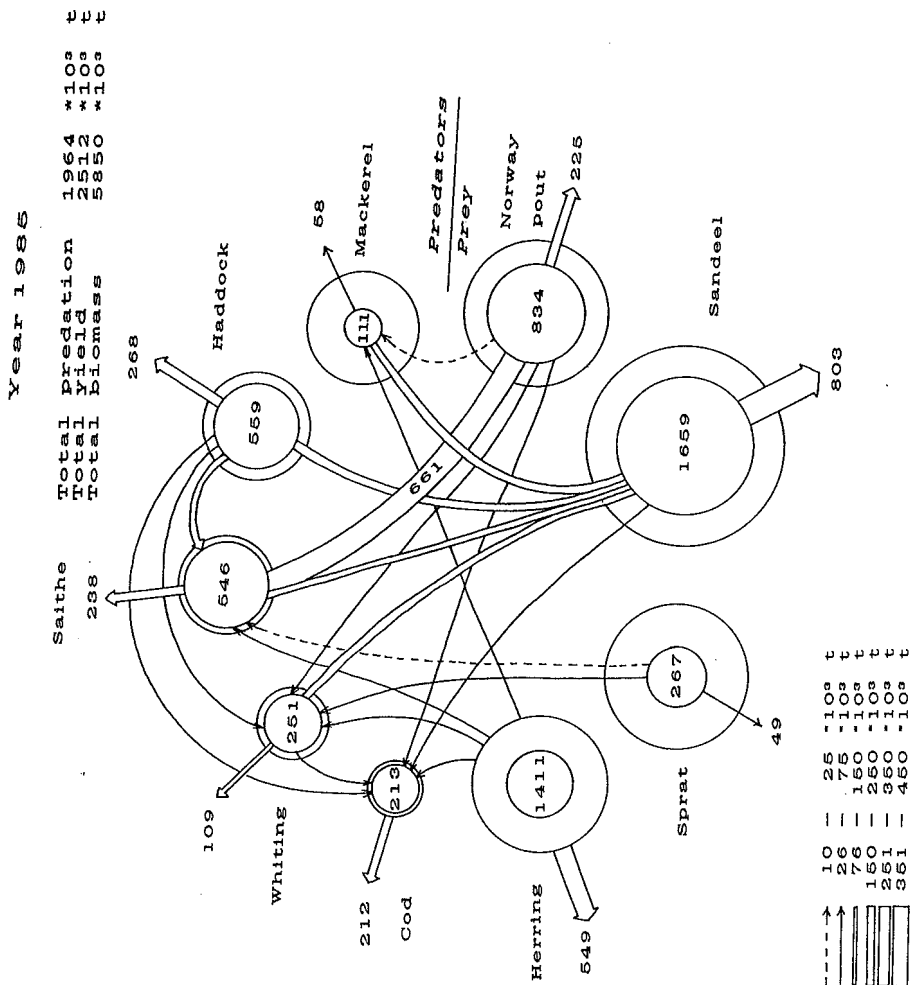


Figure 8.3.1. Predation mortality rates (M2s) at age for cod, haddock and whiting estimated from the simple MSVPA backcasting model.

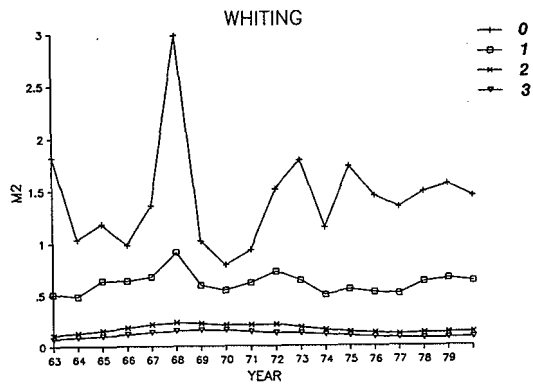
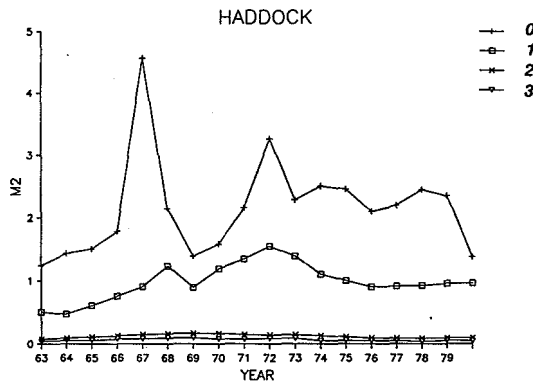
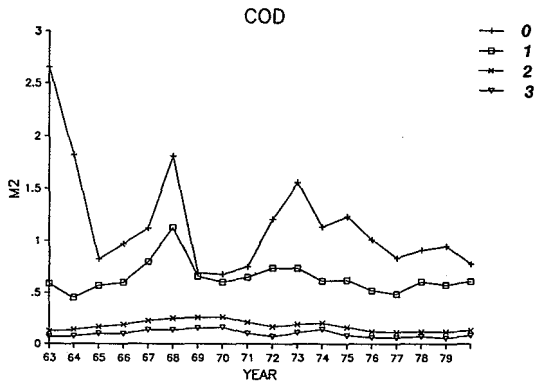
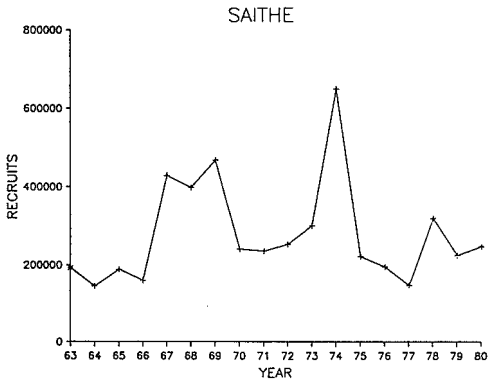
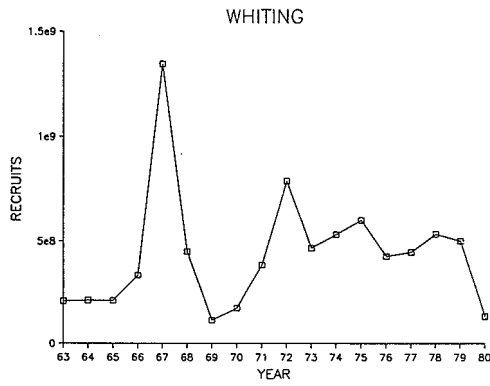
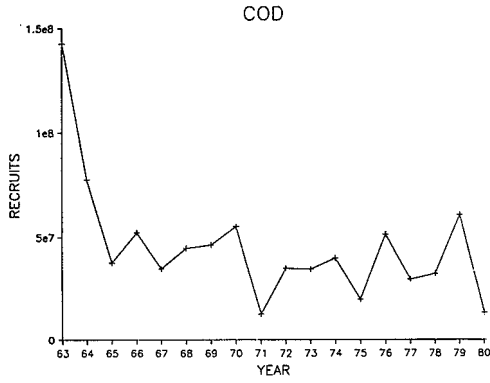


Figure 8.3.2. Estimated recruitment of age 0 cod, whiting, saithe, mackerel and haddock from the simple MSVPA backcasting model.



cont'd.

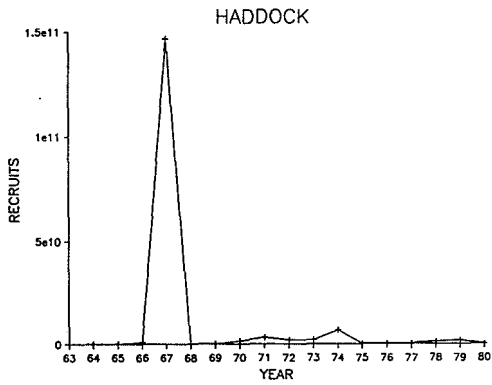
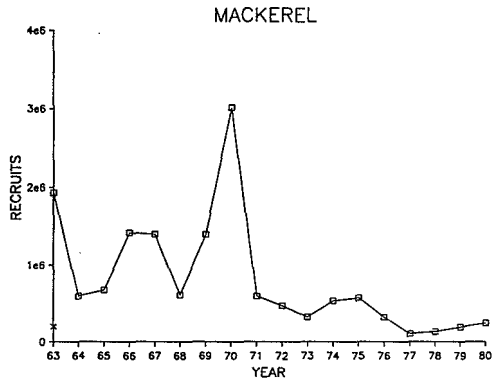
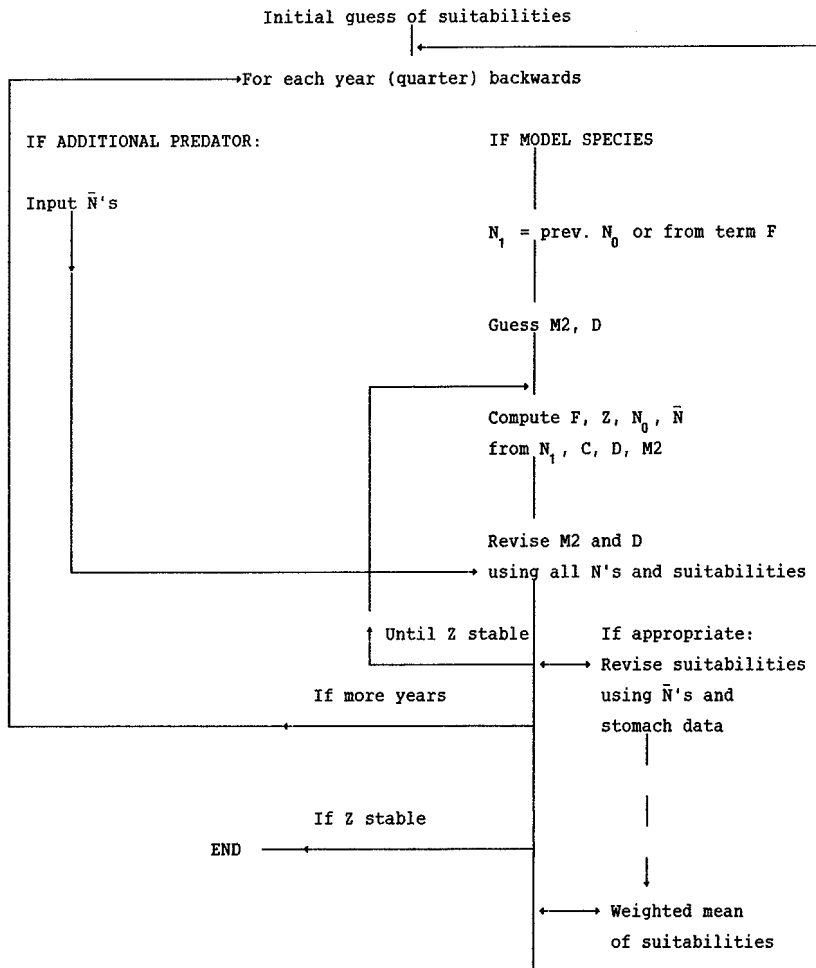


Figure 8.3.2 (continued).

Figure 8.4 Suggested algorithm for inclusion of additional predators in the MSVPA.



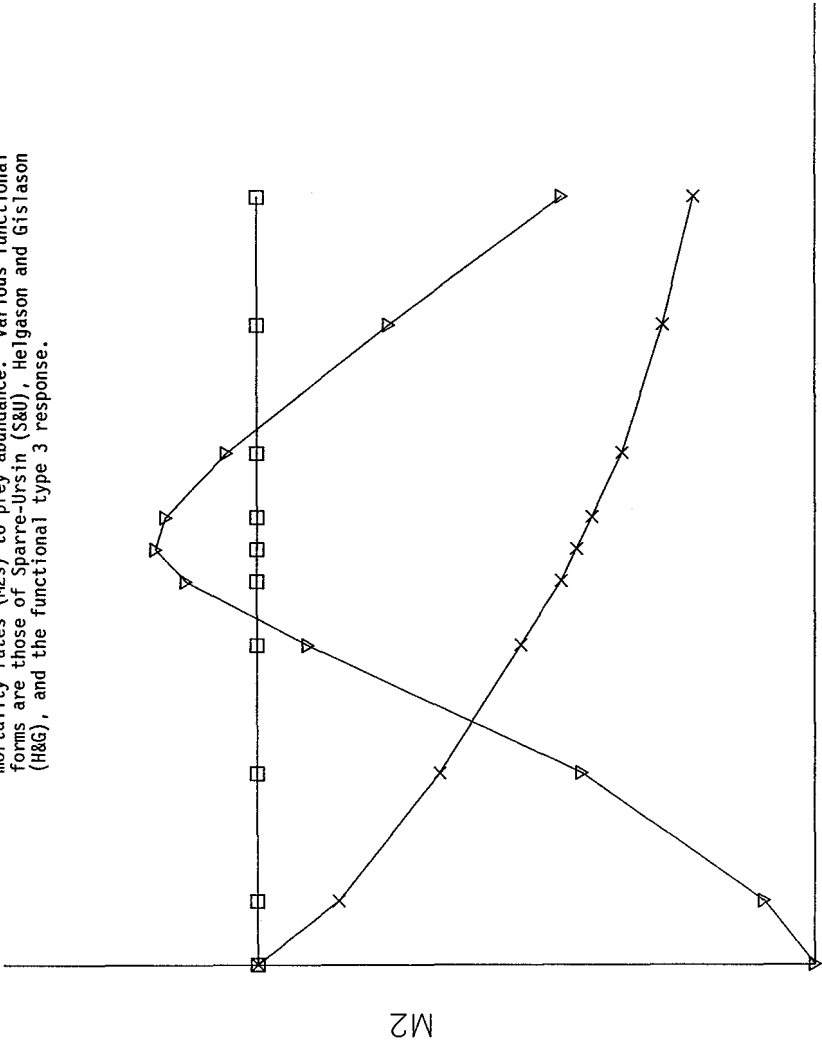
N_1 : Number at end of period

N_0 : Number at start of period

\bar{N} : Mean N

- S&U
- ×— H&G
- ▽— TYPE 3

Figure 8.5.1. Predator-prey functional response models relating predation mortality rates (M_2) to prey abundance. Various functional forms are those of Sparre-Ursin (S&U), Helgason and Gislason (H&G), and the functional type 3 response.



PREY ABUNDANCE

Figure 9.1.2. Aggregate multispecies size distributions (log numbers by 5 cm length category) in the second calendar quarter for: (1) 1974 MSVPA results, (2) 1984 MSVPA results, (3) long-term prediction using 'baseline' exploitation pattern, (4) a 120 mm minimum mesh when fishing for cod, (5) a 50% reduction in overall fishing effort, and (6) a 50% reduction in human consumption fisheries.

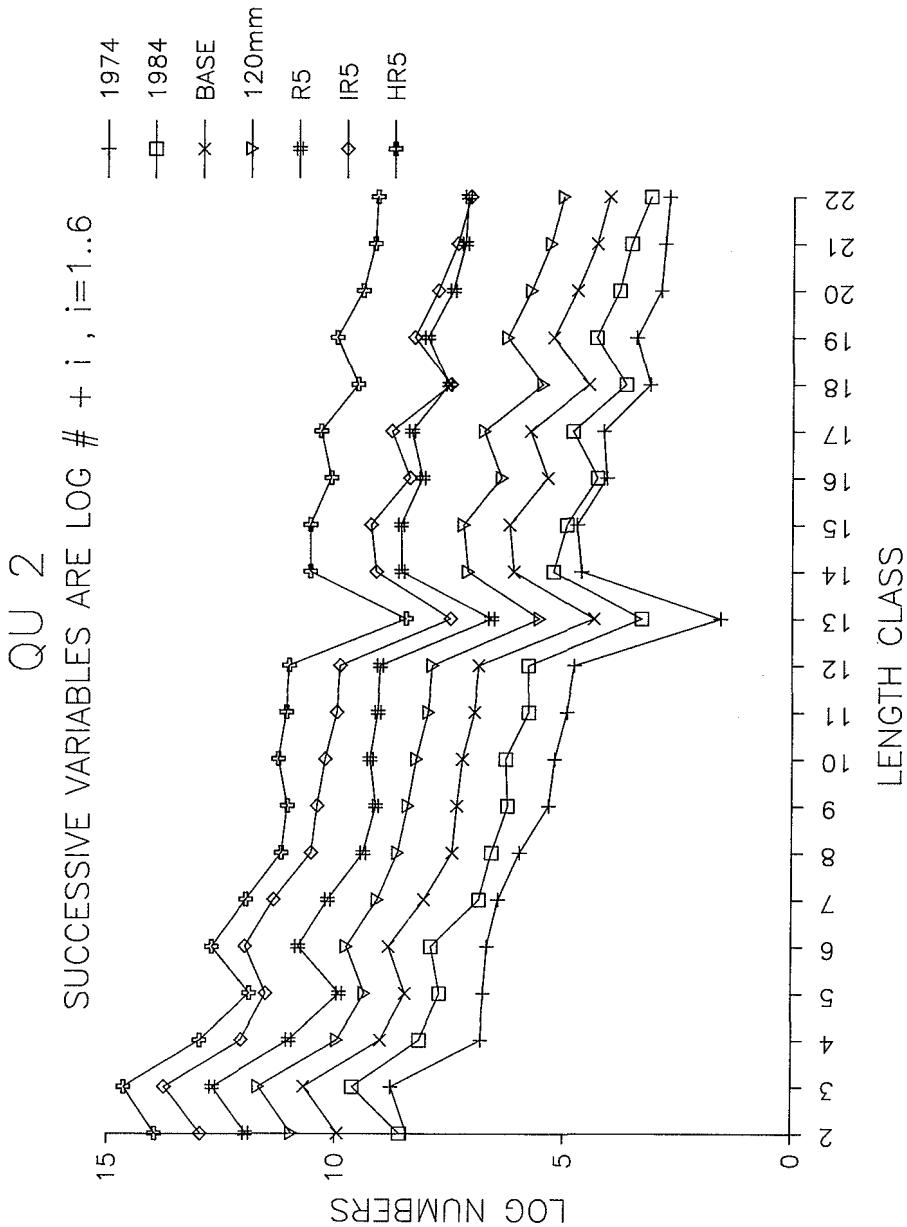


Figure 9.1.3. Aggregate multispecies size distributions (log numbers by 5 cm length category) in the third calendar quarter for: (1) 1974 MSVPA results, (2) 1984 MSVPA results, (3) long-term prediction using 'baseline' exploitation pattern, (3) long-term prediction assuming a 120 mm minimum mesh when fishing for cod, (4) a 50% reduction in overall fishing effort, (5) a 50% reduction in industrial fishing, and a 50% reduction in human consumption fisheries.

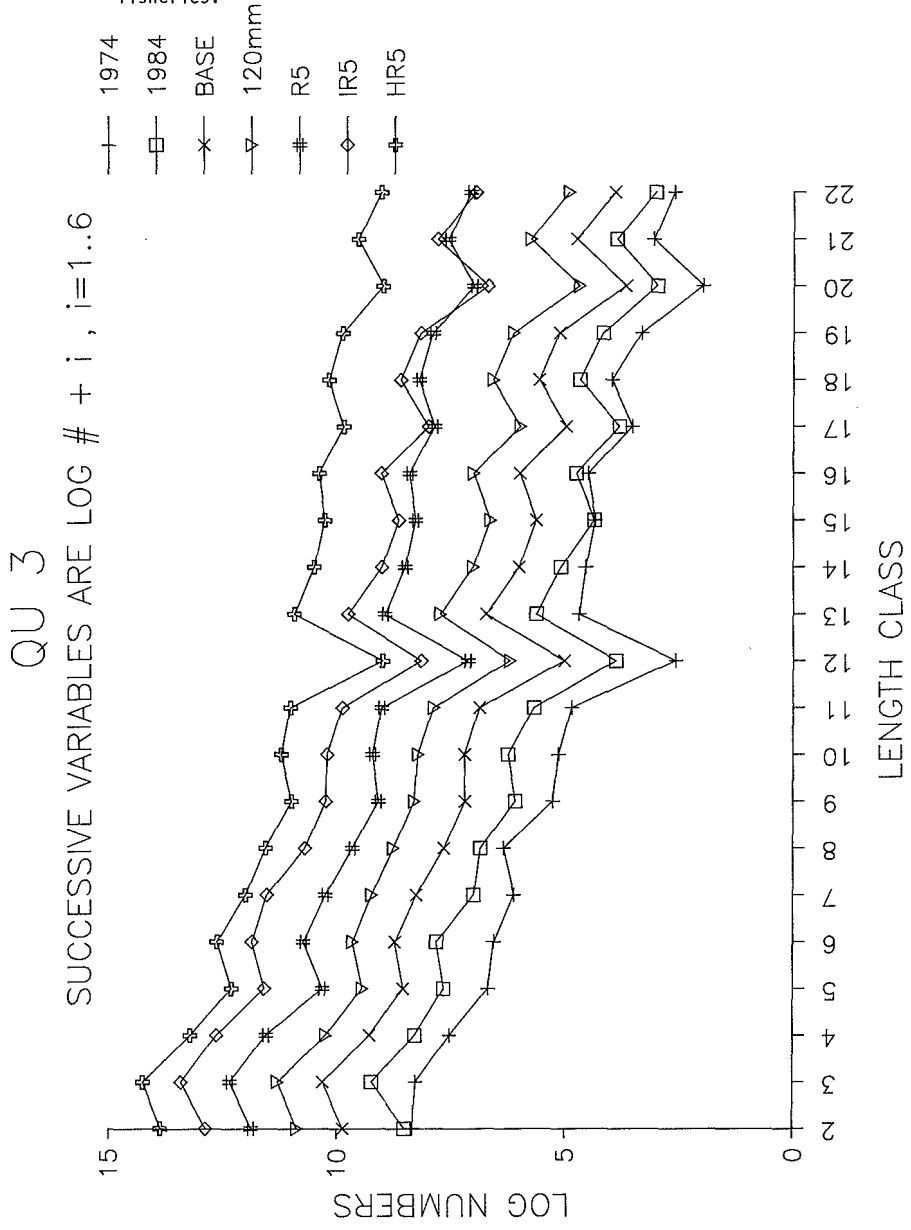


Figure 9.1.4. Aggregate multispecies size distributions (log numbers by 5 cm length category) in the fourth calendar quarter for: (1) 1974 MSVPA results, (2) 1984 MSVPA results, (3) long-term prediction using 'baseline' exploitation pattern, (3) long-term prediction assuming a 120 mm minimum mesh when fishing for cod, (4) a 50% reduction in overall fishing effort, (5) a 50% reduction in industrial fishing, and a 50% reduction in human consumption fisheries.

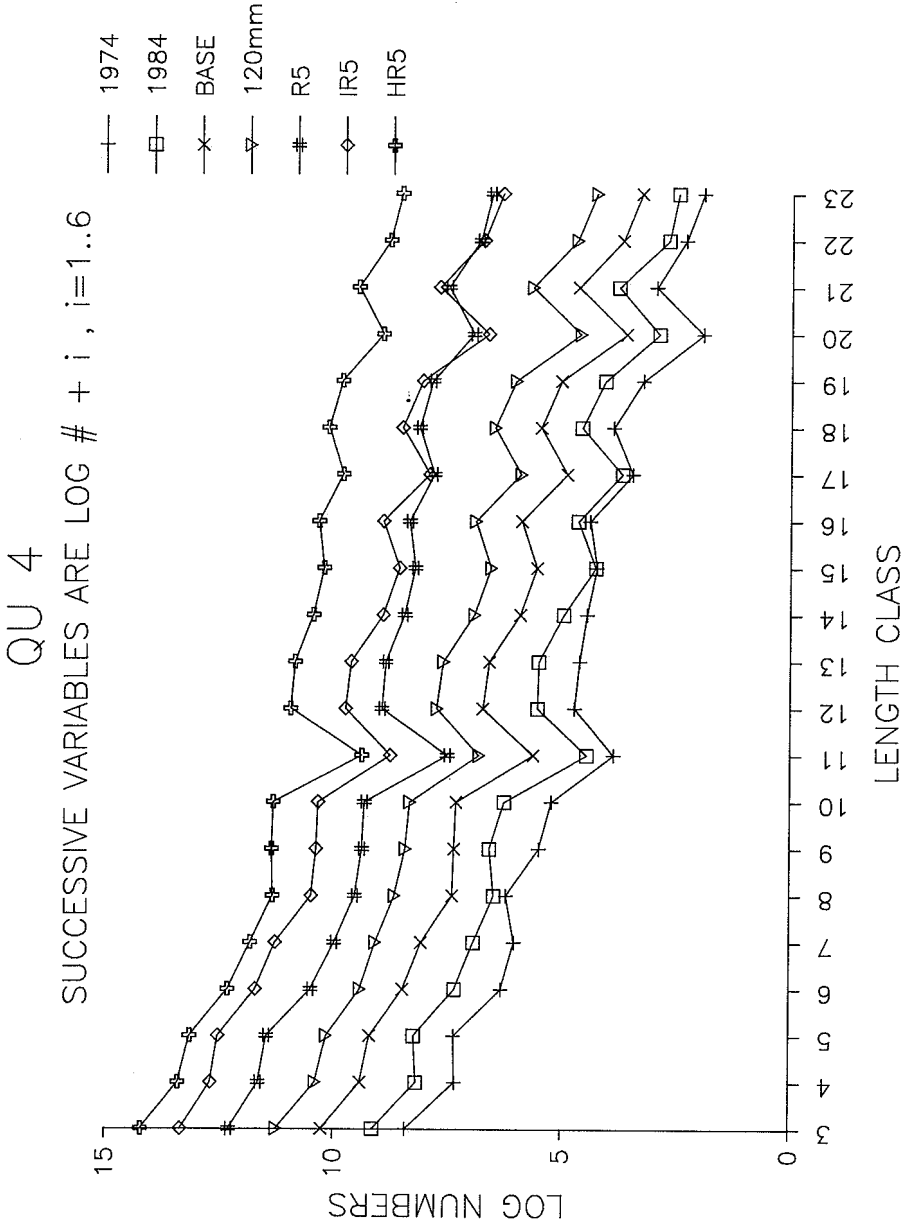
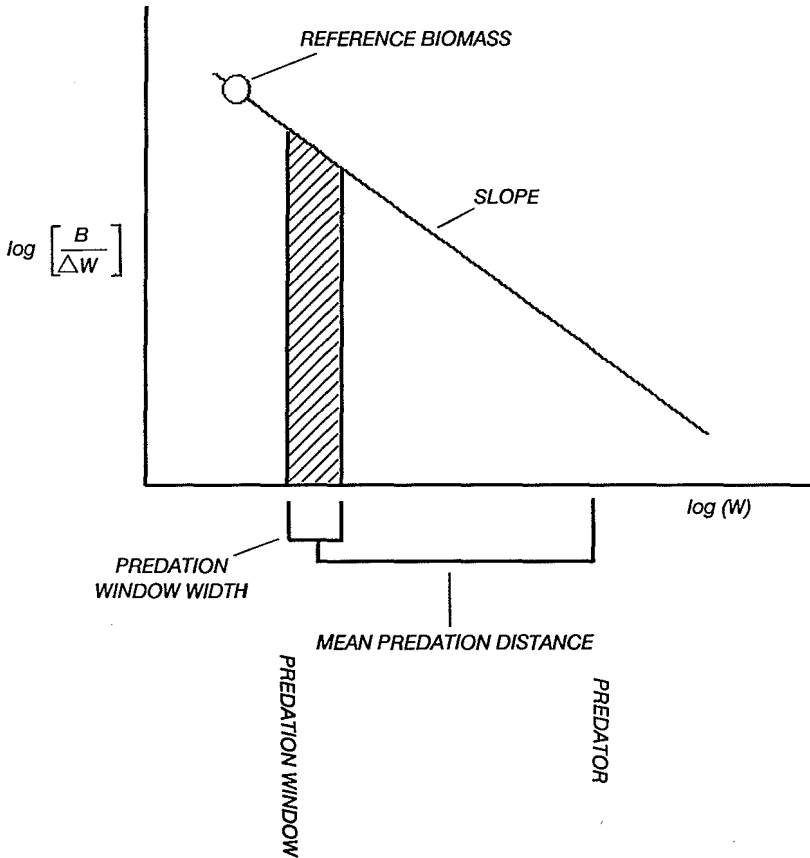


Figure 9.2.1. The normalized biomass spectrum and the parameters of structure and predation.



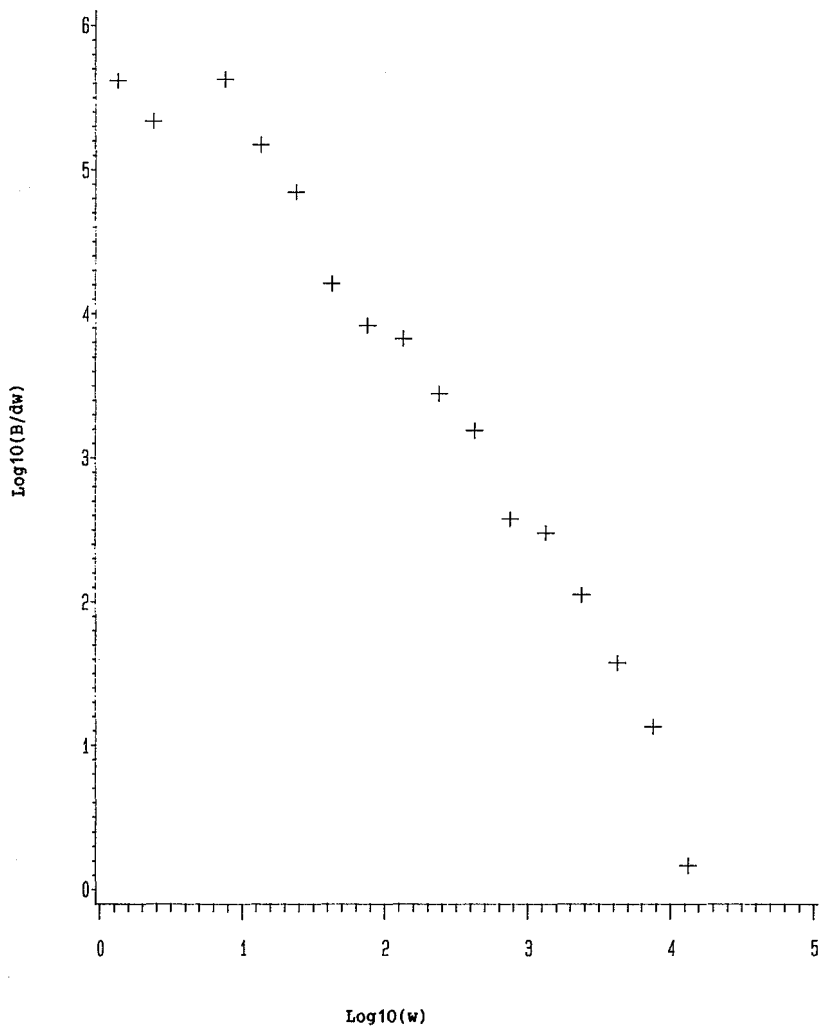
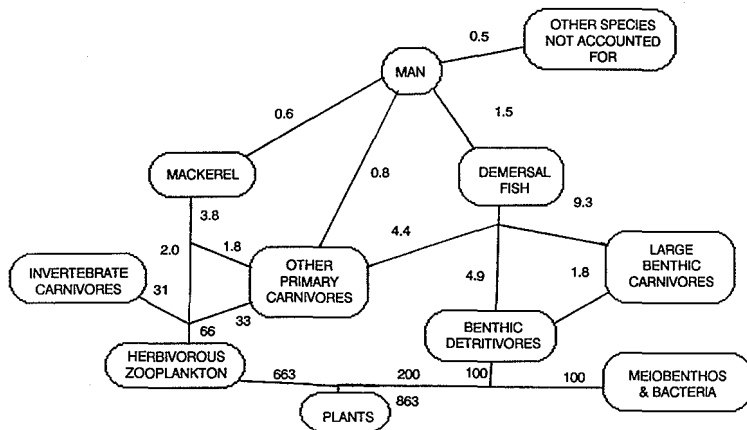


Figure 9.2.2. The normalized biomass spectrum of the North Sea MSVPA fish stocks, 1974-1988.

Jones (1984)
Late 1960s



MSVPA
1974

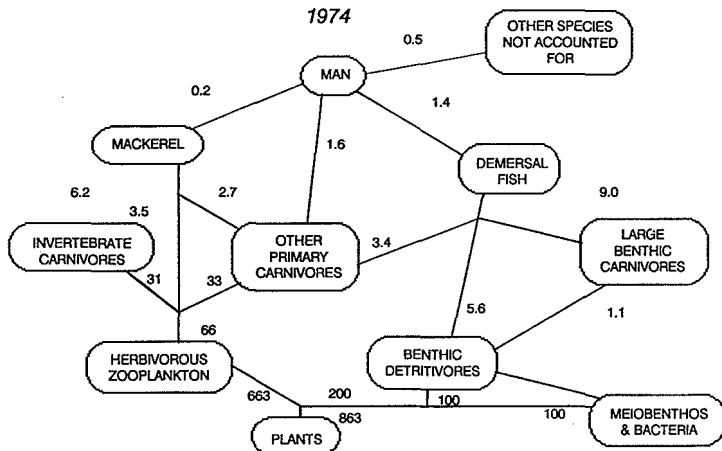


Figure 9.3. Energy-flow estimates from Jones (1984) and based on the present MSVPA model for the North Sea. Values are in wet weight (million tonnes) per year. Energy in g C is transformed to wet weight by $1 \text{ g C} = 10 \text{ kcal}$ for everything except plants, the conversion for which is $1 \text{ g C} = 15 \text{ kcal}$, and $1 \text{ g wet weight} = 1.3 \text{ kcal}$.

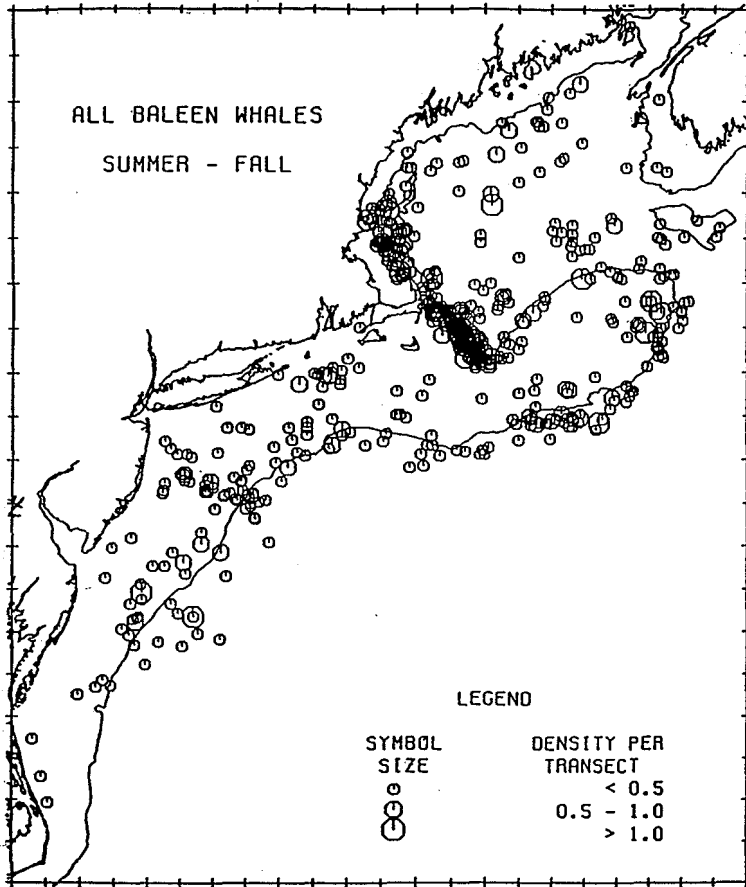


Figure 10.3.1. Distribution of all baleen whale (finback, humpback, minke) sightings during shipboard surveys on USA National Marine Fisheries Service surveys, for summer and autumn 1980-1986, in shelf waters off the northeastern USA.

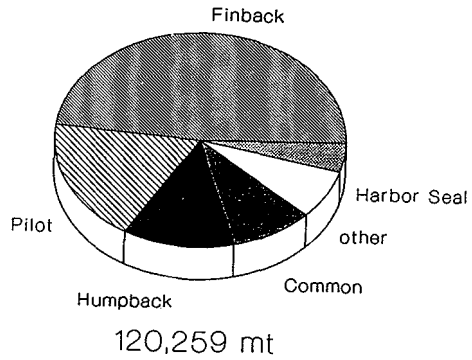


Figure 10.3.2. Total consumption and proportion of finfish biomass consumed by 10 species of marine mammals, from a simulation study of the pelagic ecosystem off the northeastern USA. Common is common dolphin, pilot is pilot whale, finback and humpback are baleen whales.

APPENDIX A

Minutes of ACFM Meeting
1 - 9 November, 1988

Report of the Multispecies Assessment Working Group

The various equations used in the MSVPA and MSFOR are complicated and pose a problem of obtaining statistically sound results. Additional stomach data for 1985-1987 made it possible to test the stability of prey suitability. Prey suitability has varied little over time, and observed changes are mainly due to prey biomass changes. Problems were encountered with sprat, herring, and mackerel (e.g., mixing of Western and North Sea stocks). Results from the key run were noted as being an important part of the work. Predation mortality estimates were in close agreement with those obtained previously. Long-term advice in the multi-species context is contrary to that which would be given in the single-species context. Results provided by the Working Group concerning the impact of an increase in the mesh in the North Sea roundfish fishery to 120 mm still contain some uncertainties. These results suggest no economic advantage to the fishing industry by increasing the mesh. Analysis of fisheries interactions remains inconclusive. The long-term effects of large changes in some fisheries were examined. There is a need for further research on predation on and among o-group fish, and a new stomach sampling programme to be done in 1991 (which will be expensive).

ACFM noted that it was a very important report and was most impressed with the outcome of the long-term forecasts. It was pointed out that the Working Group, thus far, has only considered biological interactions and not technical (fishery) interactions. The impact of an increase in mesh size in the North Sea roundfish fishery is quite different from that anticipated, and must be taken into account when drafting the advice on those stocks at this meeting.

Concern was noted with the multispecies model's sensitivity to changes in data, and with the stability of the calculations. Data seem to be treated as being exact (which they are not), some of the sensitivities are not realistic, and some details of the model are not well understood. Calculations are very data-dependent and more smoothing of the input data is perhaps necessary. Results from the Shepherd multispecies long-term forecast model agreed well with those from the MSFOR model due to data smoothing (which says nothing about the reliability of the results from either model). Some agreement in the results of both single- and multispecies models was noted in forecasting the impact of a mesh increase (Tables 4.6.1 - 4.6.9) (e.g., increase in cod and whiting SSB), but most results disagreed. It is apparent that some results are not well understood yet. It was cautioned that exporting the results from the North Sea multispecies work (e.g., M values) to other areas should be done with care.

ACFM noted that the correspondence between the MSFOR and MSJ methods of calculation has been improved by using the same form of M2 values in each (i.e., raw values as calculated by MSVPA), but was concerned that this modification is a step in the wrong direction. The Working Group itself has, on numerous occasions,

discussed the probable advantages of using some form of fitted model for M2 with MSVPA and MSFOR. This should reduce the dependence of the calculations on occasional odd observations in the data, which ACFM considers to be a serious problem. ACFM requests the Working Group to pursue this approach as its highest priority.

ACFM congratulated the Working Group on its excellent response to the requests made at the May 1988 meeting. In order to evaluate the effects of mesh increases in more detail, the Working Group is now requested to evaluate the effects of a more realistic implementation of "120 mm when fishing for cod" along the lines adopted by the Roundfish Working Group in its evaluation of the question. This should be done, if at all possible, after the modification to use modelled M2 values has been implemented.

Several points were identified for further consideration by the Working Group. Half of the "other" component of predation M is by species not included in the MSVPA model. About 75% of the biomass of the "other" species is elasmobranchs. Feeding by these species should be examined.

There is no feedback mechanism for mackerel and saithe since there is no assumed predation M (M1) on them in the model. It was pointed out, however, that there are no young saithe in the North Sea and that no mackerel were observed in stomachs of North Sea predators (those used in the model) in the initial stomach sampling programme in 1981.

It was questioned whether single-species working groups should adopt the M values for O-group fish as estimated from the MSVPA because they are so much larger than previously assumed and will lead to very large estimates of year-class size at age 0. The O-group M values estimated for the last year (1987) were the highest on record (Tables 2.8.1a-i). It was suggested that age 0 should perhaps not be used in the VPAs and forecasts for these various species. No specific explanation was possible for the high Ms at age 0 in 1987, although Working Group members themselves were apparently equally skeptical of the values. It was pointed out, however, that the MSVPA is not tuned and that the input Fs are merely taken from single-species VPAs. The desirability of tuning the MSVPA to effort data was indicated. It was agreed that the relevant working groups should not change their M-at-age values (based on MSVPA results) until these and other uncertainties are resolved.

In Tables 4.4.1 - 4.4.7 where the results of MSFOR and Shepherd model forecasts of yield changes by species and fleet were shown, it was suggested that totals (in tonnes as well as %) should be shown for fleets as well as species. It was further suggested that value would be better to sum for fleet rather than tonnes of yield for different species. In Figures 3.1a-e, some data points were mislabelled, with year plotted instead of year class.

In the MSVPA key run, the Fs are weighted by number. In order for these to be comparable with results from single-species VPAs, un-weighted Fs should be used.

The point that the multispecies forecast of the increased mesh size in the North Sea showed no economic benefits was disputed. It was felt that the higher SSBs (at least for some species)

would lead to higher catch rates and greater stability in the fisheries. However, it was noted that catch rates would increase from increased mesh sizes. It was also pointed out that fleets will change their fishing strategy and composition as the stocks change.