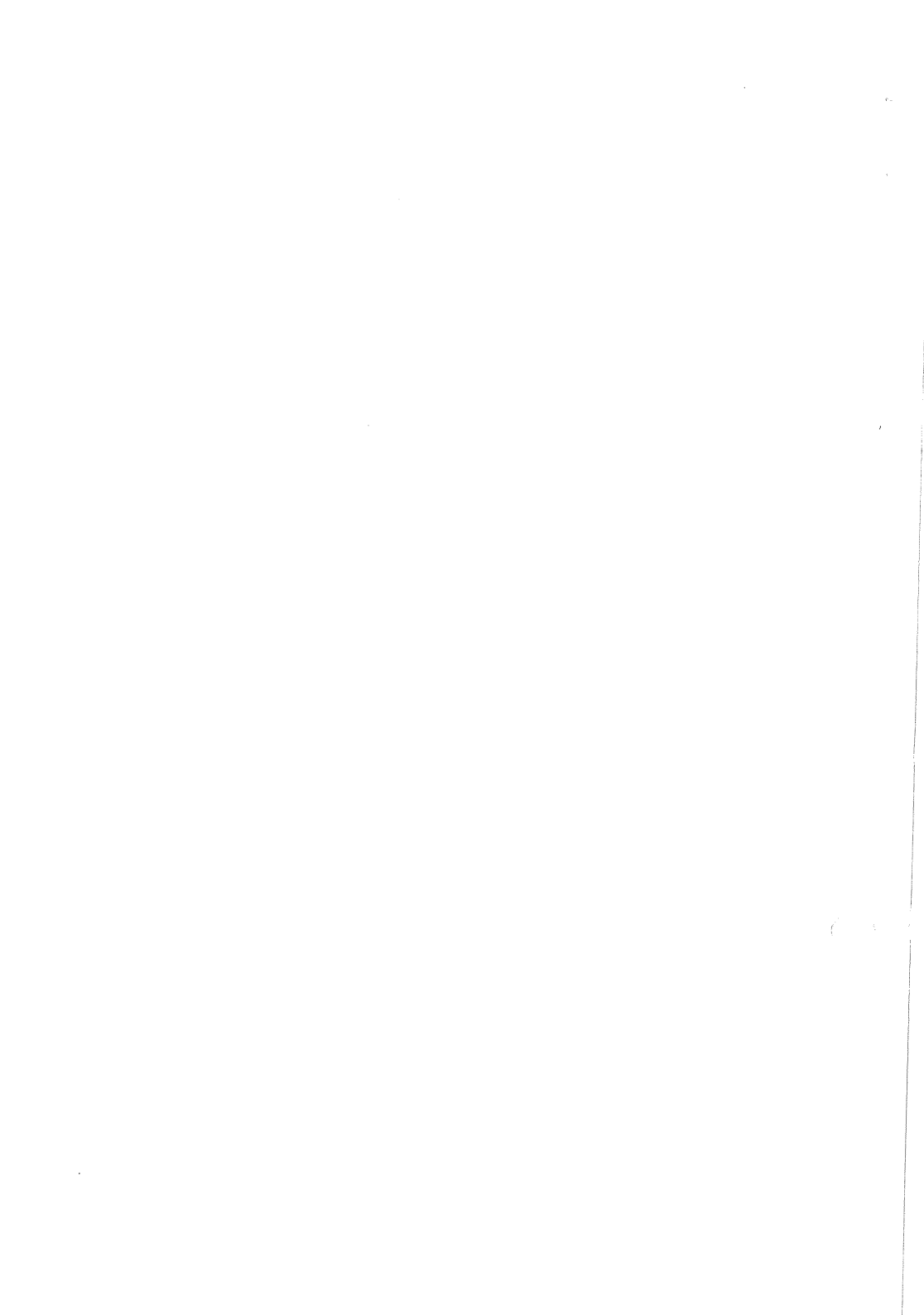International Council for the
Exploration of the Sea

C.M.1986/Assess:9

REPORT OF THE AD HOC MULTISPECIES ASSESSMENT WORKING GROUP

Copenhagen, 13 - 19 November 1985

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

< i >

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

1. INTRODUCTION

1.1. Participants

D Armstrong	U.K. (Scotland)
R Cook	U.K. (Scotland)
N Daan	Netherlands
W Dekker	Netherlands
J-E Eliassen	Norway
D Gascon	Canada
H Gislason	Denmark
K Magnusson	Iceland
S Murawski	USA
O K Pálsson	Iceland
J G Pope (Chairman)	U.K. (England)
J Rice	Canada
J Shepherd	U.K. (England)
H Sparholt	Denmark
P Sparre	Denmark
T Westgård	Norway

Dr E D Anderson, ICES Statistician, also attended the meeting.

1.2. Terms of Reference

It was decided at the 72nd Statutory Meeting (C.Res.1984/2:4:13) that the ad hoc Multispecies Assessment Working Group (Chairman: Mr J G Pope) should meet at ICES headquarters 13-19 November 1985 to continue the trials with MSVPA models.

1.3. Background to the Working Group Meeting

The previous meeting of the ad hoc Multispecies Assessment Working Group succeeded in making substantial progress towards interpreting fisheries assessment data using multispecies virtual population analysis (MSVPA). This work was based on the approaches set out in Helgason and Gislason (1979), Pope (1979), and Sparre (1980) which follow the pioneering work of Andersen and Ursin (1977). This was an approach advocated by Ursin (1982).

In 1984, the Working Group was able to make preliminary runs of the MSVPA, but there were still uncertainties about some assumptions made in the model, and some input data were not available at the time.

In the light of the results of the model, it was possible to look at the implications of multispecies effects on short-term fisheries assessment advice (total allowable catches, TAC's), but there was insufficient time to consider long-term effects. A number of suggestions for further work were also made, particularly further stomach sampling programmes for cod and whiting in the first and third quarters of 1985, 1986 and 1987.

The Working Group, therefore, set itself the following objectives for its current meeting:

1) to, where possible, narrow down assumptions on which MSVPA is based, e.g., ration-level, M1, and the proper definition of suitability;

2) to make MSVPA runs with the improved data set and to consider sensitivity of MSVPA results to uncertain assumptions;

3) to examine short-term effects in greater detail than was possible in 1984 and consider what effects, if any, the assumptions of MSVPA have on short-term predictions.

4) to provide estimates of the Jacobian matrix (expressed as the matrix of effects of 10% effort changes) of long-term yield with respect to changes in the main North Sea fisheries, i.e., fill in Tables 4.3.1 - 4.3.4 in the 1984 report, to consider the effect of various assumptions in MSVPA on these tables and to consider the possibility of presenting response surfaces of the yield function;

5) to review data collection and the progress of the 1985 stomach sampling and to discuss whether a programme should be considered for herring; and

6) improvement of the MSVPA model:

   i) to attempt to resolve the problem of the observed varying size of prey in stomachs of different ages of predators,

   ii) to consider other improvements in the MSVPA model, e.g., incorporating several years of feeding data and tests for variability of the suitability matrix, and

   iii) to consider the possibility/desirability of smoothing the M2 (prey, age, predator, age) matrix and the suitability matrix for further improvement of MSVPA.

The Working Group was able to make very substantial progress with all of these objectives during the course of the meeting, as can be seen from the body of this report. The attainment of these objectives was facilitated by:

1) work previously carried out by the relevant assessment working groups of ICES in providing data,

2) the work of the experts assigned to work up these data,

3) the work of the coordinators of the ICES 1981 Stomach Sampling Programme,

4) the work carried out by the staff of the Danish Fisheries Institute, Charlottenlund, in preparing computer programs and data inputs prior to and during the meeting and by the kindness of the Danish Institute in making computer facilities available at short notice,

5) the production before the meeting of relevant working documents and computer programs and results by a number of authors, and

6) the work of the ICES Secretariat.

The Working Group, therefore, would wish to acknowledge the help of all the persons concerned.

1.4. Future Work and Direction of the ad hoc Multispecies Working Group

The next meeting of the Working Group, scheduled for 12-18 November 1986, should substantially complete the development of the current methodology of multispecies assessments, and it is recommended that, in addition to its terms of reference, an objective of that meeting should be to agree on the format of a Cooperative Research Report to describe the methods and work of the ad hoc Working Group's 1984, 1985 and 1986 meetings.

At the 1986 meeting, it is hoped that stomach content data will be available from the 1985 sampling scheme. Its incorporation in the MSVPA can, however, only be tentative, since catch-at-age-data will only be available from 1985, and their interpretation will depend critically on values of terminal fishing mortality rates adopted in MSVPA runs. It is clear, therefore, that the definitive interpretation of these data and of those for 1986-87 will have to wait for further meetings of this or another group.

It, therefore, seems appropriate to consider the longer-term future of multispecies assessment work in ICES. Several possibilities exist:

1) The ad hoc Working Group could carry on as constituted, at least until the 1987 data can be fully analysed, with assessment advice being given by the relevant single-species working groups.

2) ICES could consider setting up area-based assessment groups, including one for all North Sea species. The work of the ad hoc Multispecies Working Group could then be included in the terms of reference of such a group and the single-species working groups disbanded.

3) ICES could consider having an area-based group for the North Sea using multispecies methods, but relying for methodological advice and research on a Multispecies Working Group, which could provide the same service to other areas. Such a group being essentially concerned with methodology might meet bi-annually in alternate years to the ICES Methods Working Group.

4) The current North Sea working groups could continue to give short-term (TAC) advice, which seems little affected by multi-species interactions, while long-term advice, which does depend on a consideration of these effects, would be supplied by a permanent Multispecies Assessment Working Group of ICES. Given the longer-term nature of its advice, such a working group might only need to meet bi-annually.

The choice of a suitable strategy is, of course, the responsibility of ACFM, but it is the belief of the ad hoc Working Group that the third or fourth options (which would require a permanent Multispecies Assessment Working Group of some form) would prove

the most workable, since multispecies advice currently involves very heavy workloads.

1.5. Computer Facilities

The _ad_ _hoc_ Working Group's proceedings are based very heavily upon the use of computers. Due to some technical difficulties with the ICES computer, much of the work of this meeting was conducted on the Danish Institute's VAX computer and on microcomputers brought to the meeting by members. The difficulties experienced with the ICES computer could largely be solved with modest hardware and software purchases, and the Working Group made some suggestions for what these should be in Appendix A.

2. TEST RUNS WITH THE MULTISPECIES VPA (MSVPA)

2.1. Fortran Program

The MSVPA program used for this meeting was written in FORTRAN 77 and executed on the VAX computer at the Danish Institute for Fisheries and Marine Research. The program requires memory for about 45,000 real numbers and uses about 7 minutes of cpu-time to execute an MSVPA run for the North Sea system.

Although the program is recently developed, it performs essentially the same calculations as that one used by the 1984 Working Group (Sparre, 1984). Sparre and Gislason (1985) describe the revised program.

The program has been changed so as to take into account differences in prey body weights in the population and prey body weights in the predator stomachs.

Suitability coefficients are now calculated by

$$
\text{SUIT}(q,s,a,j,b) = \frac{\dfrac{S(y,q,s,a,j,b)}{\overline{N}(y,q,s,a,*)\ \overline{W}\text{-stom}(q,s,a,j,b)}}{\displaystyle\sum_{\substack{i \quad d \\ \text{prey}}} \dfrac{S(y,q,i,d,j,b)}{\overline{N}(y,q,i,d)\ \overline{W}\text{-stom}(q,i,d,j,b)}}
$$

and predation mortality of (s,a) in quarter q of year y is calculated by

$$
\text{M2}(y,q,s,a) = \frac{1}{\overline{N}(y,q,s,a)} \sum_{\substack{j \quad b \\ \text{predator}}} \frac{R(q,j,b)\ \overline{N}(y,q,j,b)}{\overline{W}\text{-stom}\ (q,s,a,j,b)}\ S(y,q,s,a,j,b)
$$

per quarter

where y is index of year,
      q is index of quarter,
      s is index of prey species,
      a is index of prey age group,
      j is index of predator species,
      b is index of predator age group,
      S is relative stomach content,

$$SUIT = \frac{\text{Average observed weight of prey (s,a) in the stomachs of predator (j,b)}}{\text{Average observed weight of total stomach content of predator (j,b)}}$$

$\bar{N}$ is the mean cohort number,
$\bar{W}$-stom is the mean weight of (s,a) found in the stomach of (j,b), and
R is the total food ration per quarter.

Another change in the program deals with the iterative pro-
cedures. The iterations for estimating predation mortality and
suitability have been speeded up by introducing an option to mix
the current and the previous value of M2 and SUIT when finding
new values for the next iteration. (The iterations were pre-
viously characterized by oscillations around the final estimate.)

The new version of the program contains more options for output
tables, e.g., partial predation mortalities sorted either by
predator species or by prey species. A full listing of the pro-
gram is available from P Sparre, Danish Institute for Fisheries
and Marine Research, Charlottenlund Slot, 2920 Charlottenlund,
Denmark.

2.2. Catch-At-Age-Data for MSVPA

Following the recommendation of the 1984 report of the Multi-
species Working Group, assessment working groups were requested
to supply quarterly age compositions, mean weights at age and
catch data for input to MSVPA for the period 1974-84. With the
exception of mackerel, the assessment working groups were not
able to collate the required data in the time available at their
respective meetings. Collation of data for herring was, there-
fore, coordinated meantime at the Danish laboratory and for cod,
haddock, whiting and saithe at the Scottish laboratory.

Details of the data made available are shown in Tables 2.2.1 -
2.2.5. As far as was possible, the quarterly data were worked up
according to the standard practice adopted by the respective
single-species working groups. It became apparent, however, that
there were errors in some data and the late submission of data by
at least one nation prevented full use of all of the information
potentially available. It should, therefore, be possible to im-
prove the quality of the data base before next year's meeting,
but in view of the size of the task involved, an informal meeting
might be necessary to satisfactorily resolve outstanding pro-
blems.

The data made available to the Multispecies Working Group rep-
resent only a subset of those hitherto used by assessment working

groups, so that the data base constructed for MSVPA differs from
that used in single-species assessments. An example is given for
saithe in Table 2.2.6. The differences between the multispecies
and single-species data bases were not explored at this meeting.
In view of this, caution should be used when comparing stock size
and fishing mortality rates from MSVPA and single-species VPA
(SSVPA). In general, the quality of the data is higher for more
recent years. It should also be noted that for many years only
annual mean weights at age were made available. No attempt was
made to adjust these to account for seasonal growth, and there
may, therefore, be systematic bias in the overall mean weights
for any quarter.

The Multispecies Working Group agreed that, to facilitate the
multispecies work, ICES should set up a new data base for quar-
terly catch-at-age data for cod, haddock, whiting, saithe,
mackerel and herring.

2.3. Relative Food Compositions

The stomach content data used last year were revised because of
some errors. A mistake was identified in the age-length key of
cod used to raise stomach samples for the first quarter of 1981,
and additional cod stomach samples were included in the fourth
quarter. The saithe data were revised in respect of average prey
weights. The data base was also extended to include information
on haddock which had been presented by de la Villemarqué (1985).
In addition to the fractions of each prey age group by weight in
the food of each predator age group, estimates of the average
prey weights within each cell are now available for making the
proper adjustment in the calculation of predation mortalities.
The saithe data were revised to include additional data.

For cod, additional stomach content data by quarter (Daan, 1985
WD) were available for 1980 and 1982, but most of these data sets
are representative only for Roundfish Area 6 (southeastern North
Sea). Only the first quarter of 1982 (where the samples were
derived from the whole area) allow a valid comparison with the
1981 data.

2.4. Estimates of Ration Used in MSVPA Runs

No changes were made in the rations used last year, since the
estimated values appear to lie within the boundaries of compar-
able estimates based on energetic requirements (Anon., 1984a).
For haddock rations, the linear model used for cod (Daan, 1973)
was applied. Due to lack of information on digestion for haddock,
no adjustments could be made to the parameter values. However, it
would seem reasonable to assume the same rates of digestion in
fish prey as for cod.

During last year's meeting, it was observed that halving the
rations approximately resulted in predation mortalities being
reduced to half the original values, which would seem logical
from theoretical considerations. This run was repeated this year
to confirm this effect.

2.5. M1 Levels Used in Runs

In its earlier report, the Working Group asked for guidance from the single-species assessment working groups in selecting appropriate values of residual natural mortality (M1), but no response has so far been received. Therefore, there appeared to be no option other than to stick to the values established last year for the key run. However, in view of the probable significance of the M1 values assumed on the estimated stock sizes and mortality rates, it was decided to make an additional run with halved M1 values. Further research on ways of estimating M1 is certainly required.

2.6. Feeding Models Used in MSVPA and Assumptions About External Food

It was decided to reject the option that the total fraction of exploited fish prey in the food remains constant. Although attractive from a didactic point of view in the sense that it is the most simple model, it was considered to represent fish feeding less well than models which allow feeding to be diverted to other food when fish biomass become lower.

Because the Gislason-Helgason model of a constant other food biomass is insensitive to the actual value of other food assumed, this model was used for the key run rather than Sparre's model of a constant total prey biomass, which tends to give aberrant results at unrealistically low values of other food.

It was noted that, among benthos scientists, there is some progress in estimating total benthos biomass, but as yet it seems to be impossible to use this kind of information, because a large component of the benthos does not actually serve as prey for predatory fish, and also a large component of the other food refers to unexploited fish species such as dabs. Work on obtaining such estimates of other food would be welcomed by the ad hoc Working Group.

2.7. The Choice of Appropriate Mean Weights at Age for Prey Items in MSVPA

A significant issue raised at the 1984 ad hoc Multispecies Working Group meeting was the apparent discrepancies between mean weights at age for prey species observed in the sea and those same age groups sampled in cod and whiting stomachs. In general, mean weights in the stomachs were considerably less than in the sea for the same age of prey, although Norway pout and sprat in cod stomachs were on average larger at age than in the sea (Anon., 1984a). Another general conclusion was that the discrepancies between mean weights were more pronounced for whiting than for cod. The direction and magnitude of these discrepancies suggests 1) size-selective feeding (generally on the left-hand limb of the weight frequencies of prey species at age), or 2) overestimation of the mean weights at age of young prey in the sea (i.e., the discrepancies were most pronounced for the youngest age groups of prey). Although the effect of these differences between mean weights of prey on the results of MSVPA was considered at the meeting, time did not allow for sufficient

analysis, particularly in relation to the ages of predators and prey and the effect of calendar quarter.

As described in the report of the ad hoc Multispecies Working Group (Anon.,1984a), the discrepancies between mean weights of prey in the stock and in the sea could have a major impact on the overall results of MSVPA, particularly for certain predator/prey combinations where the effect was greatest (i.e., cod eating young cod and herring, and whiting eating cod, herring, haddock and whiting).

If, for example, the mean body weight of a prey species in the stomach of a particular predator is only half of that for the prey population, partial predation mortality will be underesti- mated by a factor of two under the assumption of equality between mean weights at age of prey in the sea and in stomachs.

At least some of the extreme discrepancies in mean weights were due to the large variability in stomach contents data in part caused by small sample size (number of stomachs sampled) within particular predator age/prey age categories (Anon.,1984b; Pope and Hunton, 1985). Several approaches were suggested for identi- fying particularly extreme weight-at-age data in the context of MSVPA, and these methods are reviewed in Section 6.3.

With respect to the MSVPA formulation, the observed weights of prey at age in the stomachs of predators are now used in the calculations of food composition and predation mortality in the revised MSVPA computer program (Section 2.1; Gislason and Sparre, 1985a WD; 1985b WD). It was generally accepted by the Working Group members that this "empirical" approach, allowing for mean weight-at-age deviations in the analyses, was a valid method for incorporating these data in the analyses.

It is recognized that including the observed weights at age in the stomachs is not, however, the only approach to the problem. Potential methods for incorporating the weight discrepancies in the MSVPA analysis are discussed in Sections 2.1 and 6.7.

Further research on the form of these alternative adjustments accounting for mean weight discrepancies and the sensitivity of MSVPA results to the adjustment procedure is necessary to assess the preferred technique. Such work could form the substance of a useful working document for the 1986 Working Group meeting.

2.8. **The Key Run of the MSVPA**

As at last year's meeting, a "key run" was identified, which was based on a selection of various possible assumptions according to the best judgement of the Working Group. This run was used as a reference for exploring the effect of alternative assumptions.

The key run adopted was based on:

1) the Helgason-Gislason feeding relationship, the justifica- tion being that the results appear to be independent of the value of the "other food" component, whose size remains largely a guess;

2) the same rations consumed as last year, extended to cover the haddock;

3) the revised stomach content data, extended to include haddock;

4) the same residual natural mortalities as last year, which were made to fit the standard working group assumptions on the oldest age;

5) the revised MSVPA, which takes care of the prey weight correction;

6) terminal F values for the last quarter of each year at the highest age and for 1984 for each stock were input at levels which produced an annual value of F approximately equal to that used in the most recent assessments carried out by the single-species working groups;

7) revised quarterly catch-at-age data (see Section 2.2).

In the case of herring, it was observed that the quarterly catch-at-age data presented to the Multispecies Working Group are generally lower than those used by the Herring Working Group. These discrepancies are often large and this results in discrepancies in stock size estimates between single-species and multi-

species VPA's. In addition, the quarterly weight-at-age data for herring refer to weight in the catch rather than the stock. The latter are used by the Herring Working Group for calculation of biomass. This also results in discrepancies. To obtain consistent results from single-species and multispecies VPA's, these problems must be solved.

Input data listings for the key run will be kept at ICES and be available on request on the same basis as the Working Group report.

Tables 2.8.1a-i presents the MSVPA results for the species included in the model (cod, whiting, saithe, mackerel, haddock, herring, sprat, Norway pout and sandeels). This table is the equivalent to the conventional VPA tables, i.e., it gives fishing mortality and population numbers but in addition gives the predation mortality caused by predators (cod, whiting, saithe, mackerel and haddock) in the model. The predation mortalities observed in this year's key run are generally higher than those of 1984. This is due to the appropriate method of incorporating the mean weight of prey in stomachs in the modified MSVPA and also due to the inclusion of haddock as predator.

Saithe and mackerel are not preyed upon by any of the predators in the model and consequently should be identical to the results given in the single-species working group reports. This is broadly the case and the deficiencies can easily be explained by the differences in the data base for catch in numbers (see Section 2.2).

The levels of fishing mortalities for the different species are in agreement with the results of the single-species assessments. Due to the substantial predation on the younger age groups,

mostly on the 0- and 1-group, the numbers at age of the youngest age groups and the estimates of stock biomass (calculated from mean weight in the catch) are, therefore, considerably higher than the traditional estimates. For instance, 0-group haddock and whiting numbers at age are about 12 times those of the single-species working groups, while the factor for the 1-group is about 3. These factors are not, however, very variable for a particular stock.

In the case of herring, the total biomass computed by the single-species working group was considerably higher than the results from the MSVPA. This implies that there is something erroneous in the data base for herring which must be clarified.

The total and spawning stock biomasses computed in the MSVPA and in the single-species working group reports are shown in Figures 2.8.1a-h for all the species except Norway pout where no biomass estimates were available.

It can be seen that, for the most heavily preyed-upon species, the estimates of total biomass from the MSVPA are considerably higher than the corresponding single-species estimates. The estimates of spawning stock biomass are, however, in fairly good agreement, which is as expected since the spawning age groups generally experience a much lower predation mortality than do the younger age groups. The result for herring is clearly anomalous (see comments above).

The means of the ratios between numbers at age in the MSVPA key run and in the single-species VPA's for the years 1975-84 are shown in Figures 2.8.2a-b for cod, whiting, haddock, herring, sprat, Norway pout and sandeel. Generally all single-species working groups estimate lower numbers of 0-, 1- and 2-group fish (especially cod, whiting and haddock). For age groups 3 and older, the agreement between MSVPA and SSVPA is reasonable for all species.

2.9. Comparing Runs Under Different Assumptions with the Key Run

In addition to the key run, two runs were made with different assumptions. The half-food run assumed the ration for each predator was one half the ration assumed in the key run. The half-M1 run assumed M1 was one half the non-predation natural mortality assumed by the key run. A third alternative run was also made assuming total biomass in the sea was constant, whereas the key run assumed that yearly "other food" was constant, regardless of the biomass of species in the model. Summary results of this run are shown in Table 2.9.2.

In the key run, the biomass of other food was assigned the value 40 x 10^6 tonnes. A run with other food biomass equal to 10 million tonnes gave almost the same result (deviations less than 0.1 per mille).

A comparison of the results of the different runs is given by species. The 1974-84 averages for F, N, and M2 were calculated for each run and summarised in Table 2.9.1a-d. Using the key run as a standard, several consequences of changing model assumptions are apparent. Time did not allow a detailed examination of all

results of each run. Such an examination is warranted and might reveal other effects of changing model assumptions. Preliminary conclusions include:

1) Halving the ration level decreases predation mortality for all species (of course). The decrease is less than 50% for young ages, but reaches 50% by age 3 or 4 for long-lived species. The decrease in M2 at age 0 and 1 is greatest for sprat (40%) and least for haddock (14%). M2 of saithe and mackerel were zero, and so did not change.

2) Halving M1 generally changed M2 values very little. M2 on Norway pout did increase by 32% at age 0, decreasing to a marginal change in M2 at age 4. Halving M1 reduced M2 on the older ages of some species such as sandeels (9% decrease by age 7), sprat (9% decrease by age 4) and herring (5% decrease by age 5).

3) Halving the ration levels increased the estimated values of F on the early age groups of most species. F increased most for haddock (up 65%) and by around 50% for all other species except cod, where the change was marginal. By age 2, estimated values of F were similar to key run values of F for all species except Norway pout, sprat (up 30%) and sandeels (up 13%). Again, values of F for saithe and mackerel did not change because they were not eaten in the model.

4) Halving M1 increased the estimated F on all species, generally by larger amounts on younger age groups. The effect was largest for Norway pout (47% on the youngest), somewhat less on saithe and mackerel (25% on young ages) and similar for the other species (between 11 and 20% increase on young ages).

5) Halving the estimated rations decreased estimated numbers for all species except saithe and mackerel. The effect was greatest at age 0, of course. By age 5, the effect was negligible for all species except sandeel.

6) Halving M1 also decreased estimated numbers, usually by around 20% on young ages and 10% or less on other ages. The decrease is greater for saithe and mackerel, which do not suffer M2, and also greater for Norway pout, which has the largest M1

The yearly effects of the different runs are summarised in Table 2.9.2. Halving M1 decreased estimated total biomass by about 18%, and the estimated biomass eaten by predators 14%. Halving the estimated ration of predators decreased the estimated biomass by 22-25%, and the biomass eaten by predator by around 52%. Estimates for the last years in the model runs are close to key run values, but this is not a real effect.

In the alternative run assuming constant total biomass, predation mortalities and, hence, total biomass eaten were identical to key run results for 1981, the calibration year. M2's and biomass eaten in the fixed total biomass run both diverged from key run values, being consistently higher. By 1974, the difference was about 6% (Table 2.9.2).

3. SOME IMPLICATIONS OF THE RESULTS OF MULTISPECIES VPA TO SHORT-TERM (TACTICAL) ASSESSMENTS

3.1. Comparison of VPAs and Predictions Using Constant and Age-Dependent Values of M at Age

3.1.1. Methods

VPA's were calculated for the period 1965-84 for haddock and whiting and for the period 1974-85 for cod using 1) constant M at age as currently defined by the North Sea Roundfish Working Group and 2) mean age-dependent values of M (M1 + M2) for the period 1980-82 from the key run of the MSVPA. These values are shown in the text table below.

Age	Cod	Haddock	Whiting
0	2.711	2.036	2.277
1	0.790	1.435	0.929
2	0.366	0.361	0.444
3	0.229	0.249	0.343
4	0.200	0.230	0.289
5	0.200	0.209	0.249
6	0.200	0.200	0.234
7	0.200	0.200	0.200
8	0.200	0.200	0.200
9	0.200	0.200	0.200
10	0.200	0.200	0.200
11	0.200	0.200	–

M1 = 0.2 for all ages.

In each case, the values of F at age in the last data year were tuned by iterative replacement by average F at age for the period 1974-82. In the case of haddock and whiting for which good relationships exist between IYFS indices and VPA results at age 1, the terminal F at age 0 and 1 in 1984 was tuned using these relationships.

The VPA results were summarised by evaluating the following quantities for the period over which the VPA's were calculated: 1) mean catches (disaggregated in the case of haddock and whiting into human consumption landings, discards and industrial by-catch), 2) mean recruitment, 3) mean F over an appropriate range of ages (disaggregated in the case of haddock and whiting into human consumption, discards and industrial by-catch), 4) mean total and spawning biomass, and 5) coefficient of determination for the respective IYFS/VPA relationships. These quantities are shown in Table 3.1.1.

Short-term status quo predictions were also carried out for the period 1985-86. In the case of haddock and whiting, these predictions were carried out using the methods routinely adopted by the North Sea Roundfish Working Group in which F's in the prediction years are based on recent average F and not on F only in the last data year. For cod, the predictions were based on F in the last

data year. Predicted catches (for human consumption landings, etc. as appropriate) and biomasses are shown in Table 3.1.2.

3.1.2. Results

Comparison of the VPA's carried out using constant M and variable M shows all of the expected results (Table 3.1.1). Recruitment and biomass (particularly the biomass of the younger age groups which experience the high natural mortality rates) are increased while mean F is decreased. As noted in last year's report of the Multispecies Working Group, the correlation between VPA-derived recruitment and IYFS indices is little affected by using age-dependent M.

In the case of cod, the short-term predictions of catch are almost identical for both sets of M values (Table 3.1.2). For haddock and whiting, however, the human consumption catches predicted under the assumption of age-dependent M are considerably lower than those predicted assuming constant M. In the case of haddock, the difference is about 20%, while it is rather less for whiting.

For cod, the predicted biomasses are stable at about the historical average values under both assumptions about M. For haddock and whiting, the predicted biomasses increase irrespective of the assumption about M. However, assuming constant M, the predictions indicate that, by 1987, total and spawning biomass will be somewhat above the historical average, while the predictions using age-dependent M give the opposite result.

The results for cod are in good agreement with the suggestion made in last year's Multispecies Working Group report that short-term predictions would be little affected by the choice of M at age. The results for haddock and whiting are somewhat disturbing, and further work is required on the effect of changing our assumptions about M at age. It is possible that further attention needs to be given to the establishment of the exploitation pattern for the prediction years. Attempts will be made during the forthcoming meeting of the Methods Working Group to resolve these problems.

It should be made clear that the predictions described above are not multispecies predictions in the strict sense. The multispecies short-term predictions can be carried out by the method of Sparre (1980), but this was not done during this meeting.

3.2. Correlations Between Recruitment Estimates

Estimates of the number of fish at age 1 for various stocks obtained from the MSVPA key run were compared by linear correlation to other estimates of the same populations. Figures 3.2.1 - 3.2.9 show correlations between MSVPA, SSVPA and IYFS indices, where appropriate. The correlation coefficients between the MSVPA and SSVPA populations are above 0.9, with the exception of sandeel (0.773). This is in line with the findings of the 1984 Multispecies Working Group meeting. The correlations between the IYFS indices and MSVPA are similar to those between IYFS and SSVPA in the case of cod, haddock and whiting. The correlations between

MSVPA and IYFS are higher than those obtained between SSVPA and IYFS for herring and Norway pout. It is uncertain whether the herring result is due to differences between the VPA models or differences between the data bases used by the single-species and multispecies working groups (see Section 2).

4. LONG-TERM ASSESSMENTS

4.1. Introduction

A general discussion of the problems of carrying out long-term multispecies assessments was given in the report of the 1984 Working Group (Section 4). This remains valid and should be consulted for necessary background material.

As discussed there, a major problem is the presentation of the results of the calculations in a compact and comprehensible form, particularly when many fisheries are involved. In Section 4.3 of the 1984 report, an alternative presentation of results was proposed, but only blank tables were presented since it was not possible to make the necessary changes to existing programs or assemble the data required in the time available.

4.2. New Configuration of the Multispecies Steady-State Model

Since that meeting, Shepherd (1985 WD) had constructed a reconfigured version (HRMSJ) of his multispecies steady-state model (Shepherd, 1984), which permits tables of the required format to be printed directly. This new version allows for nine species and eight fisheries, but these limits could easily be increased. The new version of the model uses exactly the same basic algorithm as the original version. The data required are slightly modified in two ways:

1) the base level (usually the current level) of overall fishing mortality in each fishery must be specified, and

2) in each fishery, one need supply information only for species caught in that fishery.

The basic computation of yield, etc. under specified fishing mortalities is now carried out in a subroutine. This is called once to establish the yields and biomasses under the base level of fishing mortalities, and then once more for each fishery, with the fishing mortality only increased by 10%. The differences between these results and those for the base level of fishing mortality are computed and printed.

Preliminary data files for the nine species (four predator) system had also been prepared from ICES working group material, based on the recognition of six fisheries, namely:

```
Roundfish   - human consumption
Industrial  - demersal
Industrial  - pelagic
Herring     - human consumption
Saithe      - directed fishery
Mackerel    - human consumption
```

These provide a reasonable first approximation to the major rel-evant North Sea fisheries. Two data files had been prepared.

The first data file was an approximation to the present situation as evaluated by conventional single-species assessments (file DR-MSSO). Natural mortalities here were set at conventional values, predation was set to zero, and the stock-recruitment parameters were adjusted to give recruitment levels which led to a reason-able estimate of the steady-state spawning stock biomasses as judged by informed assessment working group members. The fishery data includes reasonable estimates of by-catch mortalities and proportions discarded. Except for the inclusion of by-catches (technical interactions), this is, therefore, equivalent to a set of single-species assessments.

The second data file was a trial data set in which predation had been included. All basal natural mortalities were reduced to 0.1, with indiscriminate predation (preferred food weight ratio = 0.01, log SD of preference function = 2) at a mortality coef-ficient of 0.5 per Mtonne of predator. The stock-recruit par-ameters were adjusted to give similar levels of SSB as obtained in the no- predation case, since it was not clear how best to set up broadly comparable runs.

The results of runs of the new model based on these data files were examined. It was agreed that various modifications were re-quired (including the inclusion of haddock as a predator) and that the data including predation should be revised to take ac-count of the most recent runs of MSVPA. This was done by incor-porating average fishing mortalities for 1980-82, as estimated by MSVPA, to represent the current state of exploitation, the aver-age recruitments for 1974-83 (except for herring and mackerel where higher values were substituted to allow for stock recov-ery), and by using the results described in Section 6.6.2 to provide parameters for the predation equations.

The preferred food size ratio was set to 0.014, and the log SD of the size preference function to 1.7 in accordance with the re-sults of Section 6.6.2. The predator/prey preference matrix used was identical to that in Table 6.6.2. Values for mackerel as prey have been interpolated by eye, based on values for herring, sprat and Norway pout, since mackerel were absent from the stomachs in 1981, but are known to be fed upon. Values for saithe as prey have been set to zero since they are never caught in the survey area at sizes which would be vulnerable. It was noted that the preference of saithe for cod in this matrix seems to be unre-alistically high, but since no other objective estimate was available, no attempt was made to adjust the value. The other values in the table seem to be quite reasonably consistent with the judgement of Working Group members with experience in these matters. Note that all values are normalised to whiting feeding on whiting (this is an arbitrary choice), and all predators have been assigned the same predation mortality coefficient of 3.7 per

Mtonne, in strict accordance with the results of Section 6.6.2 (where <u>quarterly</u> cumulative mortalities are analysed). It would equally have been possible to assign each predator an individual predation coefficient and renormalise the values in Table 6.6.2, but this would have no effect on the calculation. The recruitment figures in the no-predation case were revised to give yields (rather than biomasses) comparable with recent average levels, since these are known more reliably.

After preliminary runs of the predation model, the recruitment figures were again adjusted so that the estimated yields were comparable with those in the no-predator run. It should be noted that the stock-recruitment parameters have been adjusted to give appropriate constant recruitment in all cases.

The data files thus obtained are held at ICES headquarters and will be made available on request on the same basis as the Working Group report.

<u>An alternative calculation of the Jacobian matrix</u>

In a working document, Pope (1985 WD) suggested a simple method of calculating the Jacobian matrix of yield based upon the approach of Jones (1961) that is the equivalent of Tables 4.3.1 - 4.3.4 in the 1984 report. This assumes a knowledge of the steady-state yield of current fishing mortality levels (this is usually provided by a simple averaging of the catches of a number of years). The change in yield at a new level of fishing mortality is then calculated as the product of the change in population size at age (due to a change in cumulative fishing mortality) and the change in exploitation rate. This approach provided a simple means of calculating yield change. A similar approach can be adopted for a multispecies system.

The change in yield is the product of the change in population size (due to the change in cumulative fishing and cumulative predation mortality) and the change in exploitation rate. Cumulative predation mortality is clearly changed by relative changes in predator stock sizes, so a matrix formulation is appropriate. That is:

$$\frac{\partial \varrho(I)^*}{\partial \varphi(f)} = -CUM \times F - CUM \times M2 \frac{\partial \varrho(I)^*}{\partial \varphi(f)}$$

where * indicates the value of the current situation where $\varrho(I)$ is the change in the population of the Ith species/age (s,a) combination. φ is the proportional change in the fth fleet and F and M2 have their usual meanings. The matrix CUM is the square matrix such that its product with $F(I)$, or equivalently $M2(I)$, gives:

$$\sum_{all\ j<a} F(s,j) + \frac{F(s,a)}{2}$$

where s,a is the species and age of the Ith element.

The consequent system of linear equations can be readily solved and values of

$$\frac{\partial \varrho(I)^*}{\partial \varphi(f)}$$

calculated for all fleets. The differential of the Ith yield for fleet g can then be written as

$$\frac{\partial y^*(I,g)}{\partial \varphi(f)} = y^*(I,g) \ \delta(f,g) + Y^*(I,g) \ \frac{\partial \varrho(I)}{\partial \varphi(f)}$$

where

$$\delta(f,g) = 1 \text{ if } f = g$$
$$\qquad\qquad 0 \text{ if } f \neq g$$

A computer program JACOB was provided by J Pope to make these calculations. An advantage of the formulation is that the catch at age and weight at age from the assessment working groups and the F(I) and M2(I) from the MSVPA can be used directly and provide unequivocal inputs to the method. The disadvantage of the approach is the assumption of stationarity of the recent past. While the pelagic stocks are in a depressed condition, as in the past 10 years, this assumption would be open to question. The unequivocal inputs of the approach, however, could make it particularly suitable for testing the relative effects on long-term yield considerations of the different assumptions used in the various MSVPA runs shown in Section 2.9.

Minor modifications to this program would enable it to consider the exact MSVPA feeding model. Apart from this, the calculations in this model are not entirely comparable with Shepherd's method, because Shepherd's calculation uses smoothed (fitted) values of mortality per unit predator biomass, whereas Pope's uses the actual M2 values output by MSVPA.

4.3. Results

The principle results of runs of HRMSJ on these data files for the no-predation case and the predation case are given in Tables 4.3.1 - 4.3.10. A comparison with results of MSVPA is also given in Table 4.3.11. It was not possible to run the alternative program JACOB during the time of the Working Group meeting.

In both cases, Table 4.3.1 gives estimates of the steady-state yield of each species in each fishery, and Tables 4.3.2 - 4.3.10 a summary of the changes estimated to occur when F in each fishery in turn is increased by 10%, as follows:

```
Table  4.3.2          - change in total yield
Table  4.3.3          - change in spawning stock biomass
Table  4.3.4          - change in recruitment
Tables 4.3.5 - 4.3.10 - yield of each species in each fishery
```

The results in Tables 4.3.5 - 4.3.10, therefore, represent the elements of the Jacobian matrix (see Section 4.2) which summarise the effects of making modest changes in the level of exploitation about the current state.

These results are a first attempt at a complete yield analysis of
the MSVPA system. It should be noted, however, that it is not
straightforward to specify the appropriate conditions for a
steady state. In particular, the levels of recruitment must be
specified, and this involves a substantial element of judgment.
The values used here have been chosen to conform with historical
averages, so far as possible, but some adjustment has been
necessary to allow for potential recovery of depleted stocks and
also to ensure that levels of steady-state yields are comparable
with historical average levels. No atttempt has been made to
specify stock-recruitment relationships, although this would, in
principle, be a preferable procedure. Note that absolute levels
of recruitment in the "with-predation" calculations are usually
much higher than conventional values, because of the much larger
predation mortalities on juvenile fish compared with conventional
assessments.

In addition, it should be recalled that the feeding model assumed
by Shepherd is different from that of MSVPA. It would be expected
that repeated forecasting to steady state by MSVPA would give re-
sults which are not identical to those presented here, although
the matrix method of Pope (1985 WD) (Section 4.2) is more closely
equivalent and should give similar results. The results should,
however, be regarded as preliminary until they have been compared
with those from the forecast mode of MSVPA (Sparre, 1980). Other
differences are, of course, the smoothing applied to the pre-
dation mortality in preparing input data for HRMSJ and the ex-
plicit modification of the recruitment values taken to be rep-
resentative of the steady state.

As stated above, recruitment levels have been adjusted to give
comparable levels of yield. The levels required are within about
a factor of two of those determined by MSVPA and closer to them
than to the results of conventional VPA, as would be expected. It
is, therefore, interesting to find that the estimated levels of
spawning stock biomass are quite similar for the two runs (these
are not usually known directly, only inferred from catch data).
This is not, in fact, particularly surprising because the average
levels of total natural mortality on mature fish are not dissimi-
lar in the two cases, so that yield/biomass ratios should be
similar.

It should be noted that the stock size of herring in these simu-
lations is probably unrealistically large. However, since herring
is a prey species, and prey are exploited independently of one
another in this model (unlike MSVPA), this should have no effect
on the estimated yields, etc. of other species. On the other
hand, it is known that herring is a predator on fish larvae (see
Section 5.1), and inclusion of this effect, in due course when
data become available, could have a major effect on the calcu-
lations. They should, therefore, for this reason (and others) be
regarded as preliminary.

The total predation mortalities on each prey species estimated
for the steady state are tabulated in Table 4.3.12 and plotted in
Figure 4.3.9. Overall, these are quite similar to the results ob-
tained by MSVPA (Table 2.9.1). There is no reason why they should
be identical, since one set relates to the past few years, whilst
the other refers to a hypothetical steady state.

Turning to a comparison of the results with and without pre-
dation, the following points are noteworthy:

1) In the absence of predation, the effect of increased fishing
   is obviously always to reduce biomass (Table 4.3.3a) Including
   predation (Table 4.3.3b), this is no longer true. The de-
   creases are generally less, and in some cases, there are in-
   creases.

2) Because the stock-recruit parameters have been so chosen, in
   neither case does fishing have any effect on recruitment
   (Table 4.3.4a and b).

Excluding predation, the effect of increasing F in the roundfish
(human consumption) fishery is to decrease all yields (Table
4.3.5), which would indicate that it should be reduced. Including
predation, there are increased yields of cod, haddock and
whiting, as well as increased yields of herring in both human
consumption and industrial fisheries. The indications are, there-
fore, reversed, and inclusion of predation clearly would have a
major effect on management advice for this fishery.

Whether or not predation is included, the effect of increasing F
in the industrial demersal fishery (Table 4.3.6) is a trade-off
between gains of Norway pout and sandeels in the industrial fish-
ery and losses of roundfish in the human consumption fishery. A
decision whether to increase or decrease such a fishery would,
therefore, depend critically on the relative values given to the
various species.

In the absence of predation, increased F in the industrial pelagic
fishery (Table 4.3.7) leads to a gain of sprat in that fishery,
almost matched by a loss of herring, plus a much larger loss of
herring in the human consumption fishery. With predation in-
cluded, there are gains of both species in the industrial fishery
opposed by still large losses of human consumption herring. In
either case, the value of human consumption herring lost would be
the dominant factor in deciding whether or not to increase or de-
crease F in this fishery.

In both cases, increases of F in the herring human consumption
fishery (from its "current" level of about 0.25) (Table 4.3.8)
lead to gains in the human consumption fishery opposed by compar-
able losses (in tonnes) in the industrial fishery. The value of
the former exceeds that of the latter and would, therefore, prob-
ably indicate an increase of F. Note that the herring stock has
been assumed to have recovered to a very large size.

Increasing F in the directed saithe fishery has little effect on
anything when predation is excluded. With predation, there are,
however, substantial gains of cod and Norway pout. In either
case, some increase of F would be tolerable.

Increased F on mackerel (from a "current" level of about 0.3)
leads to small increases of mackerel yield in the absence of pre-
dation, and small increases of various other species when pre-
dation is included. In either case, some increase of F would be
tolerable.

Yield curves

Although Tables 4.3.1 - 4.3.10 summarise succinctly the effects of changes of exploitation, they are still not easy to compre- hend. A modified version of HRMSJ was, therefore, constructed which computed results to enable yield curves to be constructed where each fishery in turn varied by a moderate amount (relative F between 0.6 and 1.4) whilst the others were held constant. This is just a graphical representation of the tables and may be re- garded as a series of cross-sections through the yield surface (which is six-dimensional). Similar graphs were prepared for spawning stock biomass and total yield (not the yield in the fishery in question alone).

These are presented as Figures 4.3.1 - 4.3.6. They show that the yield and biomass surfaces are generally much flatter around the current F position than is conventionally assumed, although the biomass of cod seems to be extremely sensitive to fishing mor- tality, even through it appears to be underexploited in yield terms at present; a 40% change in fishing mortality causes a two- fold change in biomass.

It should be noted that:

1) mackerel has been left off most of the graphs because the package used could only display 8 lines at one time, and

2) the yield and biomass scales are logarithmic in order to pro- duce a clear visual impression. They are useful for detecting the most dramatic effects, but cannot be used directly to assess comparative gains and losses, for which value information and absolute yields are necessary.

An additional investigation of the effects of predation on long- term yield was carried out by a preliminary examination of the effects of reducing fishing mortalities substantially to simulate the effects of implementing an F_{max} or $F_{0.1}$ management target. This was done by reducing the fishing mortalities in all fish- eries, except that for saithe (until recently thought to be near F_{max}), to one half of their current values.

In the absence of predation, the effects on yield and biomass are as shown in Figure 4.3.7. There are, as expected, generally some increases in yield and substantial increases in biomass. When predation is included (Figure 4.3.8), however, the effects are small reductions in yield and generally only small increases in biomass. This indicates that great caution should be exercised in the recommendation of management measures based on these tradi- tional targets.

4.4. Conclusions

It is thus evident that, although including predation affects the details of the changes expected when fishing mortalities are changed, the overall balances of advantage and disadvantage for all fisheries, except the roundfish human consumption fishery, are rather similar to those estimated when predation is ignored.

Clearly, the mixed fishery effects are very important in assess-

ing the consequences of management action, since they control the major trade-offs and conflicts of interest between the different fisheries, particularly when these mainly exploit prey species (e.g., herring, sprat, Norway pout and sandeels). The most striking effect of including predation is the reversal of the assessment of the effects of changing F in the roundfish human consumption fishery. This is not very surprising, since cod and whiting are major predators. It does, however, imply that results of conventional assessments of yield per recruit are likely to be seriously misleading and should not be used. Consequently, F_{max} and $F_{0.1}$ should not be used as biological reference points for predators.

An additional factor brought out very clearly in these results is the great importance of the relative unit value of various species in different fisheries. The trade-offs between fisheries can only be properly assessed if this is taken into account.

It should be noted that these calculations are essentially only multiple-species yield-per-recruit calculations. Some of the objections to basing management advice on such calculations (see e.g., Anon., 1984c) have been removed by the inclusion of predation effects in the calculation. Others, however, remain (e.g., neglect of social and economic factors), so the results should not be taken as a sufficient basis for management action.

5. **ADVICE ON FUTURE DATA COLLECTION**

5.1. **Stomach Sampling Programmes**

A new stomach sampling programme for cod and whiting has been initiated in 1985 in two selected quarters of the year (first and third) according to the recommendations of the ad hoc Working Group last year. As yet, no results are available nor are the details of the sampling intensity achieved so far, but there appear to have been no major problems. The programme will at least last through 1986 and 1987, but the first results are expected to be available in November 1986.

In the past, average prey compositions of mackerel and saithe over a number of sampling years were applied to the base year 1981 to get the corresponding suitability indices. This may result in a bias (see Section 6.1) and it was suggested that some smoothing of both the fractions consumed and the prey densities by averaging over more than one year before suitability indices are tuned might be desirable. This approach would possibly allow incorporation of presently available stomach content data, which are necessarily restricted in area coverage, and also new data collections for other species than cod and whiting when they become available. In particular, further data collections of saithe stomachs are required, and it is recommended that the possibility of associating sampling with the Norwegian acoustic surveys be investigated. The possibility of dividing sandeel consumption into that associated with the northern sandeel stock and the southern sandeel stock should also be considered. This would be desirable due to the considerable difference in weight at age between these two major components of North Sea sandeel which are assessed separately by the Industrial Fisheries Working Group.

Although not strictly relevant to MSVPA problems, attention was drawn to the possible impact of the recent upsurge in the herring stock on the recruitment of other stocks. It appears that, if the herring interacts with other exploited fish species, this interaction should occur as predation on the eggs, larvae and early 0-group phase of life. Indeed in the past, some quantitative estimates of plaice and cod egg predation by herring have been made, based on stomach collections in the early 1980's when the stock size was still low (Daan et al., 1984). The recent increase offers a special occasion to study its effects on other stocks, and a sampling scheme covering the first and second quarters might contribute considerably to our understanding of long-term effects on recruitment.

5.2. Further Research

Food preference remains a critical parameter in MSVPA, and estimates of various preference indices outside the model could be used to validate the results of applying the model. Gislason and Helgason (1985) and Gislason (1985 WD) introduce the concept of geographical overlap between prey and predation in relation to observed prey fractions in the food. Their model was based on general qualitative distribution patterns. Detailed survey data could be used to extend this kind of analysis in a more quantitative way. However, it was recognised that progress is critically dependent on the availability of a computerized data base presently being developed by ICES for the International Young Fish Surveys in February. In addition, the national groundfish surveys carried out in the third quarter could be used to provide extensive information in this respect for that period.

Apparently no new investigations on the size preference have been undertaken on the basis of the various stomach content data sets. There appears still to be considerable scope for extracting more information in this respect to back up the interpretation of suitabilities as estimated by MSVPA (Dekker, 1983). Attention was also drawn to a paper by Hahm and Langton (1984) who estimated size preference in a number of species in the Northwest Atlantic.

Attention was drawn to the gastric evacuation studies initiated at Lowestoft (UK) in response to the need expressed in last year's report for reliable estimates of consumption rates. Since scattered information appears to be available on this topic in various other laboratories, the Working Group stressed the importance of making all information available before next year's meeting of the Working Group, even if it is only in a preliminary format.

6. OTHER MATTERS

In the course of the work of the Multispecies Working Group, various problems were raised and various studies and analyses were made. These are reported in this general section in the hope that Working Group members and others may be stimulated to make further studies in the course of the year and to report their results to the 1986 meeting of the Working Group.

6.1. Comparison of Observed & Predicted Prey Fractions

Among the additional stomach content data sets for cod, the first quarter of 1982 was sampled over the entire North Sea at a reasonable level of intensity (1,085 stomachs vs 4,180 in the first quarter of 1981). This allows a comparison to be made between the prey fractions by age group of prey and predator observed in stomachs and the predicted fractions calculated by MSVPA. The predicted fractions naturally reflect, to a large extent, the observed fractions in 1981, but take account of the prey densities. By comparing both predicted fractions by the model and the observed fractions in 1981 with the observed fractions in 1982, a check can be made of the validity of the preference model underlying MSVPA.

Table 6.1.1 summarises the three data sets, and a preliminary bivariate scatter analysis was carried out, the results of which are given in Table 6.1.2. Although the correlations among the three data sets are highly significant in all cases, apparently the overall coefficient of determination is much higher for observations in 1982 against the predicted fractions (0.41) than for the observations in 1982 against the fractions observed in 1981 (0.25). Within prey species, the improvement is even more remarkable. Also within predator age groups, the improvement of the MSVPA predictions, as compared with the 1981 fractions, is fairly consistent. However, theoretically, there should be a one-to-one relationship between observed and predicted fractions and apparently, even when correlation coefficients are high, the actual relationship deviates considerably from these values. This might indicate that suitabilities may be biassed. There was no time to pursue this analysis any further during the meeting. Although the general conclusion appears to hold that the MSVPA significantly improves the predicted prey fractions, further work on this type of validation procedure is certainly required.

6.2. Who Eats Who

Table 6.2.1 summarises the total consumption by individual predators and the estimated stock biomasses in 1974 and 1981.

Figures 6.2.1a-g show the biomass and annual yield together with the biomass consumed annually by various predators for each prey species. For haddock, herring, sprat and sandeel, the total annual predation is almost equal to the annual yield. For cod and whiting, it is lower, while for Norway pout, it is considerably higher.

Figures 6.2.2a-e compare the biomass and annual yield of each predator with the prey biomass consumed. For cod, saithe, whiting and mackerel, the total yearly consumption of fish is estimated to be more or less equal to the total biomass. For haddock, it is considerably lower.

6.3. Censoring the Feeding Data

Pope and Hunton (1985) and Murawski (1985 WD) emphasized the relatively high variability in the consumption estimates and mean weights at age of prey in the stomachs of cod and whiting. The potential effects of extreme outliers in the consumption and mean weights could significantly affect the results of MSVPA. Extremely low (or high) ratios of mean weights at age of the prey in the sea (STOCK) to those in the stomachs (STOM) will produce proportional effects in the partial predation mortality rates at age due to particular predator species/ages. Discrepancies in the partial predation mortality rates for particular combinations of predator/prey age groups may be compensated for in the aggregate M2 on particular prey ages, but this has not been investigated.

Since the new implementation of MSVPA (Section 2.1) utilizes the observed mean weights at age in predator stomachs directly, some screening of the input data is necessary.

The revised MSVPA computer program incorporates a routine to compare mean weights at age of prey in the stocks and in stomachs. If the ratio of weights in stomachs to that in the stocks is less than some arbitrary value (in this case 1/100), a warning message is output and the stomach weight value is set to 1/100 of the stock weight. Such a procedure cannot, however, be regarded as an effective substitute for careful examinations of the basic input data on stomach weights, so its use was followed by a careful examination of anomalous values.

Extreme values in the cod feeding data from 1981 (Anon., 1984a; 1984b) were corrected with the revision of the first quarter cod age/length keys and with additional cod stomach data for the fourth quarter (Section 2.3). In particular, some of the data for whiting and cod eating sandeels were suspect. This is mostly a result of combining the three North Sea stocks of sandeel species despite them having different growth rates. Anomalous results found were treated before the final MSVPA runs, but ways of identifying them became the basis of a study in how to censor such data. Ratios of STOCK/STOM (before censoring was applied) were usually highest in the second quarter (Figure 6.3.1), with the ratios generally increasing with prey age. The importance of examination of the input data, with appropriate reference to the adequacy of stomach sampling and the age/length keys used to partition the stomach content by age, is thus emphasized, particularly since only one year's stomach sampling data are currently being used to fit the suitability coefficients in the model.

Several different techniques were proposed to screen the feeding input data for outliers, including 1) examination of the residuals from species-specific multiple regression equations predicting mean weights at age of prey in stomachs from the assumed mean stock weights at age of the prey and that of the predators, 2) examination of the matrix of partial-predation mortalities by quarter and predator/prey age, and 3) evaluations of the deviations in the ratio of stock weights to those in the stomachs to geometric mean ratios computed over predator/prey ages and quarters. These techniques obviously can be utilised as more years of feeding data become available to be included in the MSVPA.

6.3.1. <u>Identifying extreme stomach weight-at-age data from residuals of regression equations</u>

Stepwise multiple regression analyses have indicated that the quarterly average weights at age in the stock and the quarterly average weights at age of predators were the only two variables required to predict the quarterly average weights at age of prey species in the stomach. Examination of plots of residuals from such regressions allows the identification of anomalous values. Anomalous values may indicate errors in the data base (i.e., key punching errors), weaknesses in the sampling (i.e., small sample sizes) or biological factors in the former two cases. The results of the predictive regressions may be used to smooth these data.

Results of regressions for two predators (cod and whiting) are presented in Tables 6.3.1 and 6.3.2. These equations are based on the data used last year (Anon., 1984a) and have since been edited. Further, the MSVPA program can flag the weight data when the ratio between weights in the stomach and weights in the sea differs from unity by two orders of magnitude or more. Therefore, some of the anomalies detected in the regression analyses have been corrected and will not be present in the key run of MSVPA.

Figure 6.3.2 provides an example of such residuals plotted (whiting preying on sandeels) on which 8 observations (out of 92) clearly stand out as outliers (age 3, 4, and 5 sandeels in the first quarter). Some of the data may appear on casual examination to be anomalous, but the outliers to the regression models were rarely the same points. Most of the extreme weights-in the-sea/weights-in-the-stomach ratios occurred for the 0-group, whereas most of the outliers to the regression models occurred in the older age groups (as in the above example), probably indicating small sample size. Errors in the average weights at age of prey in the stomach will affect estimates of the number consumed and, hence, predation mortalities (M2).

6.3.2. <u>Examination of the partial predation mortalities at age from MSVPA as an indication of data outliers</u>

One of the outputs of the current version of MSVPA (Section 2.1) (Sparre and Gislason, 1985 WD)is a table of predation mortalities on each prey age group by quarter generated by each predator age (Table 6.3.3). By assessing the relative leverage that particularly high ratios of STOCK/STOM have on resulting "partial" M2's, it may then be feasible to assess the impact of potential outliers on the results of MSVPA. If, for example, a particularly high or low stomach weight has no impact on the resulting partial M2's, then the amount of effort necessary to validate that datum should be correspondingly low.

An example of the use of partial M2's to assess potential outliers is given in Tables 6.3.3 and 6.3.4. For age 0 and 1 sandeels, total M2's in quarter 1 are 0.0046 and 0.1550, respectively (Table 6.3.3). Approximately 82% of the first quarter M2 on age 0 sandeels is generated by age 2 whiting, where the ratio of prey weights in the stock to sandeel weights in the stomach is 42.105 (Table 6.3.4). About 51% of the total first quarter M2 on age 1 sandeels was generated by age 1 whiting. In this case, the ratio of stock to stomach weights was 3.007, but the total consumption

estimate for age 1 whiting eating sandeels in the first quarter
was large relative to other age groups of predators and prey.

Although overall M2's of age 0 and 1 sandeels in the first quar-
ter were relatively low, patterns of partial M2's can be used to
identify potentially anomalous mean weight and consumption data.
The same technique could be utilised to assess the potential for
systematic bias in the stomach sampling data. The total M2 on age
1 sandeels by quarter is:

Quarter	M2
1	0.155
2	0.987
3	0.023
4	0.021
Total	1.186

Thus, about 83% of the total M2 on this age group was in the sec-
ond quarter. At first sight, this appears anomalous, but
interestingly, this is in line with the availability of this age
group in the fishery and is thus possibly a real effect.

6.3.3. Evaluations of the deviations in the STOCK/STOM weight ratios from mean ratios by predator/prey age and quarter

A third method used to identify possible erroneous mean weight
data was to assess the deviations of the weight ratios from aver-
ages computed over predator ages, prey ages, and quarters for
various predator/prey species combinations (Murawski, 1985 WD).
These analyses were applied to the feeding data described in the
1984 Multispecies Working Group report (Anon., 1984a). In gen-
eral, the analyses indicated a strong effect of predator age on
the variability in stock/stomach ratios followed by the effects
of quarter (Table 6.3.5) and prey age.

The techniques described in this section can be used to point out
potentially faulty weights. However, only the results of the sec-
ond method can be used to evaluate the impacts of such values on
the results of MSVPA.

6.4. Smoothing of Suitability Coefficients

Due to the high variability in stomach content data (Pope and
Hunton, 1985), which will be reflected in the calculated suit-
ability coefficients, and also due to the existence of more
structured models of suitability such as those of Gislason and
Helgason (1985) and Andersen and Ursin (1977), it was decided to
attempt to smooth the coefficients by fitting the values obtained
from the MSVPA program to a size-suitability function. The gen-
eral model is

$$\text{SUIT}(i,a,j,b,q) = a_{iajq} \ \exp-\left\{ 1/2 \left[\frac{\left(\ln(\frac{W_{ia}}{W_{jb}}) - m_i\right)^2}{s_i^2} \right] \right\} \quad \ldots \ldots \ (6.4.1)$$

where i,a,j,b are the predator species index and age and prey species index and age, respectively, q denotes the quarter of the year, W the weight in the sea and m and s the mean and standard deviation of the size-suitability function.

A number of fits were made to various models. The first one tried was a fairly general one.

$$\ln \text{SUIT}(i,a,j,b,q) = a_q + a_i + a_j + a_{ij} + a_1 \text{LWR} +$$
$$a_2 \text{LWR}^2 + a_{1i} \text{LWR} + a_{2i} \text{LWR}^2 \quad \ldots \ldots \ (6.4.2)$$

where LWR is $\ln\left(\dfrac{W_{pred}}{W_{prey}}\right).$

Using suitabilities from a preliminary key run of the MSVPA program, a fit was made to the above model. It turned out that quarterly effects on suitabilities were negligible and, furthermore, species effects in the mean and standard deviation of the size-preference function explained little of the total variance.

Therefore, another run was made using the model

$$\ln \text{SUIT}(i,a,j,b) = a_i + a_j + a_1 \text{LWR} + a_2 \text{LWR}^2 \quad \ldots \ldots \ (6.4.3)$$

i.e., no species interaction effects are included, and size-preference parameters are considered independent of species. For this model, the root mean square error (RMSE) increased from 2.15 to 2.22 compared to the previous one. In these two runs, the suitability coefficients having zero values were included in the fit after having been given the value of 10^{-6}, which is smaller than the smallest value of non-zero suitabilities (see Dekker, 1983).

The inclusion of these points would tend to increase the width of the parabola being fitted and, hence, it was decided that, in future runs, zero suitabilities would not be used, although this is not quite satisfactory either.

With the suitability coefficients from the final key run of the MSVPA program, a fit was made to a model similar to 6.4.3, but also including a species interaction term, aij.

As a result of this run, it was decided to keep the interaction term. The RMSE was 2.22, and the values of the mean and standard deviation of the normal distribution of the logs of the weight ratios were:

$$m = 6.01$$
$$s = 1.81.$$

In the MSVPA program, the suitability coefficients are only determinable up to a multiplicative constant for each predator age. This constant is fixed by requiring

$$\Sigma \; SUIT(i,a,j,b) = 1, \text{ for all } i,a.$$

This scaling means that, for the same weight ratio, the suitabilities for a large predator will be lower than the suitabilities for a small predator, since the larger one is likely to prey on a greater variety of the species-age groups included in the MSVPA model and, hence, have more non-zero suitabilities which will be summed up to 1. This will lead to a smearing out of the suitabilities when they are plotted against weight ratios.

Another result of this particular scaling of suitabilities is that it is not possible to compare suitabilities of prey for different predator ages. Another possible scaling would be to put the maximum suitability for each predator age at 1. All other suitabilities will then be relative to the maximum one. Comparison of suitabilities for different predator ages then becomes more natural.

A run was tried using suitabilities scaled in this manner. The model was the same as used in the previous run, i.e.,

$$\ln SUIT(i,a,j,b) \;=\; a_i + a_j + a_{ij} + a_1 LWR + a_2 LWR^2 \; \ldots \ldots \; (6.4.4)$$

The results of this run were, however, not ready in time for inclusion in the report.

A general predator-species-age effect was included in the model, i.e.,

$$\ln SUIT(i,a,j,b) \;=\; a_i + a_j + a_{ij} + a_a + a_{ia} + a_1 LWR + a_2 LWR^2$$
$$\ldots \ldots \; (6.4.5)$$

Here RMSE = 2.18 and size-preference parameters were

$$m = 6.47$$
$$s = 1.67.$$

However, the species-age effect was insignificant, and age effects did not improve the fit much.

Due to time limitation, no more runs could be made. However, it would be interesting to test for nested effects as opposed to main effects + interaction effects. Also, it should be worth trying to use weight in the stomach rather than weight in the sea for the prey weight. The coefficient of variation found in these studies is still considerably higher than that found by Pope and Hunton (1985), which may indicate the possibility of further effects reducing the RMSE substantially.

Further regression analyses should be carried out by Working Group members for each predator species separately to test for differences in the mean and standard deviation of the size-preference functions and reported to the 1986 meeting of the Working Group.

6.5. Comparison of Suitabilities in Different Years

The current definition of suitabilities used in MSVPA assumes they are the same for all years. However, due to the high variability in stomach content data, suitabilities calculated in different years are likely to vary.

If suitabilities could be obtained from stomach content data sampled in different years, the analysis of variance for each predator-age could be carried out to test for differences. This could, of course, also be done to test for differences between quarters in any one year. A quarterly effect is not significant when all predators are taken together (see Section 6.4), but it would be of interest to test for differences for each predator-age separately and also each prey-quarter.

It could be useful to have a simple way to compare suitabilities for a particular predator-age (i,a) prey-age (j,b) in different periods t_1, t_2.

Since the suitabilities (i,a) can be regarded as vectors, the obvious measure of the alignment between two different suitability vectors would be the cosine of the angle between them. We can, therefore, define

$$\text{VARSUIT}(i,a,t_1,t_2)$$
$$= 1 - \frac{\sum\limits_{j,b} \text{SUIT}(i,a,j,b,t_1) \times \text{SUIT}(i,a,j,b,t_2)}{\left\{ \sum\limits_{j,b} [\text{SUIT}(i,a,j,b,t_1)]^2 \times \sum\limits_{j,b} [\text{SUIT}(i,a,j,b,t_2)]^2 \right\}^{1/2}}$$

This is zero if all suitabilities are the same and if the suitability vectors are perpendicular.

The expression

$$\frac{\sum\limits_{j,b} \text{SUIT}(i,a,j,b) \times \text{SUIT}(k,c,j,b)}{\left[\sum\limits_{j,b} \text{SUIT}(i,a,j,b)^2 \times \sum\limits_{j,b} \text{SUIT}(k,c,j,b)^2 \right]^{1/2}}$$

can, of course, also be used as a measure of the level of food competition between predator-age i,a and predator-age k,c.

This expression is zero if the two predators have no common prey species and equal if all their suitabilities are equal. Some further analysis along these lines would be a useful input to the 1986 Working Group meeting.

6.6. Smoothing M2's

6.6.1. Approach

The MSVPA runs provide estimates of predation mortalities which are affected by a variety of sampling errors in the initial data. Despite these sources of noise, it is widely believed that the M2's should reflect underlying general patterns (Ursin, 1963). The patterns arise from several possible sources: species-specific predation relationships, and a general size-preference function of predators. It is also possible that there is a species-specific component to the size-preference function. The quarters may also differ due to changes in sizes and distributions of both predators and prey. The parameters and magnitudes of the species-specific predator-prey interactions, the general size-preference function, the quarter effect and the predator-specific size preferences were all estimated by fitting a log-linear multiplicative model to the M2's calculated by the key run.

The predator-prey interactions were modelled by categorical variables predator (PDNAM), prey (PYNAM) and PDNAM by PYNAM interaction. The size preference hypothesised here is a log-normal function

$$\exp[-\frac{1}{2}(LWR - \mu)^2/\sigma^2]$$

In the model, this relationship is linearized by fitting $\ln(M2)$ and including the terms $LWR = [\ln(W_{pred}/W_{prey})]$ and LWR^2 to estimate the parameters of the size-preference function. Finally, the species-specific size preferences were assessed by including interactions of PDNAM with LWR and with LWR^2. Zero values for M2 were excluded (see Section 6.4).

M2 is also affected by how much of the predator there is. This factor was addressed in two ways. In most runs, the dependent variable was $\ln(M2/\text{Predator Biomass})$. This scaling makes results directly comparable with those of Shepherd's model (see Section 4). In a separate run, the $\ln(M2)$ values were fit directly, and the $\ln(\text{prey weight at sea}) = (PYWTSEA)$ was included as a term in the model.

6.6.2. Results of fit to predation mortality per unit biomass

Preliminary runs indicated that quarter and the PDNAM interactions with LWR contributed very little to the model, and were dropped from further runs. The resulting model provided a significant fit to the data (Table 6.6.1). Although the r^2 was 0.36, the RMSE (1.65) indicates confidence intervals around the predicted M2-per-unit-biomass values of the order of x or $\div$ by 5. All terms in the model accounted for significant amounts of variation.

The relative predator-prey preferences can be calculated from the model parameter estimates. The model is underdetermined, so only

relative preferences can be calculated, with whiting arbitrarily used as a standard. These values are presented in Table 6.6.2. Whiting appears to be a particularly strong predator; haddock and mackerel have weak effects. Cod suffer most as preferred prey by some species.

The coefficients of the LWR terms provide estimates for the mean preferred predator/prey ratio of exp(4.3) = 73, with SD = 1.69. These values support well the theoretical prediction that the size-preference function is log normal with a mean preferred size two orders of magnitude smaller than the predator.

6.6.3. Fit to net predation mortalities

The actual ln(M2) values from the MSVPA were also fit significantly by the multiplicative model

$$ln(M2) = PDNAM + PYNAM + PDNAM \times PYNAM + ln(PYWTSEA) + LWR + LWR^2$$

The prey weight became very important in this model, with the LWR terms accounting for substantially less pattern (Table 6.6.3). In fact, the sign at the linear LWR term became negative (Table 6.6.3). The RMSE (2.07) is substantially larger, implying a confidence interval of x or by 8. The relative predator-prey preference matrix changes substantially when M2, rather than M2 per unit biomass is fit (Table 6.6.3). Cod and saithe become the largest species effects, and whiting is much less important. Haddock and mackerel still have consistently small values. Cod still suffer heavy predation, primarily from saithe and cod. Both species also feed heavily on haddock.

The extra covariate term makes interpretation of the LWR coefficients less straightforward. With appropriate juggling, estimates of the mean and SD of the general size-preference function are 4.1 and 2.06, respectively, so the latter is substantially larger than values from the M2-per-unit-biomass run. The values are also of less use, because the ln(prey weight) term must be specified for any case.

6.6.4. Conclusions of M2 fitting

Due to the larger RMSE, more complicated interpretation and utility of model parameter estimates, and less direct comparability to other models, the model fit directly to ln M2 values is weaker than the model fit to the M2's per unit biomass. The latter model also makes more biological sense. In general, the fitting exercise was quite successful and should be actively pursued by interested members before the next meeting of the Working Group. The pattern of residuals from the predicted curve (Figure 6.6.1) and residual MSE both imply there is information not yet extracted from the M2's. A predator or prey interaction with quarter might be a cause of some of the scatter. Other relationships are possible, and further work along these lines is encouraged. Although possibly incomplete, the current model of M2 per unit biomass is still good enough to warrant further exploration itself.

6.7. **Possible Variants of the MSVPA**

6.7.1. **Number-based VPA**

In a working document by Daan (1985 WD) the suggestion was made
to omit the average weights of individual prey items in the sea
and in the stomachs completely by calculating the food intake of
the predators in numbers rather than in weight. In this case,
predation mortality equals

$$M2(y,a) = \frac{1}{\bar{N}(y,a)} \sum_b \bar{N}(y,b) \; R^N(b) \; \frac{s^N(b,a) \; \bar{N}(y,a)}{\sum_i s^N(b,i) \; \bar{N}(y,i)}$$

where $R^N(b)$ is the ration in numbers which can be estimated from

$$R^N(b) = \frac{R^B(b)}{wst(b)}$$

where wst(b) is the average individual weight of prey items in
the stomachs of predator age group b and $R^B(b)$ is the ration in
biomass terms.

The estimated ration in numbers depends, thus, on the assumption
that the average weight of individual prey items in the stomachs
of a certain predator age group is the same irrespective of prey
species and prey age.

This assumption remains to be tested on the North Sea data base,
but the Working Group agreed that it would be interesting to make
a trial run of the MSVPA using numbers instead of weights. Unfor-
tunately, time did not allow for making the necessary changes in
the program, and it is hoped that some Working Group members will
experiment with this approach before the next meeting.

6.7.2. **Improvements in description of food selection**

It has not yet been possible to validate the description of food
selection used in the model (see Section 6.1). At present, suit-
ability is considered to be constant from year to year. It can be
partly described as a function of the log of the ratio of pred-
ator weight to prey weight (see Section 6.4) and of prey and
predator species, and such smoothing could be made within the
program. It is fairly obvious, however, that suitability also
must depend on the geographical overlap between a predator and
its prey.

If the sea area can be divided into a number of homogeneous sub-
areas, it would be sensible to apply the current model of food
selection within each subarea

$$CON(j,b,A) = \frac{H(b,j)\ DIST(b,A)\ \overline{N}(b)\ \overline{WS}(j,b)}{\sum_{i} H(i,j)\ DIST(i,A)\ \overline{N}(i)\ \overline{WS}(j,i)}$$

where CON(j,b,A) is the relative amount of prey b in the stomach
of predator j in area A, and DIST(b,A) is the proportion of the
stock of species age group b which occurs within the same area
and H(b,j) a distribution-corrected suitability.

Weighting with the proportion of the predator which occurs within
the area and summing up over areas, we obtain

$$CON(j,b) = \sum_{A} DIST(j,A)\ CON(j,b,A)$$

Given DIST(i,A) and CON(j,i) for all i, this equation can be used
to estimate a set of H(j,i)'s which are independent of the over-
lap between prey and predator, and which, given the relative di-
stribution of prey and predators, can be used to model the in-
fluence of changes in distribution on food selection. This could
prove very important, for example, for herring, which since 1981,
the stomach sampling year, has recovered in the northern North
Sea. This change in the relative distribution of the North Sea
herring must have had an effect on suitability, and this effect
may be taken into account using the above equations.

If average stomach contents were available on an areal basis in
addition to the relative distribution, it would, furthermore, be
possible to estimate suitability within each area. Comparing
these suitabilities, which should be constant from area to area
(provided the areas can be considered to be homogeneous), would
help in deciding whether the present model of food selection is
adequate or not.

It is thus recommended that, where possible, the working groups
provide charts of the relative quarterly distribution of the
various North Sea stocks considered in the MSVPA for 1981 and
1985 (see Mackerel Working Group report for 1985). It would, fur-
thermore, be of help if an analysis of the available trawl survey
results could be made with the purpose of demonstrating if
changes in distribution with time are related to abundance
changes.

6.7.3. Scaling of suitabilities

The way suitability coefficients are defined only determines them
up to a multiplicative constant for each predator age. In the
present version of the MSVPA program, this constant is determined
by requiring all prey ages for each predator age to sum to 1,
i.e.,

$$\sum_{j,b} SUIT\ (i,a,j,b) = 1,\ \text{for all } i,a$$

This particular kind of scaling produces some difficulties in
interpreting suitability constants, and comparison of suit-
abilities between different predator ages is not possible. If, on
the other hand, suitabilities were scaled differently by putting
the highest one at unity, i.e.,

```
        max SUIT(i,a,j,b)  =   1, for all i,a
        j,b
```

then all suitability coefficients are relative to the one for the most preferred prey.

6.7.4. Other possibilities

For considering predation mortality for species such as herring, where larval fish are eaten, it may be worthwhile considering a MSVPA program where predation mortality is purely a function of predator number and is unaffected by prey abundance. This should help circumvent the possibility of non-uniqueness of the MSVPA solution (Anon., 1984a; Magnus and Magnusson, 1983) on young ages. In some areas, it may be desirable to include species for which catch-at-age data are not available but for which other measures of biomass can be used (see Section 6.8).

The possibility of a more parsimonious version of the multi-species model should also be pursued.

6.8. Development in Other Areas

6.8.1. Icelandic waters

Systematic sampling of fish stomachs has been carried out in Icelandic waters since 1976. Cod has been the main target species, but in 1979-81, samples for haddock, redfish, catfish and long rough dabs were collected (see Pálsson, 1983).

Cod is the main predator of fish prey such as capelin, redfish, blue whiting and small cod, as well as shrimps. The other predators are occasional fish consumers, but are mainly preying on planktonic animals (redfish) or benthic animals (haddock, catfish, long rough dab).

Considerable variation has been observed in the stomach contents of cod on a seasonal and year-to-year basis.

Average stomach content
The change in the average stomach content (AVSTOM) of cod, length l in a particular season during 1976-83 can be described by the following model:

$$\text{AVSTOM }(t,l) \;=\; e^{A(t)}\, l^{B(t)}$$

where $\quad A(t) = a_0 + a_1 t + a_2 t^2 \text{ and } B(t) = b_0 + b_1 t.$

The coefficients a_i and b_i were estimated using two time series, first the average stomach content by length in March 1977-83 and secondly, corresponding data for October-December 1976-82. For both series, there were significant differences between years, particularly so for the March series.

For the March series, fitting the model to the data gave an RMSE value of 0.181 and $R^2 = 0.93$. The coefficients a_2 and b_1 were both significantly different from zero. The lowest value in average stomach content occurred in 1979-81, depending on length groups.

The October-December survey gave an RMSE value of 0.115 and $R^2 = 0.94$. The coefficient a_2 was significantly different from zero, whereas b_1 was not.

The minimum of the function occurred in 1979.

Estimates of the food consumption of cod
Using the results from digestion experiments made by Jones (1974), the average daily consumption of an individual cod was calculated according to the formula:

$$R = 3.80 \times 10^{-2} \times L(a)^{1.15} \times 1.39^{(T-6)} \times [STOM(a)]^{0.47}$$

where $L(a)$ is the average length of cod at age, T is temperature and $STOM(a)$ is the weight of the average total stomach content of cod at age a. The results indicate a daily ration of 0.5 - 1% of body weight.

On the basis of this formula and using relative stomach contents, the monthly consumption of some important prey species has been calculated, as well as the total amount consumed in a month.

The results, based on data from March 1979 through October 1982, are summarised as follows:

The monthly total consumption was in the range $117-255 \times 10^{-3}$ tonnes (average 189×10^{-3} tonnes). Prior to 1981, the total consumption was generally higher than 200×10^{-3} tonnes, whereas in 1981-82, it was $117-187 \times 10^{-3}$ tonnes.

The estimated consumption of major prey species was (in thousands of tonnes):

```
Capelin       12-176 (average 69), mainly in March
Shrimp         2- 52 (average 17)
Redfish        0- 72 (average 12), mainly in early winter
Blue whiting   0- 48 (average  8), mainly during summer
Cod            0- 31 (average  6).
```

These prey species account for about 60% of the total food. Other food mainly consists of various (non-commercial) fish species as well as planktonic animals.

Estimating changes in temperature and feeding conditions
Using standard growth models, attempts have been made to get some indications of changes in temperature and in feeding conditions from changes in length in a year, and the average length for different cohorts in any one year. Results correspond fairly well with observed changes in temperature. However, the poorest feeding conditions were estimated for 1980-81, somewhat earlier than the sharp decline in the capelin stock observed in 1981-82.

Predicting growth rates of cod
A simulation model is now being developed which gives future growth rates of cod on the basis of the capelin stock.

Various assumptions about growth equations and feeding relationships are being tested.

Possible application of the MSVPA model
Some thought has been given to the possibility of using the MSVPA model. However, for a number of reasons, it was not considered suitable. Environmental considerations in Icelandic waters are highly variable resulting in varying yearly growth rates and stomach contents. Thus, weights at age are different from year to year, as are rations. The most important predator-prey interaction is cod-capelin. Capelin, being a short-lived species, does not lend itself to treatment by VPA methods. Furthermore, capelin seems to be the preferred prey of cod and is not necessarily taken in proportion to its relative abundance. Thus, a different feeding relationship from the MSVPA one is required. It is, therefore, considered that a different model is required that takes into account the particularities which occur in Icelandic waters.

Many fewer species need to be considered, possibly only cod as predator and capelin and a few other species as prey, and use should be made of acoustic abundance measurements of the capelin stock.

In general, species interaction in Icelandic waters seems to be comparable to that in Newfoundland waters and in the Barents Sea.

6.8.2. **Extension of the MSVPA model to other areas**

Although specifically designed for analysing the North Sea fishery ecosystem, the current implementation of MSVPA is potentially applicable for simultaneously assessing predation and fishing mortalities in a variety of alternative situations. The Working Group discussed some potential applications of MSVPA to problems encountered by various area-based working groups in ICES (e.g., Baltic Multispecies, Irish Sea and Bristol Channel), and in Icelandic and North American waters. Apart from the lack of intensive collections of age-dependant feeding data, the major conceptual problem for more general application of MSVPA is that, in some situations, important prey or predators are not fished (e.g., sandeels in the Northwest Atlantic, large marine mammals, etc.).

In theory, the MSVPA could be adapted to include biomass estimates of predators and/or prey for which no explicit catch-at-age data are available. Dab populations in the North Sea are a significant component of other food for cod, but cannot be included in the current North Sea MSVPA. Ancillary data on biomass trends of dabs (i.e., from research vessel surveys) are available and, thus, with appropriate modification to the MSVPA algorithm, this prey could be included in the analysis. Similar fishing survey, acoustic survey and egg survey estimates of biomass exist in

other areas and might be utilised in MSVPA-like models together
with the catch-at-age data for species for which they are avail-
able.

7. CONCLUSIONS AND RECOMMENDATIONS

Section 1

1.1   ACFM should consider carefully how multispecies assessments
      advice could most suitably be fitted into the work of ICES.

1.2   The ad hoc Working Group should consider publishing its
      more significant results in a Cooperative Research Report
      following the 1986 meeting.

Section 2

2.1   Data preparation for this Working Group, particularly the
      provision of quarterly catch at age, should be undertaken
      by designated experts before the meeting. The cooperation
      of all members ensuring the timely presentation of data is
      urged.

2.2   A data base of quarterly catch-at-age and weight-at-age
      data should be set up at ICES.

2.3   Some of the discrepancies between the estimates of total
      stock biomass and spawning biomass, as calculated by VPA
      and MSVPA, may be due to the use of quarterly catch weight-
      at-age data in the MSVPA. The ad hoc Working Group, there-
      fore, requests that the various assessment working groups,
      in addition to the quarterly catch weight-at-age data,
      supply quarterly stock weight-at-age data for use in the
      MSVPA.

Section 3

3.1   The impact of varying natural mortality at age on short-
      term forecasts should be further investigated and reported
      as a research document to the 1986 meeting of the ad hoc
      Working Group.

Section 4

4.1   Mixed fishery effects are very important since they intro-
      duce trade-offs and conflicts of interest between different
      fisheries.

4.2   A knowledge of the appropriate relative unit values
      (weighting) of various species in various fisheries is very
      important since it is very difficult to assess the balance
      of advantage and disadvantage of changing different fish-
      eries unless these are explicitly stated.

4.3   Including predation in the calculations modifies the esti-
        mated effects of changing fishing mortalities quite con-
        siderably. The effects are, however, only large enough to
        substantially change the balance of advantage and disadvan-
        tage in one case considered, the roundfish (human consump-
        tion) fishery.

4.4   The methodology for the calculation of the long-term yield
        needs to be further developed and the advantages and disad-
        vantages of each method reported to the 1986 Working Group
        meeting.

Section 5

5.1   Countries are urged to continue their sampling effort on
        cod and whiting stomachs during the first and third quar-
        ters of 1986 and 1987.

5.2   Countries are urged to make available all recent infor-
        mation on digestion experiments with the various predator
        species before next year's meeting in order to allow a
        critical review of the estimated rations.

5.3   The possibility of a feeding study on herring should be in-
        vestigated, with a pilot study being carried out on an op-
        portunistic basis in 1986. Members aware of scheduled
        cruises which might be capable of collecting some herring
        stomachs, particularly during the second quarter of 1986,
        are asked to inform J Pope, Fisheries Lab., Lowestoft.

Section 6

6.1   The various interesting studies in this section should be
        further pursued by interested members of the Working Group
        and results presented in research documents to the 1986
        meeting.

6.2   The assessment working groups should study the anomalous M2
        values to see if they make biological sense or are poten-
        tially erroneous.

6.3   Further research on the form of alternative methods for ac-
        counting for mean weight discrepancies and the consequent
        sensitivity of MSVPA results is necessary to assess the
        preferred technique.

6.4   As it can be anticipated that changes in the geographical
        distribution of prey and predator stocks within the North
        Sea will result in changes in the estimates of suitability,
        the ad hoc Working Group requests that the various working
        groups supply information on the relative distribution of
        the stocks at different ages by quarters.

8. REFERENCES

Andersen, K. P. and Ursin, E. 1977. A multispecies extension to the Beverton and Holt theory of fishing, with accounts of phosphorus circulation and primary production. Medd. Danm. Fisk.-Havunders. NS.7.

Anon., 1984a. Report of the ad hoc Multispecies Assessment Working Group. ICES, Doc. C.M.1984/Assess:20.

Anon., 1984b. Report of the Meeting of the Coordinators of the Stomach Sampling Project 1981. ICES, Doc.C.M.1984/G:37.

Anon., 1984c. Report of the Working Group on Methods of Fish Stock Assessments. ICES, Doc. C.M.1984/Assess:19.

Daan, N. 1973. A quantitative analysis of the food intake of the North Sea cod (Gadus morhua). Neth. J. Sea Res.6:279-517.

Daan, N. 1985. Working paper on predation mortalities estimated by MSVPA. ICES, Working Doc., ad hoc Multispecies Assessment Working Group, Nov. 1985.

Daan, N., Rijnsdorp, A. D. and van Overbeeke, G. R. 1984. Predation of plaice and cod eggs by North Sea herring. ICES, Doc. C.M.1984/L:13.

Dekker, W. 1983. An application of the Andersen consumption model in estimating prey size preference of North Sea cod. ICES, Doc. C.M.1983/G:63.

Gislason, H. 1985. A note on the influence of the geographical distribution of prey and predators on the estimation of accessibility. ICES, Working Doc., ad hoc Multispecies Assessment Working Group, Nov. 1985.

Gislason, H. and Helgason, T. 1985. Species interaction in assessment of fish stocks with special application in the North Sea. Dana 5:1-44.

Gislason, H. and Sparre, P. 1985a. A review of the changes introduced in the MSVPA computer programme and data file. ICES, Working Doc., ad hoc Multispecies Assessment Working Group, Nov. 1985.

Gislason, H. and Sparre, P. 1985b. A version of MSVPA (Multispecies Virtual Population Analysis) in which differences in prey weight at age in the population and in the predator stomachs has been accounted for. ICES, Working Doc., ad hoc Multispecies Assessment Working Group, Nov. 1985.

Hahm, W. and Langton, R. 1984. Prey selection based on predator/prey weight ratios for some northwest Atlantic fish. Mar. Ecol. Prog. Ser. 19:1-5.

Helgason, T. and Gislason, H. 1979. VPA analysis with species interaction due to predation. ICES, Doc. C.M.1979/G:52.

Jones, R. 1961. The assessment of the long-term effects of changes in gear selectivity and fishing effort. Dept. Agri. Fish. Scot., Mar. Res. 2, 19 pp.

Jones. R. 1974. The rate of elimination of food from the stomachs of haddock (_Melanogrammus aeglefinus_), cod (_Gadus morhua_ and whiting (_Merlangius merlangus_). J. Cons. Int. Explor. Mer, 35:225-243.

Magnus, R.J. and Magnusson, K. G. 1983. Existence and uniqueness of solutions to the multispecies VPA equations. ICES, Doc. C.M. 1983/D:20.

Murawski, S. A. 1985. Some further fiddling with the 1981 stomach data: What do the means mean? ICES, Working Doc., _ad hoc_ Multispecies Assessment Working Group, Nov. 1985.

Pálsson, Ø. K. 1983. The feeding habits of demersal fish species in Icelandic waters. Rit Fiskideildar 7(1):1-60.

Pope, J. G. 1979. A modified cohort analysis in which constant natural mortality is replaced by estimates of predation levels. ICES, Doc. C.M. 1979/H:16.

Pope, J. G. 1985. Going straight for the Jacobian (Jonessan?). ICES, Working Doc., _ad hoc_ Multispecies Assessment Working Group, Nov. 1985.

Pope, J. G. and Hunton, J. K. 1985. Further analyses of the 1981 stomach sampling data. ICES, Doc. C.M.1985/G:51.

Shepherd, J. G. 1984. A promising method for the assessment of multispecies fisheries. ICES, Doc. C.M.1984/G:4.

Shepherd, J. G. 1985. Assessing the effects of modest changes in mixed fisheries, using a multispecies steady-state model. ICES, Working Doc., _ad hoc_ Multispecies Assessment Working Group, Nov. 1985.

Sparre, P. 1980. A goal function of fisheries (legion analysis). ICES, Doc. C.M.1980/G:40.

Sparre, P. 1984. A computer program for estimation of food suitability coefficients from stomach content data and multispecies VPA. ICES, Doc. C.M.1984/G:25.

Sparre, P. and Gislason, H. 1985. Multispecies VPA (updated version 22.10.85) FORTRAN 77 program for VAX/11/750. ICES, Working Doc., _ad hoc_ Multispecies Assessment Working Group, Nov. 1985.

Ursin, E. 1963. On the seasonal variation of growth rate and growth parameters in Norway pout (_Gadus esmarki_) in the Skagerrak. Medd. Danm. Fisk.-Havunders (N.S.), 4:17-29.

Ursin, E. 1982. Multispecies fish stock and yield assessment in ICES. pp 39-47 <u>In</u> M. C. Mercer (ed.). Multispecies approaches to fisheries management advice. Can. Spec. Publ. Aquat. Sci. 59.

Villemarque de la, J. 1985. Rapport préliminaire sur l'analyse des estomacs d'eglefins récoltés en 1981 dans le cadre du programme d'échantillonnage d'estomacs de poissons en Mer du Nord. ICES, Doc. C.M.1985/G:39.

Uncited Working Documents

Daan, N. 1985. Working paper on using additional stomach content data in MSVPA. ICES, Working Doc., <u>ad</u> <u>hoc</u> Multispecies Assessment Working Group, Nov. 1985.

Murawski, S. A. 1985. Proposed multispecies programme for Georges Bank. ICES, Working Doc., <u>ad</u> <u>hoc</u> Multispecies Assessment Working Group, Nov. 1985.

Pope, J. G. 1985. A note on the relationship of long-term yield effects to some assumptions about natural mortality. ICES, Working Doc., <u>ad</u> <u>hoc</u> Multispecies Assessment Working Group, Nov. 1985.

Table 2.2.1 Cod quarterly age composition data, 1975-84

Nation	Fishery	Age compositions	Landed weight	Mean weights at age	
UK, Scotland	HC	1975-84	1975-84	Quarterly	1975-84
UK, Scotland	DIS	1975-84	1975-84*	Quarterly	1975-84
UK, England	HC	1975-84	1975-84	Quarterly	1975-84
Denmark	HC	1975-84	1975-84	Annual 1975-78 Quarterly 1979-84	
Belgium	HC	1975-82	1975-82	Quarterly	1975-82
Norway	IBC	1974-84	1974-84*	Annual	1974-84
Fed.Rep.of Germany	HC	1980-84	1975-84	Quarterly	1980-84
Netherlands	HC	1975-84	1975-84	Quarterly	1975-84
Poland	HC	No data	1975-81**	No data	
German Dem.Rep.	HC	No data	1975-80**	No data	
USSR	HC	No data	1975-79**	No data	

HC = human consumption

DIS = discards

IBC = industrial by-catch

  * = denotes data not used in compiling data base

 ** = denotes quarterly landings reported in Bulletin Statistique

Note: No data from Faroe Islands, Ireland, Spain and Sweden;
      French data available, but not yet included in data set

Table 2.2.2 Haddock quarterly age composition data, 1975-84

Nation	Fishery	Age compositions	Landed weight	Mean weights at age	
UK, Scotland	HC	1975-84	1975-84	Quarterly	1975-84
UK, Scotland	DIS	1975-84	1975-84	Quarterly	1975-84
UK, England	HC	1975-84	1975-84	Quarterly	1975-84
Denmark	IBC	1975-84	1975-84	Annual Quarterly	1975-78 1979-84
Belgium	HC	No data	1975-82*	No data	
Norway	IBC	1974-84	1974-84	Annual	1974-84
Norway	HC	No data	1975-84	No data	
Fed.Rep.of Germany	HC	No data	1975-84	No data	
Netherlands	HC	1975-84	1975-84	Quarterly	1975-84
Poland	HC	No data	1975-82*	No data	
German Dem.Rep.	HC	No data	1975-82*	No data	
USSR	HC	No data	1975-79*	No data	

HC = human consumption

DIS = discards

IBC = industrial by-catch

 * = denotes quarterly landings reported in Bulletin Statistique

Note: No data from Faroe Islands, Ireland, Spain and Sweden;
      French data available, but not yet included in data set

Table 2.2.3 Whiting quarterly age composition data, 1975-84

Nation	Fishery	Age compositions	Landed weight	Mean weights at age	
UK, Scotland	HC	1975-84	1975-84	Quarterly	1975-84
UK, Scotland	DIS	1975-84	1975-84	Quarterly	1975-84
UK, England	HC	1975-84	1975-84	Quarterly	1975-84
Denmark	HC	1975-84	1975-84	Annual Quarterly	1975-78 1979-84
Denmark	IBC	1975-84	1975-84	Quarterly	1975-84
Belgium	HC	1975-84	1975-84	Quarterly	1975-84
Norway	IBC	1974-84	1974-84	Annual	1974-84
Norway	HC	No data	1978-84	No data	
Fed.Rep.of Germany	HC	No data	1975-84	No data	
Netherlands	HC	1975-84	1975-84	Quarterly	1975-84
Netherlands	DIS	1975-84	1975-84	Quarterly	1975-84
Poland	HC	No data	1975-79*	No data	
German Dem.Rep.	HC	No data	1975-79*	No data	
USSR	HC	No data	1975-79*	No data	

HC = human consumption

DIS = discards

IBC = industrial by-catch

 * = denotes quarterly landings reported in Bulletin Statistique

Note: No data from Faroe Islands, Ireland, Spain and Sweden;
      French data available, but not yet included in data set

Table 2.2.4 Saithe quarterly age composition data, 1975-84

Nation	Fishery	Age compositions	Landed weight	Mean weights at age	
UK, Scotland	HC	1975-84	1975-84	Quarterly	1975-84
UK, England	HC	1975-84	1975-84	Quarterly	1975-84
France	HC	1975-84	1975-84	Annual 1975-83 Quarterly 1984	
Denmark	HC	1981-84	1979-84	Quarterly	1981-84
Denmark	IBC	No data	1976-79	No data	
⁻elgium	HC	1975-84	1975-84	Quarterly	1975-84
.orway	IBC	1975-77, 1979-84	1975-77, 1979-84	Annual	1974-84
Norway	HC	1979-84	1979-84	Annual	1979-84
Fed.Rep.of Germany	HC	1975-84	1975-84	Quarterly	1975-84
Netherlands	HC	No data	1975-82*	No data	
Poland	HC	No data	1975-82*	No data	
German Dem.Rep.	HC	No data	1975-82*	No data	
USSR	HC	No data	1975-79*	No data	

HC = human consumption

IBC = industrial by-catch

 * = denotes quarterly landings reported in Bulletin Statistique

Note: No data from Faroe Islands, Ireland, Spain and Sweden

46

Table 2.2.5 Herring quarterly age composition data, 1974-84

Nation	Fishery	Age compositions	Landed weight	Mean weights at age
Denmark	IBC	1974-77, 1979-84	1974-84	1974-77, 1979-83
Denmark	HC	1975-76, 1983-84	1975-77,1979-81,1983-84	1984
Fed.Rep.of Germany	HC	1976,1978-80,1982-84	1974-84	1976,1978-80,1984
Norway	HC	1974-76, 1983-84	1974-76, 1983-84	1974-76,1983-84
Netherlands	HC	1974-77, 1983-84	1974-77, 1983-84	1974-77,1983-84
UK, Scotland	HC	1974-76, 1983-84	1974-76, 1983-84	1983-84

HC = human consumption

IBC = industrial by-catch

Note: No data from Belgium, German Democratic Republic, Poland, USSR, England, Sweden, Faroe Islands, Iceland, and Finland.

Table 2.2.6 Annual saithe age compositions for 1975 and 1982 from a summation of quarterly age compositions compared with Saithe Working Group data

Age	1 9 7 5		1 9 8 2	
	Quarterly	Saithe WG	Quarterly	Saithe WG
1	68	311	1,482	1,462
2	49,413	72,546	23,245	22,474
3	56,697	51,287	24,023	23,636
4	46,443	23,585	34,011	33,759
5	19,584	9,028	10,370	10,645
6	9,481	6,717	6,417	6,466
7	8,719	12,660	1,855	1,816
8	5,187	8,656	1,373	1,346
9	1,598	3,299	1,001	978
10	544	1,100	301	294
11	284	616	110	108
12	263	254	126	129
13	149	275	99	98
14	38	77	143	146
15+	47	25	154	146

Table 2.8.1a

FISHING MORTALITY   COD

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0908	0.1543	0.0627	0.2406	0.1272	0.2081	0.1669	0.1855	0.2643	0.2433	0.1982
2	0.8699	0.7975	1.0247	0.9021	1.1191	0.9001	0.9346	1.1066	1.0365	1.1895	1.2713
3	0.7532	0.8192	0.8781	0.7405	0.9826	0.9564	0.9544	1.0458	1.2842	1.1896	1.2343
4	0.7097	0.6679	0.7993	0.5824	0.8080	0.5450	0.7364	0.7491	0.7616	0.8703	0.8064
5	0.7056	0.7925	0.6185	0.5692	0.9600	0.7285	0.5692	0.7020	0.7494	0.7953	0.7992
6	0.7273	0.6682	0.9172	0.4619	0.7450	0.5418	0.6073	0.6554	0.8373	0.7650	0.7891
7	0.6398	0.8029	0.8331	0.5607	0.7562	0.6525	0.7394	0.7265	0.6825	0.6090	0.7494
8	0.7108	0.5179	0.5693	0.5658	0.8899	0.5364	0.7185	0.6402	0.6876	0.6772	0.7177
9	1.0236	0.9124	0.4284	0.6796	0.8504	0.8123	0.7217	0.6828	0.6807	0.5423	0.7597
10	0.6303	0.7220	0.8662	0.3527	1.4182	0.5149	0.8065	0.8945	0.5073	0.3531	0.8025
11	0.7500	0.7477	0.7477	0.7495	0.7488	0.7988	0.7980	0.7985	0.7995	0.7995	0.7984

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

	0.7125	0.7976	0.9050	0.7012	0.9974	0.8994	0.9162	0.9501	1.2421	1.0207	1.1485

STOCK NUMBERS   COD

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	4034600.	2884854.	10469863.	7214864.	6299176.	8222105.	5049739.	7662776.	3768735.	5617786.	2130720.
1	287327.	377399.	179630.	705441.	409709.	409828.	861800.	329702.	532553.	239164.	563094.
2	123593.	108958.	175798.	88951.	289256.	172826.	164392.	348564.	108002.	199358.	89757.
3	22737.	33849.	34728.	45548.	25760.	66380.	50296.	45896.	79001.	26195.	41511.
4	32009.	8376.	11898.	11542.	17361.	7695.	20406.	15433.	12799.	17398.	6336.
5	9493.	12889.	3516.	4380.	5278.	6336.	3653.	8000.	5974.	4893.	5966.
6	1948.	3838.	4777.	1551.	2030.	1655.	2504.	1693.	3246.	2312.	1808.
7	965.	771.	1611.	1563.	800.	789.	788.	1117.	720.	1150.	881.
8	802.	417.	283.	573.	730.	308.	336.	308.	442.	298.	512.
9	543.	323.	203.	131.	267.	246.	147.	134.	133.	182.	124.
10	175.	160.	106.	108.	54.	93.	89.	59.	56.	55.	87.
11	370.	104.	69.	49.	91.	42.	49.	40.	44.	37.	44.

TOTAL STOCK BIOMASS ON 1. JANUARY

	467774.	429952.	467809.	526325.	569278.	533295.	639397.	638079.	535503.	442541.	412047.

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

	249770.	207255.	179131.	176720.	169324.	200234.	208709.	204604.	248129.	167089.	155392.

PREDATION MORTALITY   COD

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	2.1696	2.5767	2.4978	2.6688	2.5328	2.0560	2.5293	2.4665	2.5573	2.1002	2.9871
1	0.6790	0.4099	0.4402	0.4511	0.5361	0.5055	0.5383	0.7305	0.5183	0.5368	0.3187
2	0.2255	0.1461	0.1259	0.1372	0.1527	0.1343	0.1414	0.1778	0.1801	0.1796	0.1140
3	0.0454	0.0263	0.0235	0.0240	0.0256	0.0233	0.0271	0.0312	0.0289	0.0297	0.0172
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2.8.1b

FISHING MORTALITY   **WHITING**

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.0674	0.0735	0.0852	0.1009	0.0559	0.0480	0.0578	0.0975	0.0360	0.1620	0.0846
1	0.4914	0.2740	0.2523	0.5304	0.2019	0.3265	0.1427	0.2134	0.2649	0.3059	0.2431
2	0.9395	0.8166	1.0383	0.5749	0.4431	0.5475	0.4646	0.3510	0.3231	0.4885	0.4455
3	1.0937	1.0911	1.2799	0.9372	0.7280	0.8266	0.8119	0.7577	0.5268	0.6819	0.7231
4	0.9723	1.0743	1.1397	1.0255	0.8827	0.7395	1.0020	0.9808	0.7303	0.7472	0.8420
5	1.0665	1.0592	0.8218	0.8652	0.7488	0.9518	1.1462	1.0656	0.8805	0.8945	1.0520
6	1.9508	0.9821	1.2885	1.0417	1.1862	1.0093	1.4386	1.2980	1.1248	0.9888	1.1838
7	1.2411	0.9915	0.7673	0.8723	1.5754	0.8590	1.1051	1.3655	0.8228	1.1766	1.1132
8	0.8526	1.5573	0.5389	2.6312	2.1216	0.9443	1.7732	1.6414	1.3021	1.1953	0.9983
9	2.5301	1.2940	1.5466	0.2869	1.5996	1.0223	0.6602	0.5547	1.2497	1.5805	0.9735
10	1.0000	0.9998	0.9986	0.9995	0.9979	0.9980	0.9975	0.9984	0.9971	0.9976	0.9989

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

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	0.9007	0.8658	1.1278	0.6824	0.5500	0.6822	0.5840	0.5229	0.4883	0.6005	0.5919

STOCK NUMBERS   **WHITING**

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	24727462.	32361152.	28965438.	38112340.	38025404.	28630532.	33764504.	16141635.	11716277.	10270417.	8668265.
1	2854668.	5439918.	3555745.	3676134.	3975068.	4323337.	3959340.	2113685.	1812266.	1552230.	2409081.
2	3082466.	892008.	2202341.	1355162.	1051546.	1422605.	1340063.	1531350.	544311.	568753.	500010.
3	425838.	518331.	271880.	529306.	518795.	451925.	555375.	568401.	688507.	255232.	229240.
4	60568.	97240.	126247.	54794.	149596.	180427.	143362.	177751.	188276.	284755.	91297.
5	8448.	16921.	25549.	31220.	14944.	47066.	65252.	39843.	49711.	67460.	101751.
6	1593.	2266.	4646.	8835.	10323.	5558.	14246.	16284.	10693.	15951.	21570.
7	8954.	179.	675.	1016.	2474.	2511.	1609.	2687.	3521.	2734.	4709.
8	671.	2119.	54.	257.	348.	419.	871.	436.	561.	1266.	690.
9	62.	234.	366.	26.	15.	34.	133.	121.	69.	125.	314.
10	33.	7.	60.	333.	16.	14.	38.	88.	59.	71.	40.

TOTAL STOCK BIOMASS ON 1. JANUARY

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	854268.	952977.	945496.	964519.	958856.	944495.	984705.	724582.	550755.	460957.	442525.

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

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	427149.	286651.	431829.	351799.	328173.	385819.	397621.	430004.	319419.	260463.	204070.

PREDATION MORTALITY   **WHITING**

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	1.2468	1.9354	1.7795	1.9601	1.9188	1.7308	2.5137	1.8893	1.7853	1.0880	1.7313
1	0.4721	0.4305	0.5126	0.5214	0.6257	0.6450	0.6073	0.9433	0.6940	0.6369	0.4178
2	0.2515	0.1717	0.1875	0.1854	0.2015	0.1931	0.1931	0.2483	0.2342	0.2202	0.1392
3	0.1833	0.1214	0.1220	0.1265	0.1282	0.1216	0.1274	0.1472	0.1561	0.1461	0.0922
4	0.1030	0.0623	0.0676	0.0739	0.0737	0.0776	0.0784	0.0934	0.0960	0.0819	0.0513
5	0.0495	0.0334	0.0401	0.0416	0.0402	0.0433	0.0419	0.0497	0.0562	0.0458	0.0302
6	0.0367	0.0291	0.0320	0.0314	0.0273	0.0302	0.0295	0.0333	0.0389	0.0313	0.0224
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2.8.1c

FISHING MORTALITY   SAITHE

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0085	0.0004	0.0027	0.0843	0.0040	0.0038	0.0079	0.0172	0.0042	0.0003	0.0000
2	0.0621	0.1544	0.1936	0.1265	0.1476	0.2511	0.1107	0.1240	0.1008	0.1140	0.1004
3	0.4387	0.3656	0.7489	0.1606	0.2689	0.2073	0.2804	0.1211	0.2461	0.1392	0.1964
4	0.4911	0.7259	0.7731	0.5641	0.5379	0.4230	0.2956	0.3146	0.3279	0.2888	0.3082
5	0.3463	0.6536	0.8124	1.0633	0.5816	0.4936	0.6138	0.3286	0.6945	0.4188	0.5488
6	0.5521	0.4911	0.6174	0.9597	0.4542	0.3970	0.6178	0.6460	0.5412	0.7297	0.5986
7	0.6193	0.4659	0.5060	0.6043	0.3143	0.4913	0.5769	0.6314	0.6163	0.8992	0.6009
8	0.4043	0.4562	0.4810	0.6067	0.2968	0.4506	0.4314	0.9821	0.5998	1.2020	0.6688
9	0.3818	0.2101	0.3180	0.5439	0.2548	0.2478	0.5633	0.5573	0.9545	1.0284	0.6917
10	0.3300	0.2331	0.2803	0.4598	0.2291	0.1711	0.3923	0.6435	0.5085	0.8676	0.5209
11	0.3515	0.1788	0.3653	0.3149	0.2404	0.2109	0.3282	0.6731	0.5362	0.7232	0.5556
12	0.3652	0.3803	0.4229	0.5366	0.1649	0.2321	0.2044	0.6325	0.4947	0.8356	0.5194
13	0.5385	0.4232	0.4842	0.4754	0.4389	0.0902	0.2426	0.4207	0.3694	0.7638	0.4088
14	0.2100	0.2762	0.7394	0.8906	0.3397	0.1984	0.1235	0.5128	0.3727	0.2449	0.3991
15	0.4000	0.3973	0.3993	1.7991	1.8061	0.3995	0.3999	0.3978	0.3997	0.3941	0.3995

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

| | 0.4703 | 0.5106 | 0.5778 | 0.7739 | 0.5071 | 0.4282 | 0.6214 | 0.5139 | 0.6922 | 0.5062 | 0.5557 |

STOCK NUMBERS   SAITHE

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	222970.	139226.	156680.	142164.	382222.	256638.	419459.	488603.	719408.	290979.	119113.
1	474724.	182553.	113989.	128279.	116394.	312937.	210118.	343424.	400035.	589001.	238233.
2	268930.	385371.	149396.	93074.	96535.	94915.	255227.	170669.	276377.	326152.	482086.
3	187577.	206920.	270375.	100787.	67146.	68193.	60456.	187069.	123439.	204584.	238254.
4	89965.	99041.	117532.	104685.	70274.	42012.	45378.	37395.	135696.	79019.	145732.
5	46620.	45077.	39238.	44415.	48756.	33598.	22532.	27645.	22352.	80042.	48466.
6	53276.	26996.	19197.	14257.	12557.	22314.	16792.	9986.	16295.	9138.	43109.
7	34480.	25112.	13526.	8477.	4471.	6528.	12283.	7412.	4285.	7765.	3606.
8	16597.	15198.	12903.	6677.	3793.	2673.	3270.	5648.	3228.	1894.	2587.
9	4936.	9069.	7885.	6530.	2980.	2308.	1395.	1739.	1732.	1451.	466.
10	3160.	2759.	6018.	4697.	3104.	1891.	1475.	650.	815.	546.	425.
11	1526.	1860.	1789.	3723.	2429.	2021.	1305.	816.	280.	402.	188.
12	797.	879.	1273.	1017.	2225.	1563.	1340.	769.	341.	134.	159.
13	348.	453.	492.	683.	487.	1544.	1015.	894.	335.	170.	48.
14	174.	166.	243.	248.	348.	257.	1155.	652.	481.	189.	65.
15	90.	149.	136.	111.	85.	302.	240.	1061.	497.	367.	172.

TOTAL STOCK BIOMASS ON 1. JANUARY

| | 1007331. | 933563. | 823212. | 594564. | 466883. | 455028. | 479058. | 535004. | 648693. | 786145. | 910653. |

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

| | 516714. | 422893. | 353443. | 300393. | 245909. | 235161. | 209100. | 184705. | 152518. | 248424. | 256526. |

NO PREDATION MORTALITY ON   SAITHE

Table 2.8.1d

FISHING MORTALITY MACKEREL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.7327	0.0245	0.0102	0.0085	0.0000	0.0236	0.0199	0.0174	0.0110	0.0068	0.0014
2	0.8202	0.0290	0.1960	0.0884	0.0739	0.0292	0.0715	0.0530	0.0791	0.0764	0.1503
3	0.8219	0.1420	0.2690	0.2260	0.2162	0.1329	0.1661	0.1937	0.1815	0.2138	0.4216
4	0.8450	0.2079	0.1649	0.3295	0.2300	0.1904	0.2399	0.1035	0.2392	0.2890	0.4566
5	0.8860	0.1996	0.2407	0.1602	0.2673	0.2851	0.3228	0.3201	0.2588	0.2524	0.6304
6	0.9009	0.2847	0.1984	0.2877	0.1323	0.2041	0.3632	0.3947	0.3207	0.2027	0.6584
7	0.9017	0.1767	0.2676	0.5361	0.0371	0.1238	0.3389	0.4304	0.2871	0.3829	1.1475
8	1.0898	0.4396	0.3206	0.4783	0.5492	0.1797	0.3752	0.3858	0.3488	0.4076	0.8002
9	0.9719	0.3928	0.2898	0.5790	0.3017	0.1131	0.4397	0.4133	0.3292	0.3431	0.6290
10	0.8130	0.2130	0.3832	0.5245	0.5604	0.2805	0.2866	0.4182	0.4083	0.4663	0.7143
11	0.3496	0.0938	0.2472	0.7640	0.1014	0.3784	0.3213	0.2755	0.3481	0.4391	0.7075
12	0.6098	0.1411	0.1273	0.4629	0.1641	0.2904	0.5098	0.6312	0.4676	0.5734	1.0755
13	0.5370	0.2185	0.0793	0.2823	0.5812	0.5465	0.3082	0.4501	0.5599	0.4597	0.7783
14	0.1813	0.1816	0.2226	0.0877	0.3426	0.4989	1.1706	1.4023	1.0368	1.6662	0.6802
15	0.6674	0.3598	0.2529	0.4047	0.5687	0.2913	0.2908	1.1418	0.4095	0.7452	0.6795

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

	0.8058	0.2350	0.2502	0.3710	0.2592	0.2229	0.3070	0.3805	0.2795	0.2994	0.4607

STOCK NUMBERS MACKEREL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	649223.	351075.	176204.	29089.	127850.	179790.	291850.	355655.	33075.	24121.	1150198.
1	969637.	553231.	299167.	150151.	24788.	108946.	153207.	248698.	303069.	28185.	20554.
2	366647.	397110.	460033.	252353.	126866.	21123.	90672.	127984.	208272.	255429.	23854.
3	677769.	137585.	328722.	322243.	196838.	100402.	17482.	71937.	103428.	163978.	201650.
4	471713.	253896.	101727.	214059.	219048.	135119.	74911.	12617.	50506.	73509.	112832.
5	2494353.	172666.	175748.	73507.	131210.	148309.	95175.	50219.	9694.	33882.	46920.
6	513406.	876333.	120512.	117723.	53369.	85587.	95029.	58728.	31072.	6377.	22432.
7	186308.	177716.	561767.	84209.	75234.	39840.	59469.	56316.	33725.	19213.	4437.
8	190671.	64435.	126917.	366300.	41981.	61778.	29996.	36108.	31204.	21568.	11165.
9	91344.	54641.	35377.	78486.	193476.	20657.	43983.	17563.	20921.	18761.	12226.
10	17374.	29451.	31436.	22563.	37483.	121930.	15720.	24146.	9899.	12827.	11344.
11	5645.	6566.	20283.	18261.	11379.	18238.	78486.	10057.	13544.	5608.	6856.
12	6129.	3391.	5094.	13499.	7248.	8762.	10646.	48501.	6507.	8149.	3080.
13	6736.	2839.	2509.	3822.	7241.	5242.	5585.	5449.	22207.	3474.	3913.
14	16892.	3355.	1944.	1975.	2456.	3450.	2586.	3497.	2960.	10811.	1869.
15	183167.	78863.	15540.	8383.	8121.	10049.	9760.	2417.	4375.	3792.	9460.

TOTAL STOCK BIOMASS ON 1. JANUARY

	1988270.	869607.	763090.	603973.	425649.	326476.	269668.	231583.	224093.	206964.	173913.

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

	1781430.	708469.	619604.	527317.	392781.	307318.	228510.	169779.	138747.	144628.	160147.

NO PREDATION MORTALITY ON MACKEREL

Table 2.8.1e

FISHING MORTALITY   HADDOCK

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.0284	0.0310	0.0380	0.0286	0.0355	0.0558	0.0651	0.0797	0.0490	0.0628	0.0731
1	0.4652	0.4400	0.4043	0.3931	0.5751	0.1884	0.2426	0.2297	0.2738	0.2793	0.1883
2	0.9480	1.0596	0.8705	1.0351	0.8518	1.0178	0.7502	0.4813	0.4879	0.7715	0.7049
3	0.9413	1.2925	1.4233	1.0564	1.1045	1.4659	1.1280	0.9548	0.7923	1.1131	0.9548
4	0.9839	1.1222	0.7978	1.2853	1.1187	1.1144	1.1157	1.0227	0.8573	1.1708	0.9834
5	0.7206	1.0265	1.3841	1.0680	1.1298	0.9978	0.8957	0.8565	0.6414	1.2404	0.8884
6	0.9389	0.7050	1.1636	1.0711	1.0609	1.0910	0.8763	0.5964	0.8283	0.9773	0.8188
7	1.1333	1.3089	0.3865	0.9386	1.1760	0.5942	0.9250	0.9383	1.0295	1.1295	0.8376
8	0.7402	1.1504	0.6082	0.4515	0.7002	1.1334	0.5207	0.6831	0.9837	0.7006	0.7805
9	0.2902	0.8828	1.1845	0.4351	0.8407	0.5892	1.2709	0.8173	0.3092	0.7104	0.8703
10	0.9557	3.8090	2.9165	0.9131	0.2110	0.5749	0.7960	0.7783	0.5416	2.0234	0.8997
11	0.9000	0.8988	0.8990	0.8995	0.8992	0.8986	0.8991	0.8991	0.8991	0.8992	0.8989

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

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	0.9447	1.0370	0.8625	1.0821	0.9862	1.0199	0.7520	0.5453	0.6785	0.8896	0.7908

STOCK NUMBERS   HADDOCK

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	49761648.	6088613.	9240520.	19674586.	25113196.	37486244.	17985722.	25321324.	14007135.	27481570.	2470362.
1	7280730.	12636387.	1188854.	1795403.	3372246.	4155895.	7508472.	2040085.	3196603.	1762993.	6498359.
2	340917.	1222372.	2116320.	191576.	292950.	439002.	862146.	1560927.	318718.	622852.	386698.
3	597369.	90496.	305031.	634215.	47924.	88406.	111737.	288258.	662890.	135527.	205317.
4	93587.	179110.	19308.	57082.	171348.	12381.	15983.	28235.	86554.	233590.	34695.
5	3889.	27626.	46173.	6874.	12509.	44517.	3231.	4160.	8090.	29112.	57558.
6	2353.	1532.	8010.	9358.	1914.	3279.	13323.	1081.	1436.	3457.	6834.
7	16941.	753.	620.	2048.	2625.	542.	902.	4541.	487.	513.	1065.
8	492.	4466.	167.	345.	656.	663.	245.	293.	1455.	143.	136.
9	95.	192.	1157.	74.	180.	267.	175.	119.	121.	445.	58.
10	56.	58.	65.	290.	39.	63.	121.	40.	43.	73.	179.
11	15.	20.	6.	4.	126.	34.	77.	68.	20.	31.	26.

TOTAL STOCK BIOMASS ON 1. JANUARY

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	1380962.	1373676.	766157.	640846.	677896.	838567.	958722.	841397.	729519.	727757.	713490.

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

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	359133.	402970.	588155.	314829.	183959.	164480.	238254.	441298.	359292.	326005.	220904.

PREDATION MORTALITY   HADDOCK

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	1.1424	1.4027	1.4006	1.5354	1.5637	1.3524	1.9119	1.7899	1.8236	1.1792	1.3127
1	1.1202	1.1481	1.2222	1.2208	1.2640	1.1848	1.1283	1.4267	1.1617	1.0378	0.9676
2	0.1784	0.1286	0.1346	0.1506	0.1463	0.1506	0.1454	0.1751	0.1672	0.1383	0.0925
3	0.0633	0.0523	0.0526	0.0523	0.0489	0.0446	0.0476	0.0483	0.0507	0.0494	0.0332
4	0.0363	0.0334	0.0350	0.0327	0.0291	0.0291	0.0302	0.0272	0.0323	0.0299	0.0220
5	0.0112	0.0115	0.0121	0.0105	0.0092	0.0086	0.0094	0.0075	0.0089	0.0089	0.0068
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2.8.1f

FISHING MORTALITY   HERRING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.1059	0.1761	0.1887	0.0876	0.0000	0.0628	0.0985	0.3995	0.4017	0.4656	0.0660
1	0.5027	0.8917	0.3499	0.1591	0.3570	0.5326	0.1080	0.1890	0.2664	0.2348	0.0804
2	1.0672	1.3110	1.2908	0.2256	0.0260	0.1022	0.2913	0.3326	0.1433	0.2613	0.3033
3	0.8450	1.4962	1.6453	1.0623	0.1209	0.0697	0.3664	0.2913	0.3016	0.2653	0.3375
4	0.9381	1.4843	1.9618	0.6562	0.2248	0.1076	0.2257	0.2480	0.3318	0.3490	0.3800
5	0.8088	5.8069	2.0409	3.9256	0.2293	0.0381	0.2036	0.3471	0.1404	0.3015	0.3829
6	1.0081	1.6981	2.2977	6.0790	1.3983	0.0481	0.0301	0.5466	0.1231	0.2629	0.4115
7	0.6476	1.8744	2.2794	1.6453	0.4643	2.0153	0.1921	1.3680	0.2865	0.2513	0.4389
8	0.7263	3.7568	2.2760	6.1590	1.2563	0.0000	0.0000	1.7479	0.7419	0.5614	0.3191
9	0.1346	0.9694	0.9903	0.7975	0.1000	0.1000	0.3000	0.3000	0.2998	0.3006	0.3212

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

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	0.8731	1.4446	1.4546	1.9704	0.1398	0.0710	0.2549	0.3493	0.2600	0.2683	0.3420

STOCK NUMBERS   HERRING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	11664625.	2384831.	2067239.	4176289.	4580345.	7486021.	21173756.	32550522.	40123000.	34498720.	44839916.
1	2682763.	5391394.	933251.	740154.	1681335.	1983710.	3124743.	6509641.	8587001.	11917165.	11872428.
2	1370965.	743989.	1270077.	297919.	315385.	504464.	478890.	1199918.	1573857.	2718012.	3972357.
3	732700.	401022.	172933.	299491.	203032.	262184.	386546.	306190.	719072.	1154233.	1796506.
4	292591.	232087.	69492.	25232.	75764.	133835.	176847.	199310.	158671.	387970.	695423.
5	96046.	102173.	47012.	8704.	11642.	53786.	106994.	125617.	138296.	101828.	245658.
6	43420.	37821.	272.	5387.	151.	8135.	45618.	76876.	78038.	106622.	67245.
7	10732.	13936.	6159.	24.	11.	33.	6885.	39093.	39261.	61036.	72864.
8	3195.	5081.	1935.	570.	4.	6.	4.	5141.	9007.	26675.	42954.
9	11430.	1691.	1129.	403.	11.	11.	59.	38.	1901.	40783.	63201.

TOTAL STOCK BIOMASS ON 1. JANUARY

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	381624.	332674.	184151.	95681.	120365.	177112.	273848.	465605.	614074.	898859.	1183037.

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

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	163582.	115192.	41849.	40741.	37466.	63386.	103982.	116889.	160504.	264355.	417682.

PREDATION MORTALITY   HERRING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.5659	0.6623	0.7386	0.7224	0.7370	0.7111	0.9812	0.8330	0.7123	0.5011	0.6241
1	0.6802	0.4545	0.6926	0.5945	0.7470	0.7889	0.7493	1.1307	0.7840	0.7639	0.4591
2	0.0621	0.0482	0.0540	0.0579	0.0587	0.0641	0.0560	0.0794	0.0668	0.0528	0.0386
3	0.2047	0.1567	0.1796	0.2123	0.1959	0.2241	0.1961	0.2661	0.2154	0.1413	0.1025
4	0.0140	0.0124	0.0156	0.0173	0.0178	0.0162	0.0164	0.0175	0.0117	0.0080	0.0053
5	0.0232	0.0205	0.0255	0.0284	0.0291	0.0266	0.0270	0.0290	0.0197	0.0135	0.0090
6	0.0283	0.0168	0.0204	0.0245	0.0218	0.0188	0.0243	0.0254	0.0226	0.0178	0.0112
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2.8.1g

FISHING MORTALITY			SPRAT								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.0143	0.0039	0.0315	0.0114	0.0041	0.0055	0.0106	0.0148	0.0047	0.0051	0.0010
1	0.1624	0.3912	0.4152	0.2670	0.7048	0.5355	0.5191	0.6022	0.8981	1.1791	0.4897
2	0.6412	0.7721	0.9879	0.7871	0.6751	0.9651	1.0742	1.5506	1.3807	1.2603	1.7389
3	1.2378	2.0379	3.6903	0.9219	2.8570	2.5432	2.4669	1.5137	2.2087	2.1682	1.6877
4	3.2524	2.1815	2.9532	4.8569	1.6139	2.0990	2.3090	0.3642	2.6235	2.4515	2.4659
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 2)											
	0.8408	0.8884	1.7588	0.8950	0.9498	1.6362	1.4188	1.6557	2.5619	1.3444	1.6579

STOCK NUMBERS			SPRAT								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	150075120.	253550512.	126973720.	136120064.	218196208.	112324744.	73123488.	33152222.	14798087.	35397796.	119469920.
1	201437136.	107711752.	169455472.	86331936.	94244632.	152584432.	76038248.	47558028.	23537576.	11154969.	27009758.
2	35147952.	79209512.	33942788.	52772036.	30222620.	21544572.	41112384.	17665578.	11593639.	4735801.	1930687.
3	2108255.	6106907.	9480664.	3044380.	6475990.	3401897.	1799821.	1907191.	758077.	731472.	450737.
4	315497.	378507.	504465.	135175.	772304.	204339.	146675.	101922.	191356.	45883.	49238.
TOTAL STOCK BIOMASS ON 1. JANUARY											
	938801.	1169176.	947037.	783342.	722998.	694636.	609363.	319970.	181377.	98499.	155127.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 2)											
	329955.	756965.	434494.	486503.	364152.	234125.	371300.	177365.	111603.	51240.	23816.

PREDATION MORTALITY			SPRAT								
AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.2173	0.2990	0.2542	0.2562	0.2536	0.2846	0.3196	0.3277	0.1779	0.1653	0.2080
1	0.6710	0.6637	0.6515	0.6827	0.6710	0.6759	0.8406	0.7093	0.6054	0.4749	0.6150
2	1.0091	1.2511	1.3239	1.2111	1.4094	1.4175	1.8969	1.4980	1.2825	0.9917	1.4719
3	0.3902	0.3583	0.4606	0.4210	0.5097	0.5052	0.5873	0.6855	0.4960	0.4351	0.3926
4	0.1549	0.1906	0.2346	0.2095	0.2494	0.2570	0.3623	0.3071	0.2474	0.1699	0.2489

Table 2.8.1h

FISHING MORTALITY   NORWAY POUT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.0367	0.0538	0.0340	0.0181	0.0106	0.0105	0.0109	0.1757	0.0066	0.0156	0.0260
1	0.8673	0.6490	0.6078	0.5041	0.3974	0.4241	0.5779	0.4668	0.4572	0.4320	0.3933
2	2.4407	0.9862	1.4009	1.0003	1.1321	1.4606	1.9710	1.1598	1.1707	1.2813	1.6529
3	1.6323	0.5489	0.4818	0.8985	1.4216	1.0164	0.9631	1.4344	1.2417	0.7115	1.0483
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 1)											
	0.5420	0.4596	0.4198	0.4063	0.3604	0.3757	0.4549	0.4555	0.3284	0.3236	0.3058

STOCK NUMBERS   NORWAY POUT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	620797888.	654956352.	571202880.	291987072.	402366112.	422006080.	178696832.	645599360.	510733632.	498588416.	245689744.
1	218892000.	139206704.	157796640.	147628112.	77861144.	111600376.	123356472.	49463400.	158120256.	145143760.	152100144.
2	2977776.	9078153.	6461870.	8107826.	9683270.	5569683.	10724925.	11042991.	3453825.	12514830.	13043348.
3	715257.	61840.	857120.	416188.	761504.	698387.	328451.	394654.	718824.	312440.	937190.
TOTAL STOCK BIOMASS ON 1. JANUARY											
	2135628.	1644480.	1720083.	1521138.	1080092.	1253586.	1332771.	995199.	1613949.	1706630.	1674554.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 1)											
	1835229.	1317002.	1434481.	1375145.	878909.	1042583.	1243423.	672399.	1358582.	1457336.	1551710.

PREDATION MORTALITY   NORWAY POUT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.4584	0.3695	0.3191	0.3038	0.2718	0.2195	0.2736	0.2311	0.2515	0.1717	0.2338
1	1.3164	1.4223	1.3618	1.2211	1.2405	0.9185	0.8355	1.1950	1.0792	0.9775	1.1696
2	0.5450	0.5745	0.5575	0.5280	0.5708	0.4828	0.4181	0.6183	0.4834	0.4622	0.4351
3	1.1895	1.2171	1.2061	1.1624	1.0645	0.7721	0.6759	0.7965	1.2493	1.2213	1.7051

Table 2.8.1i

FISHING MORTALITY — SANDEEL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.0358	0.0431	0.0380	0.0711	0.0681	0.1587	0.0971	0.1776	0.2987	0.0581	3.1262
1	0.4678	0.2874	0.4794	0.5662	0.6830	0.3800	0.6582	0.4892	0.5130	0.3831	0.5170
2	0.3139	0.6413	0.7993	0.7683	1.0362	1.2219	1.0905	1.0851	1.0265	1.0007	0.3733
3	0.2549	0.7954	0.6707	1.1674	0.6123	0.9691	1.2614	0.7342	1.3304	0.6141	1.6789
4	0.8505	0.6205	0.8188	0.8792	0.7581	0.9950	0.7212	1.1707	1.9152	0.3281	0.3234
5	0.9303	1.1889	0.4455	1.3545	0.5211	1.4839	0.8975	1.4185	1.4385	1.2070	0.2975
6	0.3303	0.2444	0.2856	0.5790	0.2845	0.5749	0.4932	0.5432	0.4582	0.3952	0.6098

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

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	0.5294	0.8697	0.9462	1.2135	1.3227	1.5622	1.5081	1.3370	1.6770	1.2821	1.2659

STOCK NUMBERS — SANDEEL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	819442048.	521872704.	620968256.	644929088.	430656832.	590547904.	327950688.	663245504.	159965728.	565647232.	9720185.
1	177281488.	204678496.	130533696.	197785296.	251910960.	169522784.	214727488.	106480648.	261401232.	60708992.	308446944.
2	28451148.	22017972.	42819544.	21981694.	38211304.	45071812.	40134664.	35582520.	18260320.	72996864.	19089486.
3	4729522.	9023399.	6619261.	11043334.	6271068.	8767860.	8744619.	8301106.	6956185.	4265158.	18846458.
4	4840549.	2762192.	3197024.	2616447.	2673789.	2688768.	2633089.	1895980.	2950555.	1437886.	1882858.
5	658361.	1163061.	901955.	816754.	623628.	754256.	592130.	693351.	295086.	247925.	685084.
6	484838.	536612.	851050.	1143648.	552206.	759605.	412083.	457537.	257436.	182167.	220330.

TOTAL STOCK BIOMASS ON 1. JANUARY

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	1821827.	1661053.	1629955.	1763158.	1877879.	1796879.	1702725.	1485120.	1504033.	1514111.	1740029.

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

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	474876.	445309.	624099.	475852.	550901.	663301.	602927.	539249.	356595.	824828.	529310.

PREDATION MORTALITY — SANDEEL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	1.2516	1.2428	1.0063	0.7691	0.7643	0.7531	0.9279	0.6535	0.5701	0.4483	0.6912
1	1.5185	1.1773	1.2022	0.9780	0.9380	0.9611	1.0395	1.1740	0.6627	0.6738	0.5289
2	0.7347	0.4607	0.4560	0.3860	0.3359	0.3180	0.3855	0.4471	0.3278	0.2534	0.2093
3	0.1829	0.1422	0.1575		0.1510	0.1346	0.1339	0.1673	0.2002	0.1461	0.0853
4	0.4756	0.3989	0.4459	0.4550	0.4075	0.4183	0.5133	0.5895	0.4614	0.3133	0.2792
5	0.6993	0.3863	0.3893	0.3350	0.2912	0.2939	0.2938	0.4032	0.2858	0.2260	0.1663
6	0.2537	0.1551	0.1680	0.1713	0.1419	0.1701	0.1520	0.2065	0.1853	0.1236	0.1001

Table 2.9.1a Comparison of runs of the MSVPA under "Key Run" assumptions, and with half ration or half M1 assumptions. Fishing mortality, predation mortality and numbers in table are means of values predicted from 1974 to 1984, by age

Age	Fishing mortality			Predation mortality			Mean numbers		
	Key run	Half ration	Half M1	Key run	Half ration	Half M1	Key run	Half ration	Half M1
					Cod				
0	0.00	0.00	0.00	2.425	1.997	2.450	6,184,459	3,167,982	4,934,214
1	0.17	0.19	0.19	0.532	0.319	0.541	432,211	332,819	365,539
2	0.99	1.01	1.09	0.160	0.081	0.153	177,920	166,106	160,815
3	0.96	0.96	1.07	0.028	0.014	0.028	43,036	42,632	38,862
4	0.72	0.72	0.82	0.000	0.000	0.000	15,492	15,492	13,756
5	0.72	0.72	0.81	0.000	0.000	0.000	6,441	6,441	5,721
6	0.69	0.69	0.78	0.000	0.000	0.000	2,555	2,555	2,273
7	0.70	0.70	0.80	0.000	0.000	0.000	1,027	1,027	911
8	0.65	0.65	0.74	0.000	0.000	0.000	450	450	399
9	0.73	0.73	0.82	0.000	0.000	0.000	231	231	207
10	0.71	0.71	0.81	0.000	0.000	0.000	96	96	86
11+	0.77	0.77	0.80	0.000	0.000	0.000	89	89	85
					Whiting				
0	0.08	0.11	0.09	1.810	1.463	1.877	27,068,532	14,867,126	22,843,632
1	0.30	0.35	0.34	0.604	0.390	0.634	3,321,469	2,538,028	2,847,580
2	0.60	0.64	0.67	0.208	0.114	0.217	1,298,622	1,158,526	1,149,682
3	0.87	0.91	0.96	0.138	0.071	0.137	478,060	445,614	428,563
4	0.93	0.95	1.02	0.080	0.041	0.079	146,214	140,285	132,105
5	0.95	0.96	1.04	0.044	0.022	0.043	36,630	35,775	33,327
6	1.23	1.24	1.33	0.032	0.016	0.031	9,039	8,935	8,326
7	1.08	1.08	1.17	0.000	0.000	0.000	2,636	2,636	2,425
8	1.46	1.46	1.59	0.000	0.000	0.000	700	700	649
9	1.23	1.23	1.49	0.000	0.000	0.000	119	119	106
10+	1.00	1.00	1.02	0.000	0.000	0.000	72	72	67

58

Table 2.9.1b Comparison of runs of the MSVPA under "Key Run" assumptions, and
with half ration or half M1 assumptions. Fishing mortality,
predation mortality and numbers in table are means of values
predicted from 1974 to 1984, by age

Age	Fishing mortality			Predation mortality			Mean numbers		
	Key run	Half ration	Half M1	Key run	Half ration	Half M1	Key run	Half ration	Half M1

Haddock

0	0.05	0.08	0.05	1.515	1.305	1.552	23,242,910	12,908,508	19,027,964
1	0.35	0.40	0.39	1.188	0.780	1.204	4,483,799	2,984,978	3,842,735
2	0.83	0.85	0.90	0.151	0.078	0.151	796,611	746,784	713,149
3	1.13	1.14	1.23	0.051	0.025	0.049	296,137	290,414	270,334
4	1.06	1.07	1.16	0.031	0.016	0.031	89,712	88,809	82,403
5	1.00	1.00	1.10	0.010	0.005	0.010	18,618	18,574	17,051
6	0.93	0.93	1.03	0.000	0.000	0.000	4,574	4,574	4,156
7	0.96	0.96	1.06	0.000	0.000	0.000	2,997	2,997	2,732
8	0.77	0.77	0.86	0.000	0.000	0.000	892	892	809
9	0.73	0.73	0.82	0.000	0.000	0.000	283	283	256
10	1.35	1.35	1.53	0.000	0.000	0.000	85	85	77
11+	0.90	0.90	0.92	0.000	0.000	0.000	40	40	38

Herring

0	0.20	0.28	0.22	0.720	0.513	0.720	15,915,568	10,861,082	14,172,723
1	0.36	0.40	0.40	0.736	0.465	0.747	4,322,563	3,156,323	3,927,998
2	0.50	0.53	0.54	0.060	0.032	0.059	1,046,618	975,282	951,706
3	0.63	0.66	0.69	0.199	0.105	0.194	463,928	427,378	421,651
4	0.62	0.63	0.67	0.015	0.007	0.014	177,699	175,647	161,756
5	0.82	0.82	0.88	0.025	0.012	0.023	81,454	80,394	73,832
6	0.80	0.80	0.85	0.022	0.011	0.022	42,249	41,914	38,340
7	1.03	1.03	1.22	0.000	0.000	0.000	18,247	18,247	16,461
8	1.15	1.15	1.47	0.000	0.000	0.000	5,442	5,442	4,614
9+	0.21	0.21	0.21	0.000	0.000	0.000	7,980	7,980	7,661

Table 2.9.1c Comparison of runs of the MSVPA under "Key Run" assumptions, and with half ration or half M1 assumptions. Fishing mortality, predation mortality and numbers in table are means of values predicted from 1974 to 1984, by age

Age	Fishing mortality			Predation mortality			Mean numbers		
	Key run	Half ration	Half M1	Key run	Half ration	Half M1	Key run	Half ration	Half M1

Saithe

Age	Key run	Half ration	Half M1				Key run	Half ration	Half M1
0	0.00	0.00	0.00				321,835	321,835	219,694
1	0.01	0.01	0.02				287,145	287,145	211,584
2	0.14	0.14	0.17				211,665	211,665	165,704
3	0.30	0.30	0.35				147,655	147,655	122,361
4	0.47	0.47	0.55	No predation			82,100	82,100	70,016
5	0.60	0.60	0.69				41,028	41,028	35,322
6	0.60	0.60	0.70	mortality			20,081	20,081	17,086
7	0.57	0.57	0.67				12,434	12,434	10,494
8	0.59	0.59	0.69	in			7,188	7,188	5,858
9	0.51	0.51	0.60				4,002	4,002	3,180
10	0.41	0.41	0.49	MSVPA			2,511	2,511	1,984
11	0.39	0.39	0.46				1,632	1,632	1,303
12	0.42	0.42	0.49	run			1,059	1,059	863
13	0.41	0.41	0.47				662	662	556
14	0.34	0.34	0.38				408	408	356
15+	0.40	0.40	0.42				334	334	313

Mackerel

Age	Key run	Half ration	Half M1				Key run	Half ration	Half M1
0	0.00	0.00	0.00				221,793	221,793	149,382
1	0.09	0.09	0.11				283,908	283,908	215,020
2	0.15	0.15	0.19				230,649	230,649	179,400
3	0.26	0.26	0.32				212,038	212,038	170,145
4	0.28	0.28	0.34	No predation			160,711	160,711	129,138
5	0.32	0.32	0.38				338,476	338,476	284,663
6	0.33	0.33	0.39	mortality			195,814	195,814	159,343
7	0.35	0.35	0.41				129,380	129,380	105,715
8	0.46	0.46	0.53	in			97,096	97,096	81,514
9	0.42	0.42	0.49				57,521	57,521	47,873
10	0.44	0.44	0.53	MSVPA			32,283	32,283	26,657
11	0.33	0.33	0.40				18,807	18,807	15,507
12	0.40	0.40	0.49	run			11,793	11,793	9,815
13	0.40	0.40	0.52				6,510	6,510	5,219
14	0.68	0.68	0.93				4,993	4,993	3,445
15+	0.51	0.51	0.52				32,447	32,447	30,461

Table 2.9.1d Comparison of runs of the MSVPA under "Key Run" assumptions, and
with half ration or half M1 assumptions. Fishing mortality,
predation mortality and numbers in table are means of values
predicted from 1974 to 1984, by age

Age	Fishing mortality			Predation mortality			Mean numbers		
	Key run	Half ration	Half M1	Key run	Half ration	Half M1	Key run	Half ration	Half M1
					Sprat				
0	0.01	0.02	0.01	0.248	0.152	0.246	116,737,688	69,055,120	98,039,600
1	0.57	0.74	0.61	0.671	0.398	0.639	97,877,232	62,280,600	85,995,27
2	1.02	1.33	1.09	1.337	0.775	1.259	32,796,538	23,356,534	30,028,7~
3	2.21	2.34	2.27	0.364	0.194	0.344	3,495,843	3,270,624	3,405,534
4+	2.25	2.32	2.29	0.458	0.220	0.414	301,042	288,106	293,393
					Norway pout				
0	0.04	0.06	0.06	0.292	0.214	0.386	481,490,016	306,286,752	231,455,872
1	0.54	0.71	0.74	1.157	0.791	1.409	132,765,288	88,973,336	92,227,144
2	1.40	1.66	1.85	0.523	0.306	0.593	7,951,123	6,415,650	5,764,297
3+	1.04	1.22	1.19	1.055	0.588	1.032	526,012	406,067	392,485
					Sandeel				
0	0.11	0.15	0.12	0.742	0.498	0.728	503,215,456	288,420,000	427,914,144
1	0.48	0.60	0.52	1.038	0.651	0.997	185,667,360	126,167,168	164,907,680
2	0.85	0.97	0.92	0.412	0.224	0.380	40,245,976	34,861,992	37,267,320
3	0.84	0.96	0.90	0.123	0.072	0.122	7,467,784	6,689,119	6,947,043
4	0.82	1.03	0.91	0.447	0.259	0.430	2,866,042	2,348,922	2,602,113
5	1.00	1.31	1.16	0.361	0.236	0.350	730,035	575,013	637,331
6+	0.42	0.43	0.43	0.172	0.087	0.156	563,713	525,036	536,890

Table 2.9.2 Total biomass and amount eaten yearly ('000 tonnes)
from 1974 to 1984 summed over all species in model
for key run and runs under alternate assumptions

Year	Total biomass	Total yield	Total eaten
		Key run	
1974	10,966	4,152	4,513
1975	9,372	3,176	3,386
1976	8,251	3,172	2,973
1977	7,506	2,537	2,607
1978	6,915	2,404	2,238
1979	7,032	2,417	2,262
1980	7,262	2,590	2,211
1981	6,292	2,440	1,979
1982	6,772	2,359	2,108
1983	7,128	2,366	1,898
1984	7,808	2,590	1,877
		Half ration	
1974	8,596	4,152	2,136
1975	7,251	3,176	1,604
1976	6,511	3,172	1,421
1977	5,753	2,537	1,247
1978	5,266	2,404	1,069
1979	5,321	2,417	1,079
1980	5,483	2,590	1,029
1981	4,911	2,440	947
1982	5,407	2,359	1,038
1983	5,941	2,366	961
1984	6,850	2,590	994
		Half M1	
1974	9,037	4,152	3,871
1975	7,733	3,176	2,874
1976	6,816	3,172	2,541
1977	6,197	2,537	2,232
1978	5,760	2,404	1,916
1979	5,799	2,417	1,954
1980	6,034	2,590	1,924
1981	5,265	2,440	1,741
1982	5,641	2,359	1,876
1983	6,091	2,366	1,767
1984	7,146	2,590	1,917
	Constant total biomass in ecosystem		
1974	11,212	4,152	4,792
1975	9,499	3,176	3,500
1976	8,314	3,172	3,027
1977	7,533	2,537	2,624
1978	6,930	2,404	2,245
1979	7,056	2,417	2,278
1980	7,259	2,590	2,203
1981	6,295	2,440	1,979
1982	6,784	2,359	2,113
1983	7,160	2,366	1,925
1984	7,840	2,590	1,902

Table 3.1.1 Summary of results of VPA's on cod, haddock and whiting using constant and age-dependent M

Parameter	Cod		Haddock		Whiting	
	Const. M	Age-dep M	Const. M	Age-dep M	Const. M	Age-dep M
Mean catch ('000 t)						
Human consumption		233		177		78
Discards		–		112		86
Ind. by-catch		–		52		71
Landings		233		229		149
Catch		233		341		235
Recruits (millions)	251	477	2,295	33,719	2,662	38,167
Average biomass ('000 t)						
Total	533	683	763	1,944	565	1,908
Spawning	159	152	293	313	323	400
Mean F (see Note 2)						
Human consumption	0.746	0.745	0.750	0.737	0.652	0.622
Discards	–	–	0.130	0.121	0.177	0.158
Industrial by-catch	–	–	0.169	0.099	0.216	0.140
VPA/IYFS relationship Coeff. determination	0.25	0.17	0.84	0.87	0.71	0.80

Note 1: Tabulated values for cod are for period 1974-84
Tablulated values for haddock and whiting are for period 1965-84

Note 2: Mean F calculation:

Species	Fishery	Ages
Cod	Human consumption	2-8
Haddock	Human consumption	2-6
Whiting	Human consumption	2-6
Haddock	Industrial	0-4
Whiting	Industrial	0-4

Table 3.1.2 Summary of results of short-term predictions for cod, haddock and whiting using constant and age-dependent M

Parameter	Cod		Haddock		Whiting	
	Const. M	Age-dep M	Const. M	Age-dep M	Const. M	Age-dep M
Predicted catch ('000 t)						
1985 Human consump.	251	255	231	195	72	67
Discards	–	–	136	108	56	50
Industrial	–	–	8	9	21	22
Total landings	251	255	239	204	93	89
Total catch	251	255	375	312	149	139
1986 Human consump.	255	259	288	230	93	81
Discards	–	–	86	69	69	58
Industrial	–	–	10	11	27	26
Total landings	255	259	298	241	120	107
Total catch	255	259	384	309	189	165
Predicted biomass						
1985 Total	556	731	837	1,303	455	1,247
Spawning	116	119	300	282	292	340
1986 Total	558	724	790	1,412	553	1,356
Spawning	123	128	378	320	355	390
1987 Total	554	719	1,046	1,409	635	1,422
Spawning	139	144	605	273	432	451

Table 4.3.1a Yield ('000 tonnes) excluding predation

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	187.29	94.99	16.10	–	146.40	–	–	–	–
Indust.-DM	2.81	31.09	1.46	–	29.15	–	–	322.70	737.49
Indust.-pel	–	2.88	–	–	–	560.96	271.46	–	–
Herring-HC	–	–	–	–	–	498.20	–	–	–
Saithe	–	–	92.69	–	–	–	–	–	–
Mackerel	–	–	–	79.20	–	–	–	–	
Total yield	190.10	128.96	110.25	79.20	175.55	1,059.16	271.46	322.70	737.49

Table 4.3.1b Yield ('000 tonnes) including predation

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	211.28	95.55	14.66	–	177.01	–	–	–	–
Indust.-DM	12.01	35.38	1.27	–	19.28	–	–	316.71	736.13
Indust.-pel	–	5.38	–	–	–	528.67	297.19	–	–
Herring-HC	–	5.38	–	–	–	512.29	–	–	–
Saithe	–	–	81.48	–	–	–	–	–	–
Mackerel	–	–	–	78.92	–	–	–	–	–
Total yield	223.29	136.30	97.42	78.92	196.30	1,040.96	297.19	316.71	736.13

<u>Table 4.3.2a</u> Changes in total yield ('000 tonnes) resulting from 10% increases in each fishery separately, excluding predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-8.67	-4.94	-0.26	–	-10.27	–	–	–	–
Indust.-DM	-5.27	-2.30	-0.10	–	– 8.23	–	–	17.58	10.04
Indust.-pel	–	-0.22	–	–	–	-64.57	5.94	–	–
Herring-HC	–	–	–	–	–	– 5.19	–	–	–
ithe	–	–	-1.66	–	–	–	–	–	–
Mackerel	–	–	–	1.83	–	–	–	–	–
Total yield	190.10	128.96	110.25	79.20	175.55	1,059.16	271.46	322.70	737.49

<u>Table 4.3.2b</u> Changes in total yield ('000 tonnes) resulting from 10% increases in each fishery separately, including predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	5.16	2.93	-0.22	1.15	0.31	19.72	0.31	2.79	1.76
Indust.-DM	-1.88	2.23	-0.08	0.25	-0.35	6.33	0.71	15.38	-2.91
Indust.-pel	0.32	0.27	–	–	0.20	-18.01	1.09	0.06	0.07
Herring-HC	–	–	–	–	–	9.93	–	–	–
Saithe	15.82	-1.18	-1.60	1.13	-0.44	-2.19	-0.33	7.18	-3.52
Mackerel	0.19	-0.03	–	2.28	0.43	1.03	0.31	0.53	1.53
Total yield	223.29	136.30	97.42	78.92	196.30	1,040.96	297.19	316.71	736.13

Table 4.3.3a Change in spawning stock biomass ('000 tonnes) resulting from 10% increases in each fishery, excluding predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-22.87	-24.66	-3.75	–	-22.88	–	–	–	–
Indust.-DM	-3.02	-13.58	-0.60	–	-12.94	–	–	-14.88	-79.29
Indust.-pel	–	-1.28	–	–	–	-223.51	-15.28	–	–
Herring-HC	–	–	–	–	–	-130.01	–	–	–
Saithe	–	–	-20.00	–	–	–	–	–	
Mackerel	–	–	–	-22.54	–	–	–	–	
Total SSB	99.81	374.78	269.89	400.31	200.19	1,654.66	182.29	788.54	676.33

Table 4.3.3b Change in spawning stock biomass ('000 tonnes) resulting from 10% increases in each fishery, including predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-17.71	-5.14	-3.52	4.91	-18.72	70.00	0.32	4.55	2.65
Indust.-DM	-1.55	-2.22	-0.52	1.15	-3.55	21.15	0.63	-15.14	-100.10
Indust.-pel	0.15	-0.65	–	0.02	0.34	-231.43	-22.08	0.12	0.10
Herring-HC	–	–	–	–	–	-150.79	–	–	–
Saithe	8.49	-3.16	-19.12	4.80	-0.73	-8.01	-0.30	11.56	-5.17
Mackerel	0.09	-0.08	–	-17.12	0.72	3.34	0.28	0.97	2.23
Total SSB	103.69	458.10	233.84	381.56	327.15	2,996.46	233.39	778.48	919.13

Table 4.3.4a Change in recruitment (10^9 fish) resulting from 10% increases in each fishery, excluding predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-	-	-	-	-	-	-	-	-
Indust.-DM	-	-	-	-	-	-	-	-	-0.01
Indust.-pel	-	-	-	-	-	-	-0.01	-	-
Herring-HC	-	-	-	-	-	-	-	-	-
ithe	-	-	-	-	-	-	-	-	-
ᵤackerel	-	-	-	-	-	-	-	-	-
Total recruitment	0.33	2.31	0.16	0.45	3.04	19.09	99.95	229.93	399.94

Table 4.3.4b Change in recruitment (10^9 fish) resulting from 10% increases in each fishery, including predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-	-	-	-	-	-	-	-	-
Indust.-DM	-	-	-	-	-	-	-	-	-
Indust.-pel	-	-	-	-	-	-	-	-	-
Herring-HC	-	-	-	-	-	-	-	-	-
Saithe	-	-	-	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total recruitment	11.99	21.59	0.15	0.96	13.00	43.99	65.55	172.45	249.97

Table 4.3.5a Change in yield ('000 tonnes) with roundfish-HC fishery increased by 10%
excluding predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-8.63	-3.25	1.31	-	-9.10	-	-	-	
Indust.-DM	-0.05	-1.55	-0.01	-	-1.17	-	-	-	-
Indust.-pel	-	-0.14	-	-	-	-	-	-	-
Herring-HC	-	-	-	-	-	-	-	-	-
Saithe	-	-	-1.57	-	-	-	-	-	
Mackerel	-	-	-	-	-	-	-	-	
Total change	-8.67	-4.94	-0.26	-	-10.27	-	-	-	-
Total yield	181.43	124.02	109.28	79.20	165.28	1,059.16	271.46	322.70	737.49

Table 4.3.5b Change in yield ('000 tonnes) with roundfish-HC fishery increased by 10%
including predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	5.00	3.19	1.17	-	0.67	-	-	-	-
Indust.-DMDM	0.16	-0.25	-0.01	-	-0.36	-	-	2.79	1.76
Indust.-pel	-	-0.01	-	-	-	8.73	0.31	-	-
Herring-HC	-	-	-	-	-	10.99	-	-	-
Saithe	-	-	-1.38	-	-	-	-	-	-
Mackerel	-	-	-	1.15	-	-	-	-	-
Total change	5.16	2.93	-0.22	1.15	0.31	19.72	0.31	2.79	1.76
Total yield	228.45	139.23	97.20	80.07	196.60	1,060.68	297.50	319.50	737.90

Table 4.3.6a Change in yield ('000 tonnes) with indust.-DM fishery increased by 10% excluding
predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-5.49	-4.24	-0.03	–	-9.75	–	–	–	–
Indust.-DM	0.22	2.03	0.14	–	1.53	–	–	17.58	10.04
Indust.-pel	–	-0.09	–	–	–	–	–	–	–
Herring-HC	–	–	–	–	–	–	–	–	–
⌐the	–	–	-0.21	–	–	–	–	–	–
Mackerel	–	–	–	–	–	–	–	–	–
Total change	-5.27	-2.30	-0.10	–	-8.23	–	–	17.58	10.04
Total yield	184.83	126.66	110.15	79.20	167.32	1,059.16	271.46	340.28	747.53

Table 4.3.6b Change in yield ('000 tonnes) with indust.-DM fishery increased by 10% including
predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-3.03	-1.13	-0.03	–	-2.16	–	–	–	–
Indust.-DM	1.15	3.38	0.13	–	1.80	–	–	15.38	-2.91
Indust.-pel	–	-0.01	–	–	–	2.91	0.71	–	–
Herring-HC	–	–	–	–	–	3.42	–	–	–
Saithe	–	–	-0.18	–	–	–	–	–	–
Mackerel	–	–	–	0.25	–	–	–	–	–
⌐tal change	-1.88	2.23	-0.08	0.25	-0.35	6.33	0.71	15.38	-2.91
⌐otal yield	221.41	138.53	97.34	79.17	195.94	1,047.29	297.90	332.09	733.22

Table 4.3.7a Change in yield ('000 tonnes) with indust.-PEL fishery increased by 10%
excluding predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-	-0.40	-	-	-	-	-	-	-
Indust.-DM	-	-0.09	-	-	-	-	-	-	-
Indust.-pel	-	0.28	-	-	-	-4.11	5.94	-	-
Herring-HC	-	-	-	-	-	-60.46	-	-	
Saithe	-	-	-	-	-	-	-	-	
Mackerel	-	-	-	-	-	-	-	-	-
Total change	-	-0.22	-	-	-	-64.57	5.94	-	-
Total yield	190.10	128.75	110.25	79.20	175.55	994.59	277.40	322.70	737.49

Table 4.3.7b Change in yield ('000 tonnes) with indust.-PEL fishery increased by 10%
including predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	0.31	-0.22	-	-	0.18	-	-	-	-
Indust.-DM	0.01	-0.04	-	-	0.02	-	-	0.06	0.07
Indust.-pel	-	0.53	-	-	-	19.07	1.09	-	-
Herring-HC	-	-	-	-	-	-37.09	-	-	-
Saithe	-	-	-	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total change	0.32	0.27	-	-	0.20	-18.01	1.09	0.06	'7
Total yield	223.61	136.58	97.42	78.92	196.49	1,022.94	298.28	316.77	73o.20

Table 4.3.8a Change in yield ('000 tonnes) with herring-HC fishery increased by 10% excluding predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-	-	-	-	-	-	-	-	-
Indust.-DM	-	-	-	-	-	-	-	-	-
Indust.-pel	-	-	-	-	-	-21.71	-	-	-
Herring-HC	-	-	-	-	-	16.52	-	-	-
ᵗthe	-	-	-	-	-	-	-	-	-
ᵤₙckerel	-	-	-	-	-	-	-	-	-
Total change	-	-	-	-	-	-5.19	-	-	-
Total yield	190.10	128.96	110.25	79.20	175.55	1,053.97	271.46	322.70	737.49

Table 4.3.8b Change in yield ('000 tonnes) with herring-HC fishery increased by 10% including predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-	-	-	-	-	-	-	-	-
Indust.-DM	-	-	-	-	-	-	-	-	-
Indust.-pel	-	-	-	-	-	-16.29	-	-	-
Herring-HC	-	-	-	-	-	26.23	-	-	-
Saithe	-	-	-	-	-	-	-	-	-
Mackerel	-	-	-	-	-	-	-	-	-
Total change	-	-	-	-	-	9.93	-	-	-
ₜal yield	223.29	136.30	97.42	78.92	196.30	1,050.89	297.19	316.71	736.13

Table 4.3.9a Change in yield ('000 tonnes) with saithe fishery increased by 10% excluding predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	–	–	-1.46	–	–	–	–	–	–
Indust.-DM	–	–	-0.04	–	–	–	–	–	–
Indust.-pel	–	–	–	–	–	–	–	–	–
Herring-HC	–	–	–	–	–	–	–	–	–
Saithe	–	–	-0.16	–	–	–	–	–	–
Mackerel	–	–	–	–	–	–	–	–	–
Total change	–	–	-1.66	–	–	–	–	–	–
Total yield	190.10	128.96	108.59	79.20	175.55	1,059.16	271.46	322.70	737.49

Table 4.3.9b Change in yield ('000 tonnes) with saithe fishery increased by 10% including predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	15.54	-0.96	-1.42	–	-0.41	–	–	–	–
Indust.-DM	0.28	-0.20	-0.04	–	-0.03	–	–	7.18	-3.52
Indust.-pel	–	-0.02	–	–	–	-0.95	-0.33	–	–
Herring-HC	–	–	–	–	–	-1.24	–	–	–
Saithe	–	–	-0.14	–	–	–	–	–	–
Mackerel	–	–	–	1.13	–	–	–	–	–
Total change	15.82	-1.18	-1.60	1.13	-0.44	-2.19	-0.33	7.18	-3.52
Total yield	239.11	135.13	95.82	80.05	195.85	1,038.76	296.87	323.89	⌐2.62

<u>Table 4.3.10a</u> Change in yield ('000 tonnes) with mackerel fishery increased by 10% excluding predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	-	-	-	-	-	-	-	-	-
Indust.-DM	-	-	-	-	-	-	-	-	-
Indust.-pel	-	-	-	-	-	-	-	-	-
Herring-HC	-	-	-	-	-	-	-	-	-
ˆaithe	-	-	-	-	-	-	-	-	-
..ackerel	-	-	-	1.83	-	-	-	-	-
Total change	-	-	-	1.83	-	-	-	-	-
Total yield	190.10	128.96	110.25	81.03	175.55	1,059.16	271.46	322.70	737.49

<u>Table 4.3.10b</u> Change in yield ('000 tonnes) with mackerel fishery increased by 10% including predation.

Fishery	Stock								
	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway pout	Sandeel
Roundfish-HC	0.19	-0.02	-	-	0.40	-	-	-	-
Indust.-DM	-	-0.01	-	-	0.03	-	-	0.53	1.53
Indust.-pel	-	-	-	-	-	0.48	0.31	-	-
Herring-HC	-	-	-	-	-	0.55	-	-	-
Saithe	-	-	-	-	-	-	-	-	-
Mackerel	-	-	-	2.28	-	-	-	-	-
Total change	0.19	-0.03	-	2.28	0.43	1.03	0.31	0.53	1.53
Total yield	223.48	136.27	97.42	81.20	196.73	1,041.99	297.50	317.24	737.66

Table 4.3.11 Comparison of recruitment levels estimated by MSVPA and used in HRMSJ runs.

Species	Recruitment (10^9)		SSB ('000 tonnes)		Yield ('000 tonnes)	
	MSVPA	HRMSJ	MSVPA	HRMSJ	MSVPA	HRMSJ
Cod	6	12	200	100		220
Whiting	27	22	370	460		140
Saithe	<1	<1	280	230		100
Mackerel*	<1	1	500	380		80
Haddock	23	13	340	330		200
Herring*	15	44	115	3,000		1,000
Sprat	120	66	334	230		300
Norway pout	290	170	1,000	780		320
Sandeel	540	250	560	920		740

*Stocks in depleted state during period of data used by MSVPA. Higher recruitment values consistent with recovery assumed for HRMSJ.

Table 4.3.12 Predation mortality generated by HRMSJ

Species	Age															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Cod	3.031	0.324	0.195	0.078	0.025	0.013	0.008	0.006	0.005	0.004	0.004	0.003	–	–	–	–
Whiting	1.721	0.452	0.222	0.147	0.111	0.087	0.073	0.065	0.050	0.043	0.028	0.047	–	–	–	–
Saithe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mackerel	0.407	0.109	0.078	0.067	0.055	0.050	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.036	0.035	0.034
Haddock	1.493	0.392	0.161	0.094	0.071	0.053	0.043	0.034	0.025	0.024	0.015	0.016	–	–	–	–
Herring	0.719	0.274	0.129	0.095	0.080	0.069	0.067	0.063	0.062	0.062	–	–	–	–	–	–
Sprat	0.499	0.362	0.294	0.257	0.238	0.228	–	–	–	–	–	–	–	–	–	–
Norway pout	0.783	0.764	0.658	0.587	0.523	–	–	–	–	–	–	–	–	–	–	–
Sandeel	0.409	0.355	0.302	0.253	0.230	0.215	0.208	0.202	0.202	–	–	–	–	–	–	–

Table 6.1.1 Prey composition in the food of cod in weight percentages
A: Observed fractions in 1982,1
B: Observed fractions in 1981,1
C: Predicted fractions in 1982,1 (MSVPA)

Prey	Age	Predator (cod) age								
		1			2			3		
		A	B	C	A	B	C	A	B	C
Cod	1	–	–	–	0.04	1.0	1.5	0.3	0.6	0.9
	2	–	–	–	–	0.2	0.05	–	0.7	0.2
	3	–	–	–	–	–	–	–	–	–
Haddock	1	–	–	–	4.3	1.8	2.8	9.4	6.4	9.0
	2	–	–	–	0.4	0.1	0.02	2.6	5.9	1.1
	3	–	–	–	0.1	0.01	0.01	1.3	0.2	0.3
	4	–	–	–	–	–	–	0.03	0.03	0.07
	5	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–
Whiting	1	0.5	0.6	0.5	7.0	4.5	3.6	4.9	5.1	3.7
	2	–	–	–	0.1	2.4	0.8	5.6	5.6	1.7
	3	–	–	–	0.2	0.2	0.2	6.8	2.6	2.9
	4	–	–	–	0.02	0.1	0.1	1.0	1.3	1.2
	5	–	–	–	–	0.02	0.03	–	0.2	0.3
	6	–	–	–	–	–	–	–	0.04	0.03
Norway pout	1	–	0.2	0.8	2.1	2.1	6.8	5.7	4.4	12.7
	2	–	–	0.04	0.03	0.5	0.02	0.1	4.5	1.3
	3	–	–	–	–	–	0.01	–	0.2	0.3
Herring	1	1.2	0.08	0.12	11.3	2.7	3.8	1.7	2.0	2.6
	2	–	–	–	0.02	0.1	0.2	0.06	1.2	1.3
	3	–	–	–	–	0.08	–	0.1	2.3	4.4
Sprat	1	0.2	9.0	4.8	0.7	2.3	1.1	0.12	0.2	0.10
	2	4.7	7.4	4.4	2.0	7.7	4.2	0.25	2.5	1.2
	3	0.9	0.02	0.01	0.3	1.1	0.3	0.03	0.5	0.1
	4	0.01	–	–	–	0.01	0.06	–	0.01	0.02
Sandeel	1	0.4	1.6	5.2	5.4	2.5	7.3	3.4	5.1	13.8
	2	0.1	0.2	0.1	0.6	1.1	0.6	0.2	6.1	2.7
	3	–	–	–	–	0.09	0.06	–	2.9	1.9
	4*	–	–	–	–	0.11	0.21	–	3.5	6.2
	5*	–	–	–	–	0.04	0.01	–	1.1	4.1
	6*	–	–	–	–	0.04	0.02	–	1.2	0.6

(cont'd)

Table 6.1.1 (cont'd)

Prey	Age	Predator (cod) age								
		4			5			6		
		A	B	C	A	B	C	A	B	C
Cod	1	1.5	1.1	2.1	2.7	2.1	4.4	2.4	0.6	1.1
	2	0.03	5.3	1.9	0.05	9.6	3.7	0.03	7.3	2.6
	3	-	0.02	0.03	-	0.04	0.07	-	0.1	0.2
Haddock	1	9.1	5.4	4.0	11.3	3.6	7.2	3.6	2.5	4.8
	2	9.3	14.8	3.6	6.5	11.2	2.9	4.3	4.4	1.1
	3	2.3	0.8	2.2	2.9	0.7	1.9	6.9	0.2	0.7
	4	1.4	0.06	0.2	2.5	0.05	0.2	7.3	0.01	0.05
	5	0.04	-	-	0.07	-	-	0.2	-	-
	6	0.06	-	-	0.10	-	-	0.3	-	-
Whiting	1	4.8	5.5	·5.3	2.6	7.5	7.9	3.2	5.3	5.2
	2	9.2	17.3	7.1	3.4	19.7	8.9	2.5	17.9	7.5
	3	4.8	7.6	11.0	1.3	8.3	13.1	2.1	5.9	8.8
	4	0.8	1.6	2.1	0.2	1.1	1.5	0.3	1.1	1.4
	5	-	0.3	0.4	-	0.2	0.3	0.01	0.3	0.4
	6	-	0.6	0.05	-	0.03	0.03	-	0.1	0.08
Norway pout	1	2.4	2.5	9.6	0.8	1.3	5.3	1.5	0.6	2.4
	2	0.03	3.8	1.5	0.01	2.2	0.9	-	1.1	0.4
	3	-	0.3	0.5	-	0.2	0.3	-	0.07	0.15
Herring	1	1.7	1.3	2.2	2.3	1.0	1.9	1.4	0.9	1.6
	2	0.2	0.7	1.1	0.3	0.4	0.6	0.2	0.6	1.0
	3	3.4	1.0	2.7	1.5	0.5	1.4	0.7	1.5	3.8
Sprat	1	0.06	0.2	0.1	0.06	0.3	0.19	0.03	0.8	0.5
	2	0.5	1.7	1.2	0.6	1.8	1.3	0.5	2.2	1.5
	3	0.08	0.3	0.09	0.1	0.3	0.09	0.08	0.2	0.07
	4	-	-	0.02	-	-	0.02	-	-	0.01
Sandeel	1	0.2	1.1	3.8	0.2	0.4	1.4	0.1	0.1	0.4
	2	0.06	1.2	0.7	0.08	0.3	0.2	0.04	0.05	0.03
	3	-	0.6	0.5	-	0.1	0.1	-	-	-
	4*	-	0.7	1.8	-	0.2	0.4	-	-	-
	5*	-	0.2	0.1	-	0.05	0.03	-	-	-
	6*	-	0.3	0.2	-	0.05	0.04	-	-	-

*Excluded from the statistical analysis

Table 6.1.2 Linear regression parameters for the relationships between the percentages of various fish prey species/age groups in cod stomachs in the first quarter of 1982 (A) and 1981 (B) and the predicted fractions from MSVPA (C)

	n	C vs A				B vs A				C vs B			
		a	b	r	P	a	b	r	P	a	b	r	P
Predator age													
1	10	0.59	0.53	0.80	0.001	0.38	0.22	0.52	0.09	1.10	0.62	0.39	0.21
2	25	0.37	0.80	0.67	<0.001	0.39	0.82	0.53	0.004	0.62	0.52	0.67	<0.001
3	25	0.18	0.98	0.59	<0.001	-0.09	0.76	0.65	<0.001	1.01	0.88	0.63	< 1
4	28	1.21	0.40	0.60	<0.001	0.30	0.58	0.84	<0.001	1.16	0.61	0.62	<0.001
5	28	1.02	0.51	0.71	<0.001	0.86	0.21	0.40	0.03	1.15	0.64	0.48	0.007
6	27	0.75	0.47	0.76	<0.001	1.20	0.09	0.17	0.38	1.32	0.27	0.23	0.24
Prey													
Cod	13	0.74	0.32	0.69	0.003	0.65	-0.05	-0.15	0.59	1.06	0.70	0.48	0.07
Haddock	26	0.83	0.35	0.56	0.002	1.94	0.62	0.66	<0.001	-0.11	0.52	0.78	<0.001
Whiting	31	1.00	0.53	0.77	<0.001	0.83	0.29	0.61	<0.001	1.62	0.75	0.51	0.002
Norway pout	17	0.52	1.43	0.59	0.007	0.03	0.51	0.53	0.02	0.76	2.37	0.94	<0.001
Herring	16	0.18	1.58	0.91	<0.001	-0.45	2.04	0.58	0.01	1.42	0.23	0.46	<0.05
Sprat	24	-0.002	0.56	0.99	<0.001	0.06	0.25	0.65	<0.001	0.42	1.01	0.69	<0.001
Sandeel	16	0.44	1.36	0.67	0.002	0.15	0.36	0.43	0.07	1.15	1.89	0.77	<0.001
Total	143	0.87	0.53	0.64	<0.001	0.73	0.36	0.50	<0.001	1.10	0.61	0.53	<0.001

Table 6.2.1   Comparison of total consumption in tonnes by individual predators with esti-
mated biomases of prey in 1974 and 1981

Prey	Predators					Total	Stock biomass (1 January)	% consumed*
	Cod	Whiting	Saithe	Mackerel	Haddock			

1 9 7 4

Prey	Cod	Whiting	Saithe	Mackerel	Haddock	Total	Stock biomass (1 January)	% consumed*
Cod	16,888	893	1,288	567	0	19,635	468,811	4.2
Whiting	93,353	42,576	5,354	569	550	142,401	861,113	16.5
Saithe	0	0	0	0	0	0	1,009,326	0
'ackerel	0	0	0	0	0	0	1,988,270	0
Haddock	121,018	103,697	138,973	23,867	2,305	389,858	1,388,478	28.1
Herring	31,216	29,964	4,321	11,720	173	77,394	386,307	20.0
Sprat	70,904	302,913	2,757	247,068	8,523	632,165	943,855	67.0
Norway pout	115,257	128,523	941,434	461,627	191,930	1,838,771	2,144,499	85.7
Sandeel	61,100	225,231	9,151	1,035,538	81,268	1,412,288	1,775,211	79.6
Total	509,736	833,796	1,103,278	1,780,954	284,750	4,512,513	10,965,869	–

1 9 8 1

Prey	Cod	Whiting	Saithe	Mackerel	Haddock	Total	Stock biomass (1 January)	% consumed*
Cod	33,165	2,019	1,212	58	0	36,455	637,830	5.7
Whiting	86,717	34,547	2,682	19	197	124,163	722,917	17.2
Saithe	0	0	0	0	0	0	535,004	0
Mackerel	0	0	0	0	0	0	231,583	0
Haddock	82,532	84,329	35,193	737	971	203,761	839,758	24.3
Herring	37,952	113,189	5,210	2,314	161	158,825	465,536	34.1
Sprat	44,229	121,325	577	4,402	3,681	174,212	320,345	54.4
Norway pout	74,483	142,143	248,363	68,068	85,170	618,229	991,692	62.3
Sandeel	114,716	274,572	5,926	140,094	127,567	662,875	1,547,492	42.8
otal	473,793	772,125	299,163	215,692	217,747	1,978,521	6,292,158	–

*The % biomass consumed is not entirely reliable since the biomass values are calculated
on 1 January

Table 6.3.1 Results of multiple regression of weight of prey in the stomach of cod against weight of prey in the stock and predator weight for all prey species combined (All) and individual prey species

Prey	R	R^2	a_1	a_e	b	n
All	0.802	0.643	0.355	0.00973	3.209	481
Cod	0.780	0.609	0.304	0.028	-61.195	47
Haddock	0.783	0.614	0.0395	0.00343	9.987	61
Whiting	0.860	0.740	0.853	0.011	-32.944	81
Norway pout	0.841	0.708	1.348	0.00103	- 0.957	55
Herring	0.577	0.333	0.603	0.0120	-10.165	50
Sprat	0.618	0.382	0.732	0.000871	4.180	72
Sandeel	0.806	0.649	1.055	0.000464	- 0.843	115

W (stomach) = a_1W (stock) + a_2W (predator) + b

(All weights in g)

<u>Table 6.3.2</u> Results of multiple regression of weight of prey in the
stomach of whiting against weight of prey in the stock
and predator weight for all prey species combined (All)
and individual prey species

Prey	R	R^2	a_1	a_e	b	n
All	0.569	0.324	0.118	0.0192	3.014	309
Cod	0.985	0.970	0.0583	-0.00682	-0.970	10
Haddock	0.857	0.734	0.176	0.0199	-2.412	36
Whiting	0.950	0.903	0.327	0.00710	-7.139	19
Norway pout	0.959	0.921	0.660	0.00871	-2.240	47
Herring	0.748	0.559	0.238	0.0116	-2.200	24
Sprat	0.843	0.711	0.535	0.00795	0.763	78
Sandeel	0.689	0.475	0.755	0.0111	-1.058	95

W (stomach) = a_1W (stock) + a_2W (predator) + b
(All weights in g)

Table 6.3.3 Partial predation mortality (M2) on two age groups of sandeel in the first quarter caused by various predators. Calculations are from the 'key run' (Section 2.8)

Prey age 0			Prey age 1		
Predator species	Predator age	M2	Predator species	Predator age	M2
Whiting	1	0.000015	Cod	1	0.002292
	2	0.003834		2	0.009291
	3	0.000696		3	0.004537
	4	0.000086		4	0.000721
	5	0.000007		5	0.000176
				6	0.000016
Total		0.004638		7	0.000010
				8	0.000003
				9	0.000001
			Whiting	1	0.079621
				2	0.023730
				3	0.008627
				4	0.004901
				5	0.000161
				6	0.000304
				7	0.000051
				8	0.000007
				9	0.000003
				10	0.000002
			Saithe	4	0.000024
				5	0.000486
				6	0.000265
				7	0.000241
				8	0.000202
				9	0.000082
				10	0.000033
				11	0.000044
				12	0.000056
				13	0.000076
				14	0.000054
				15	0.000089
			Mackerel	1	0.003256
				2	0.001675
				3	0.003536
				4	0.000621
				5	0.002463
				6	0.002877
				7	0.002758
				12	0.000001
			Haddock	2	0.000222
				3	0.001055
				4	0.000333
				5	0.000051
				6	0.000005
				7	0.000019
				8	0.000001
				9	0.000001
			Total		0.154981

Table 6.3.4 Ratios of the mean weight at age of prey in predator
stomachs to assumed mean weights in the sea (STOCK/STOM)
for various age groups of predators and prey in the first
quarter of the year. Predators are cod and whiting, prey
is sandeels.

Predator species	Predator age	Prey age						
		0	1	2	3	4	5	6
Cod	0	-	-	-	-	-	-	-
	1	-	1.068	1.719	-	-	-	-
	2	-	0.968	1.039	0.366	0.497	0.539	0.451
	3	-	0.601	0.626	0.466	0.633	0.686	0.574
	4	-	0.736	0.771	0.484	0.658	0.713	0.597
	5	-	0.865	0.930	0.484	0.658	0.713	0.597
Whiting	0	-	-	-	-	-	-	-
	1	3.361	3.007	3.062	-	-	-	-
	2	42.105	2.117	1.793	0.374	0.508	0.551	0.461
	3	7.407	1.903	1.474	0.374	0.508	-	-
	4	5.369	3.234	1.341	0.374	0.508	0.551	-
	5	7.407	0.557	1.184	0.374	0.508	0.551	-

Table 6.3.5 Analysis of the quarterly variability in ratios of assumed stock weights at age of prey to observed weights at age of prey in stomachs (STOCK/STOM). Quarterly data are the percentage of observations exceeding the geometric mean of the ratio of STOCK/STOM for each predator-prey combination. The number in parentheses is the number of observations per quarter.

Predator	Prey	Geometric mean	Quarter				Σ
			1	2	3	4	
Cod	Cod	4.96	44 (9)	67 (15)	36 (11)	17 (12)	43 (47)
	Haddock	2.02	77 (13)	47 (15)	25 (16)	59 (17)	51 (61)
	Whiting	1.43	62 (21)	85 (20)	21 (19)	10 (21)	44 (8₎
	Norway pout	0.71	83 (12)	20 (15)	69 (13)	33 (15)	49 (55,
	Herring	1.23	77 (13)	33 (9)	6 (17)	73 (11)	44 (50)
	Sprat	0.70	67 (21)	40 (20)	43 (14)	59 (17)	53 (72)
	Sandeel	1.07	25 (24)	74 (35)	36 (22)	18 (34)	39(115)
	All species	1.29	59(113)	57(129)	32(112)	34(127)	46(481)
Whiting	Cod	65.48	0 (1)	100 (5)	0 (0)	0 (4)	50 (10)
	Haddock	5.07	71 (7)	33 (12)	78 (9)	50 (8)	56 (36)
	Whiting	5.14	0 (6)	0 (4)	100 (5)	0 (5)	25 (20)
	Norway pout	1.99	31 (16)	29 (14)	63 (8)	0 (9)	30 (47)
	Herring	5.88	0 (6)	100 (5)	0 (5)	50 (8)	38 (24)
	Sprat	1.18	58 (19)	35 (17)	33 (18)	75 (24)	53 (78)
	Sandeel	1.49	55 (22)	86 (28)	32 (22)	35 (23)	54 (95)
	All species	2.30	45 (77)	56 (85)	45 (67)	42 (81)	47(310)

Table 6.6.1 Statistics of fit of log-linear model to M2 per unit
biomass (A) and M2 values (B)

Source	Df	SUMSQ	F	RMSE
A. Model fit to ln (M2/PDBIOMASS)				
Model	35	5,113.12	53.54	1.652
Error	3,309	9,029.51 (Type III)		$r^2 = 0.361$
PDNAM	4	1,253.19	114.81	
PYNAM	6	472.24	28.84	
PDNAM x PYNAM	23	1,412.54	22.51	
LWR	1	905.19	331.72	
LWR^2	1	1,075.57	394.16	
B. Model fit to ln (M2)				
Model	36	11,501.34	74.41	2.072
Error	3,347	14,215.86 (Type III)		$r^2 = 0.447$
PDNAM	4	4,994.94	209.84	
PYNAM	6	412.35	16.01	
PDNAM x PYNAM	23	1,247.14	12.63	
PREYWTSEA	1	5,464.80	1,272.80	
LWR	1	501.17	116.73	
LWR^2	1	479.96	111.79	

Table 6.6.2 Parameter estimates from model fit to ln
(M2 per unit biomass)

Log-Linear Model Parameter Estimates

Prey		Predator				
		Cod	Haddock	Mackerel	Saithe	Whiting
	Main effect	-2.46	-3.63	-6.38	-4.11	0.00
Cod	0.40	0.39	-9.99	1.94	3.58	0.00
Haddock	-0.40	0.55	0.53	3.37	2.05	0.00
Herring	-1.24	0.59	0.29	3.09	1.86	0.00
Norway pout	-2.22	0.94	2.29	4.62	5.27	0.00
Sandeel	-2.54	1.69	2.26	4.94	2.70	0.00
Sprat	-1.98	1.02	-0.24	3.26	2.07	0.00
Whiting	0.00	0.00	0.00	0.00	0.00	0.00

Relative Values for Preference

Prey	Predator				
	Cod	Haddock	Mackerel	Saithe	Whiting
Cod	0.19	0.00	0.02	0.88	1.49
Haddock	0.10	0.03	0.03	0.09	0.67
Herring	0.04	0.01	0.01	0.03	0.29
Norway pout	0.02	0.03	0.02	0.35	0.11
Sandeel	0.04	0.02	0.02	0.02	0.08
Sprat	0.03	0.00	0.01	0.02	0.14
Whiting	0.09	0.03	0.00	0.02	1.00

Overall predation mortality = 3.7 per megatonne.

Wt Ratio (LWR) Estimates

Log-linear model parameters: $LWR_2 = 1.494$
$LWR^2 = -0.174$

Conversions to size-preference function: Mean = 4.3
SD   = 1.69

Table 6.6.3 Parameter estimates from model fit to ln (M2)

Log-Linear Model Parameter Estimates

Prey		Predator				
		Cod	Haddock	Mackerel	Saithe	Whiting
	Main effect	4.85	−1.62	−4.05	3.06	0.00
Cod	0.72	−0.16	0.00	1.23	3.25	0.00
Haddock	−0.11	0.18	1.20	3.10	1.74	0.00
Herring	−0.50	−0.25	−0.18	2.28	1.12	0.00
Norway pout	−1.27	−0.10	1.75	3.52	4.22	0.00
Sandeel	−1.60	0.50	1.65	4.02	1.67	0.00
Sprat	−1.08	−0.16	−0.41	2.41	1.36	0.00
Whiting	0.00	0.00	0.00	0.00	0.00	0.00

Relative Values for Preference

Prey	Predator				
	Cod	Haddock	Mackerel	Saithe	Whiting
Cod	223.63	0.41	0.13	1,130.03	2.06
Haddock	137.00	0.59	0.35	108.85	0.89
Herring	60.34	0.10	0.10	39.88	0.61
Norway pout	32.56	0.32	0.17	410.35	0.28
Sandeel	42.61	0.21	0.20	22.99	0.20
Sprat	37.00	0.05	0.07	28.36	0.34
Whiting	127.44	0.20	0.02	21.37	1.00

Wt Ratio (LWR) Estimates

Log-linear model parameters:

$$LWR_2 = -1.138$$
$$LWR^2 = -0.118$$
$$LN(PYWTSEA) = -2.102$$

Conversions to size-preference function: Mean = 4.1
SD = 2.06

Figure 2.8.1a-h The total and spawning stock biomass from the
                 MSVPA and single-species VPA

          1 = MSVPA estimate of total biomass

          2 = MSVPA estimate of spawning stock biomass

          3 = Single-species VPA estimate of total biomass

          4 = Single-species VPA estimate of spawning
              stock biomass

Figure 2.8.1a (see legend page)

COD

Figure 2.8.1b (see legend page)
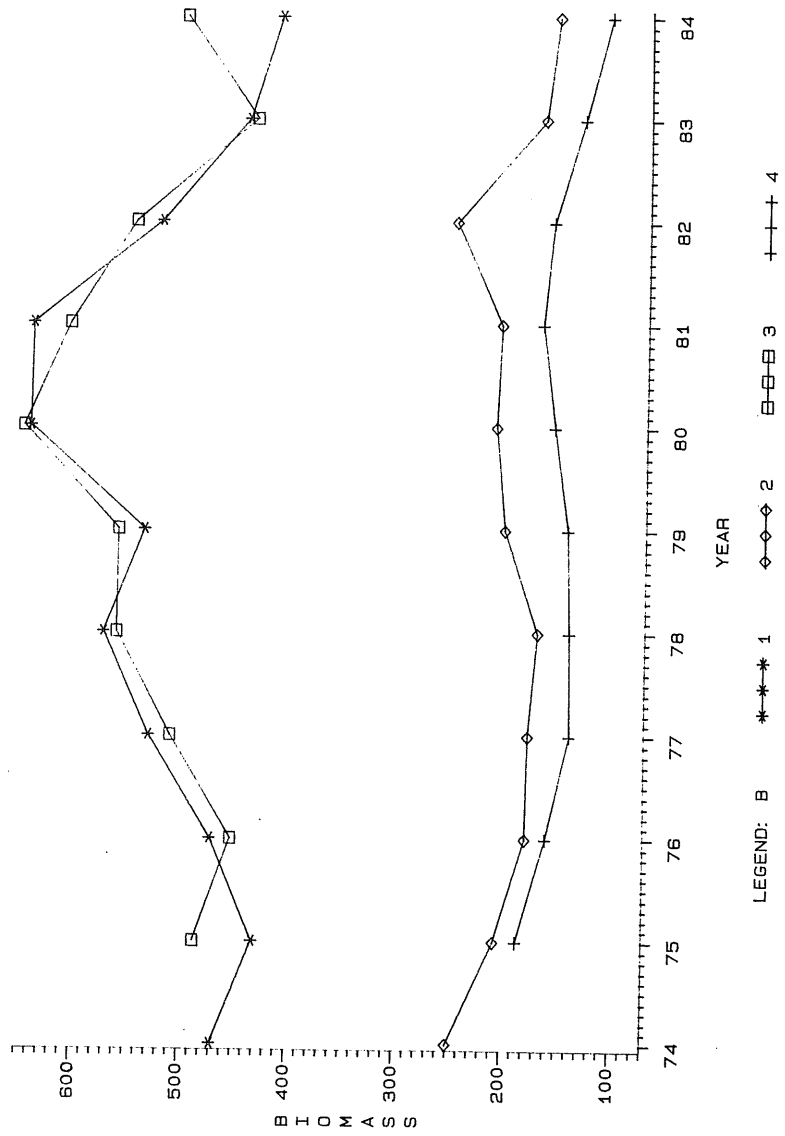
WHITING

Figure 2.8.1c (see legend page)
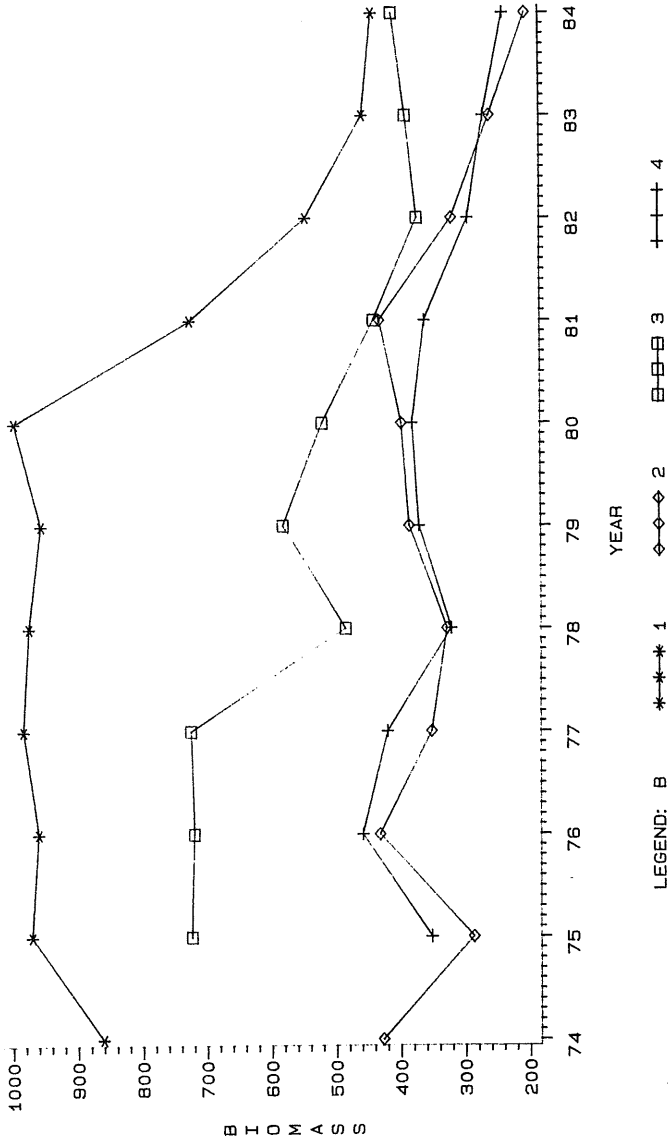
HADDOCK

Figure 2.8.1d (see legend page)

SAITHE
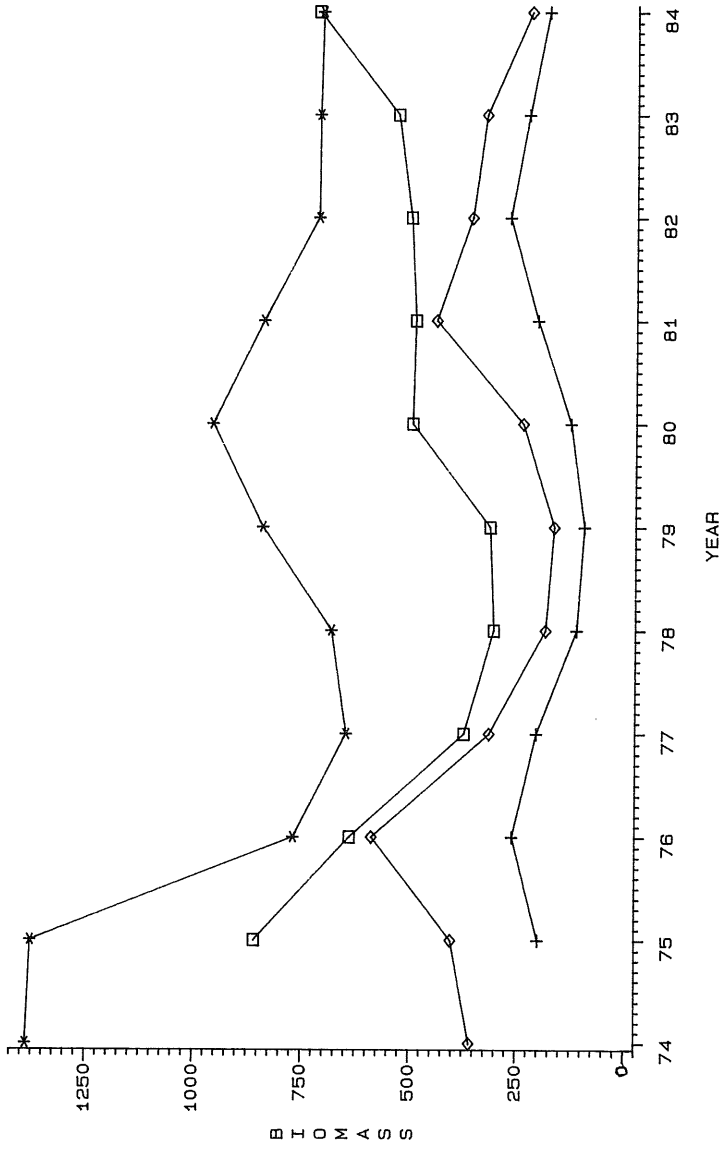
LEGEND: B   ✳✳✳ 1   ◇◇◇ 2   ▱▱▱ 3   +++ 4
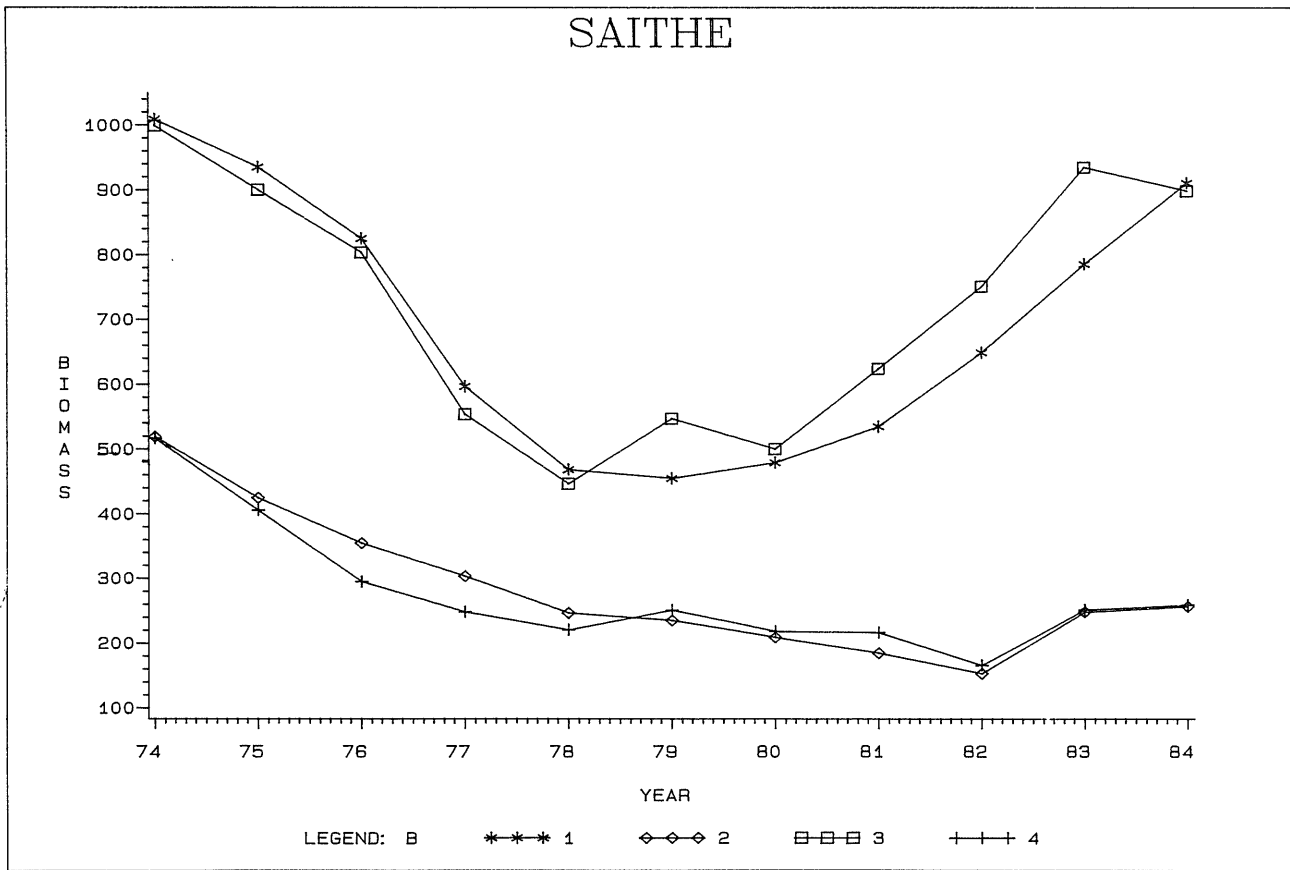
Figure 2.8.1e (see legend page)

MACKEREL
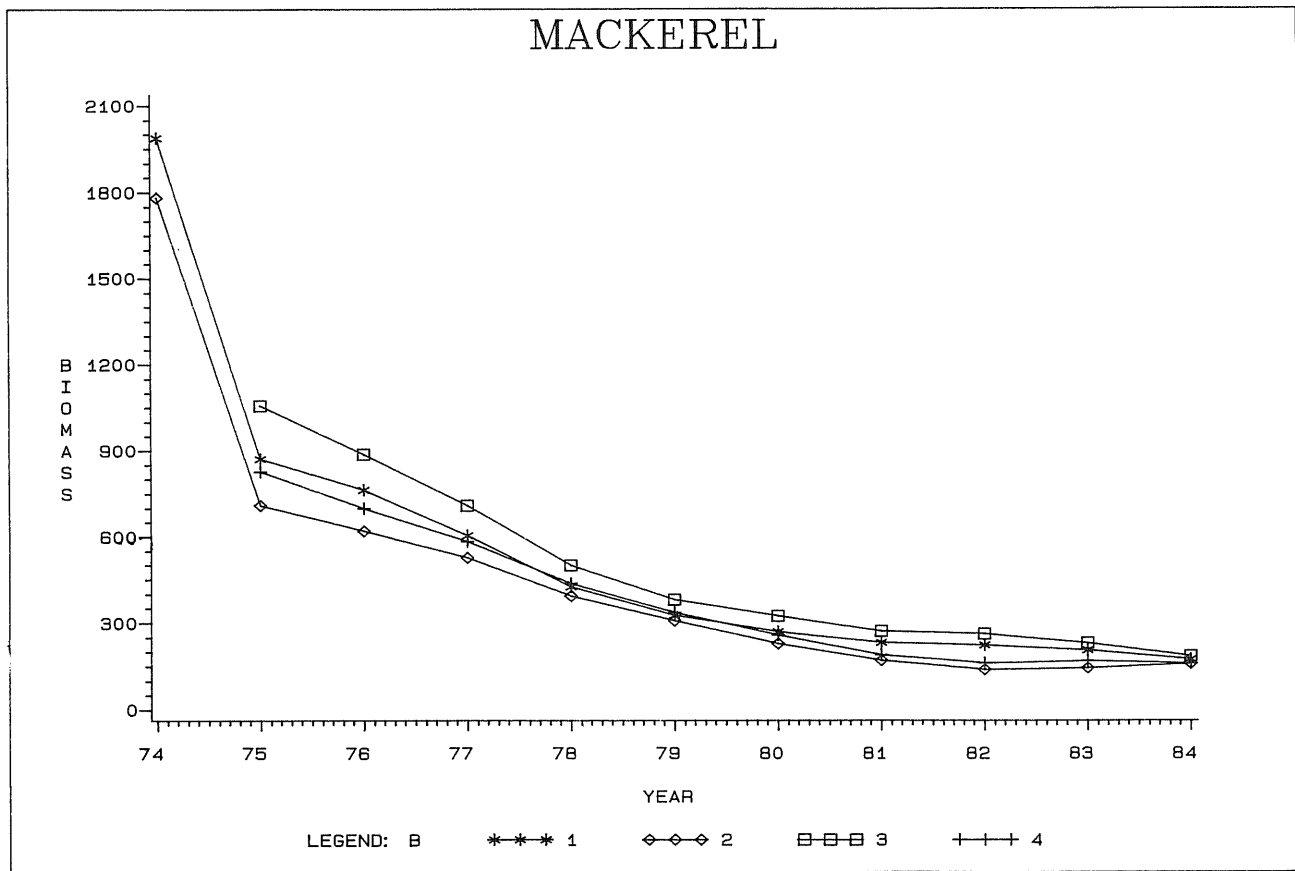
HERRING

Figure 2.8.1g (see legend page)

SPRAT
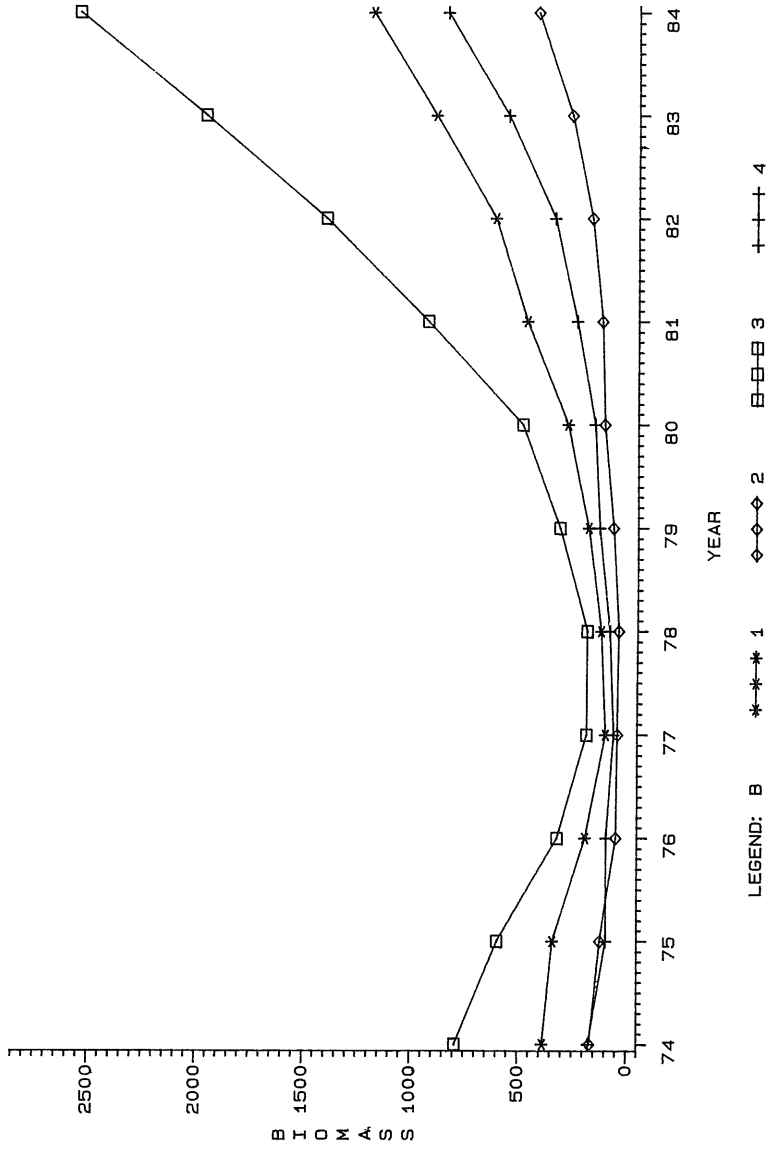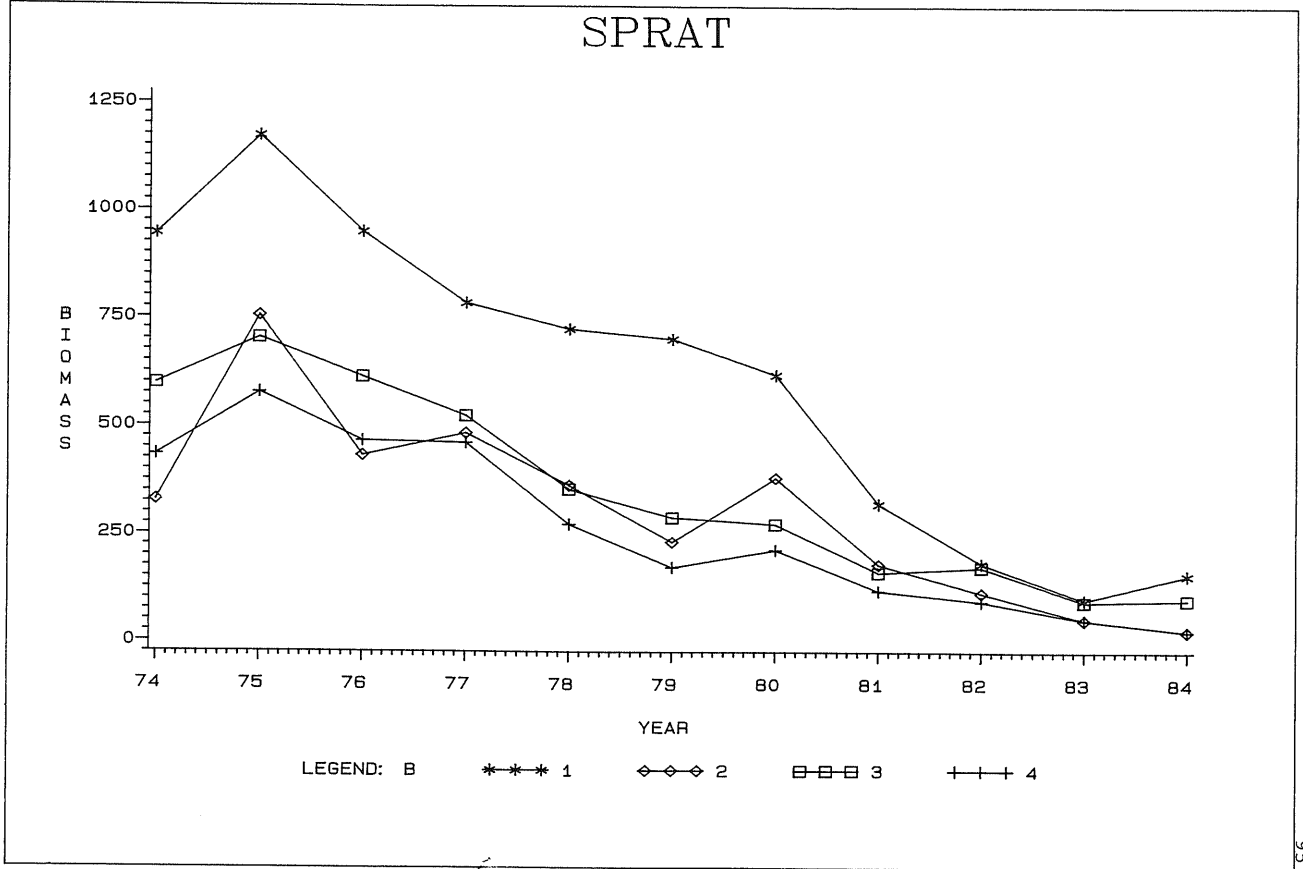
Figure 2.8.1h (see legend page)
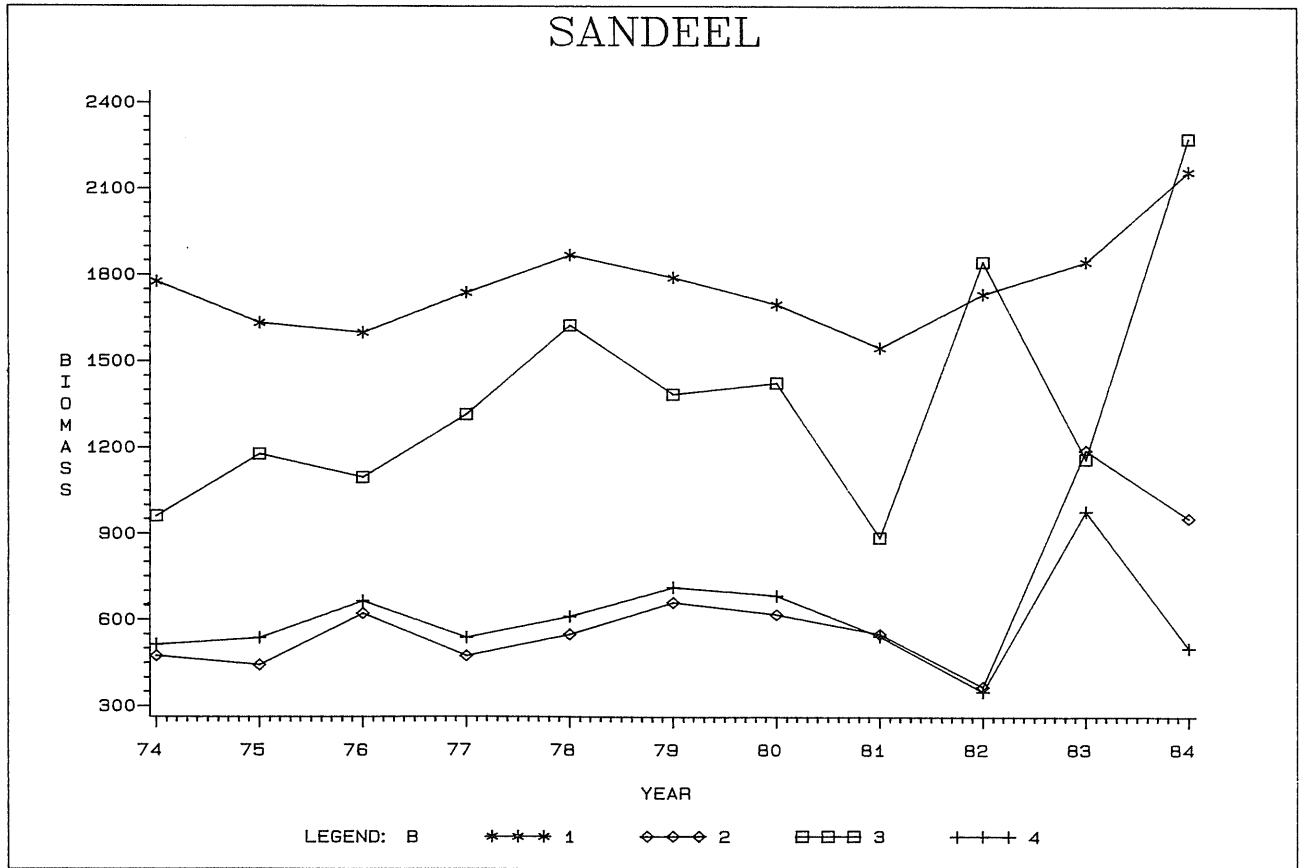
SANDEEL

Figure 2.8.28 The mean of the ratio between numbers at age in the MSVPA and in the single species VPA for the years 1974-82 for Cod, Haddock and Whiting.
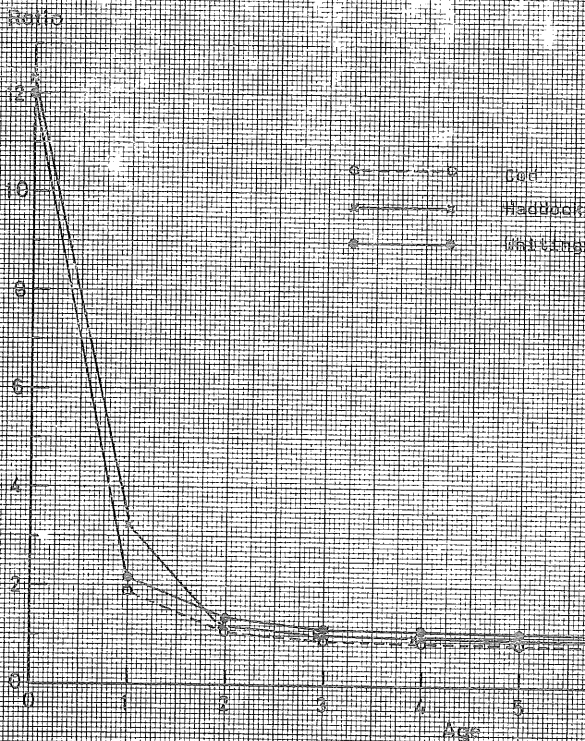
Figure 2.6.2b The mean of the ratio between numbers at age in the MSVPA and in the single species VPAs for the years 1974-84 for herring, sprat, Norway pout and sandeel.
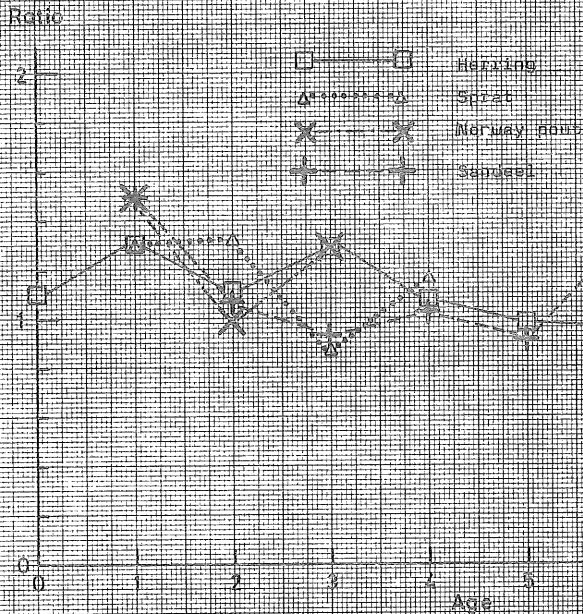
Figure 5.2.1 North Sea cod, correlations between NEWGA, WB and IYFS estimates of 1-year-old fish.

Figure 31.2.2. North Sea haddock: correlations between NSVPA, US and IYFS estimates of 1-year-old fish.

Figure 3.2.3 Noisei and national correlations between TOTSA N(W0)A, IMFS and IMFS catamaged by 1 yr and odd mail.

r = 0.93

r = 0.840

r = 0.906

N(W0)A

N(WS)A

IMFS
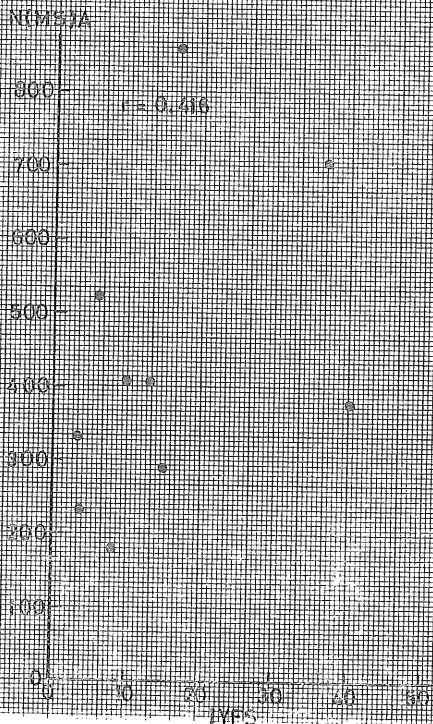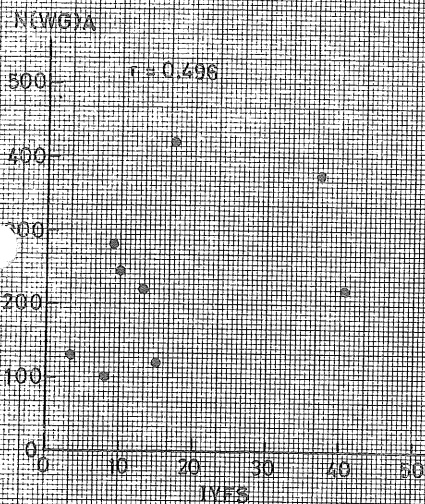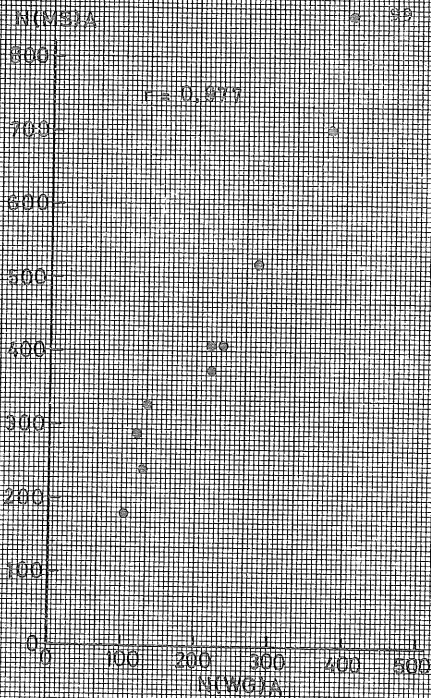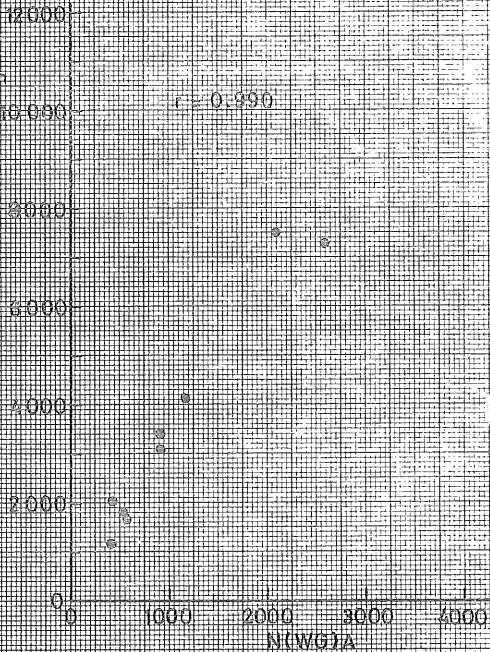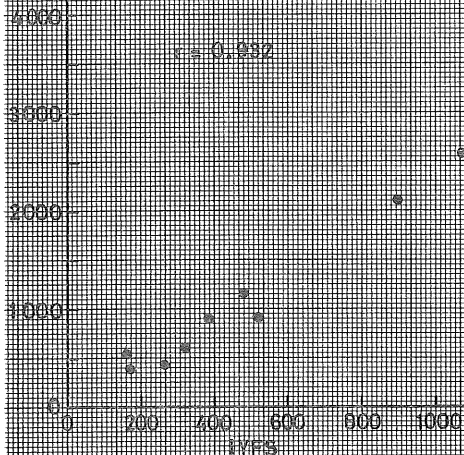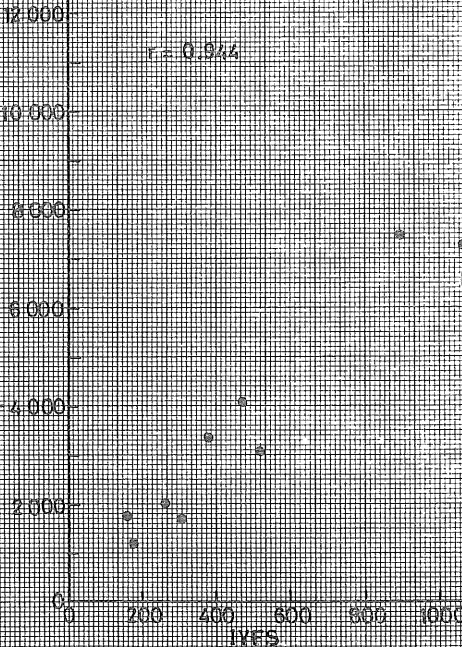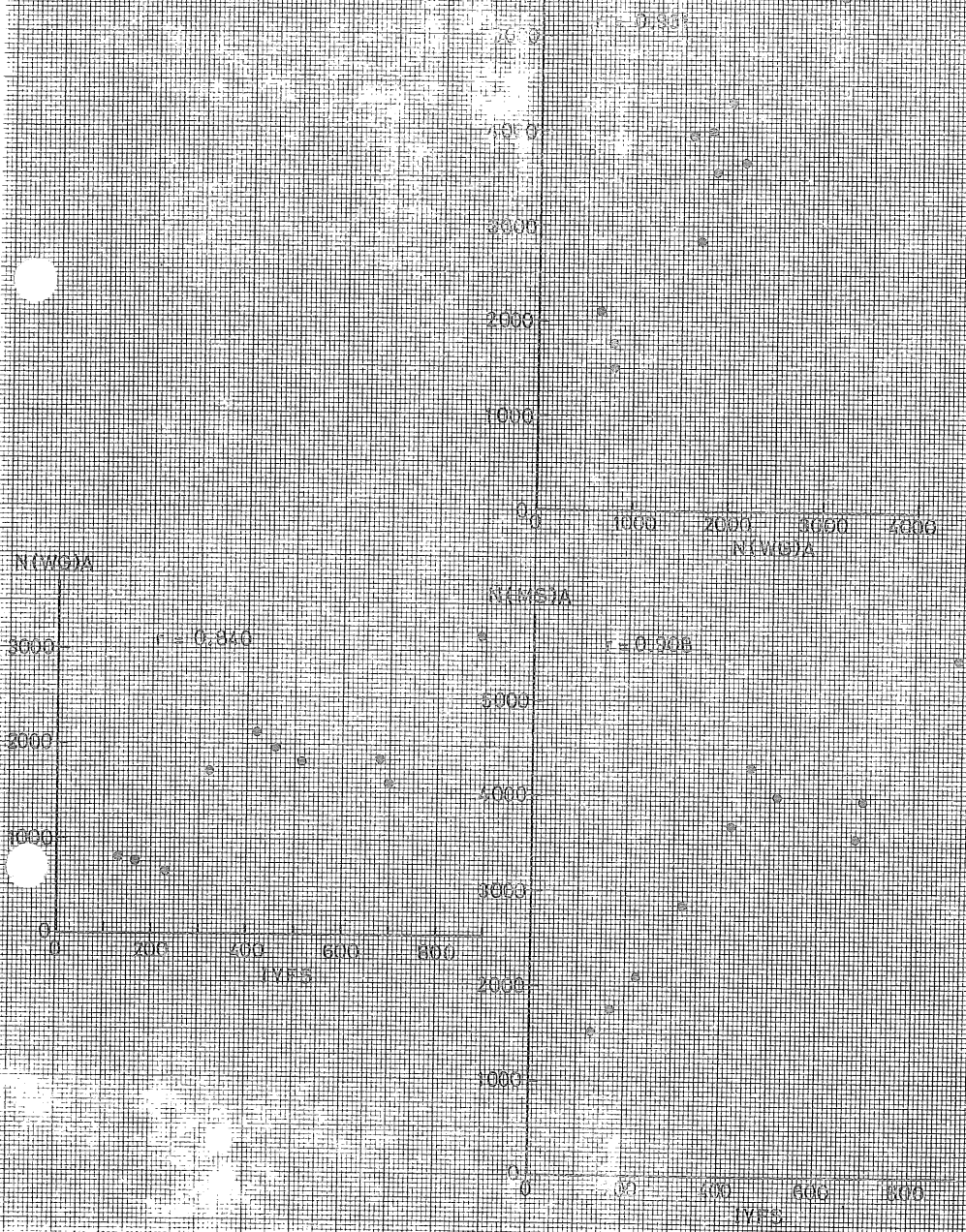
Figure 3.2.4 North Sea herring. Correlations between VPA, I/C and IYFS estimates of 1-year-old fish.

N(MS)

r = 0.907

N(WG)

N(MS)

N(WG)

r = 0.800

r = 0.920

DFS

DFS
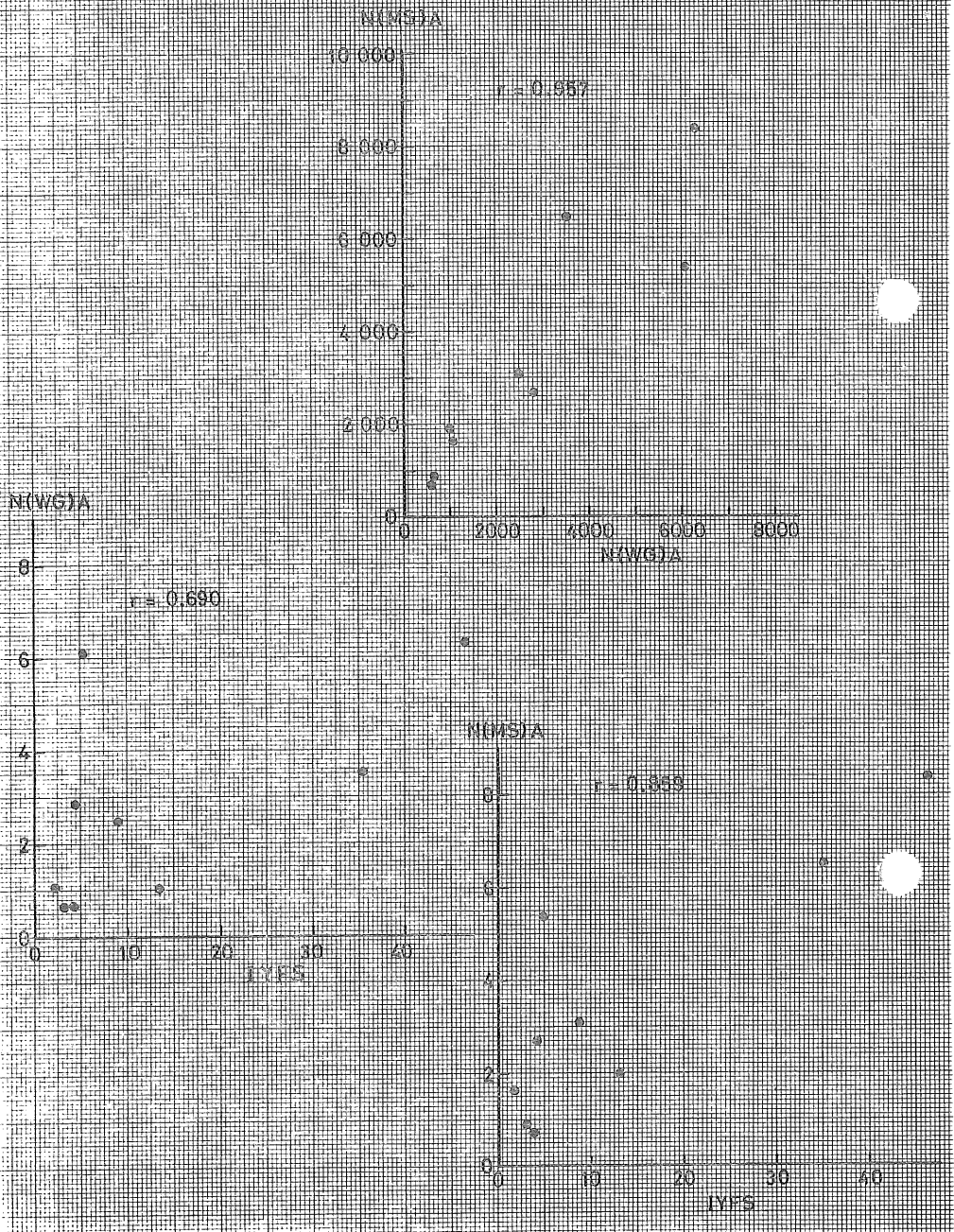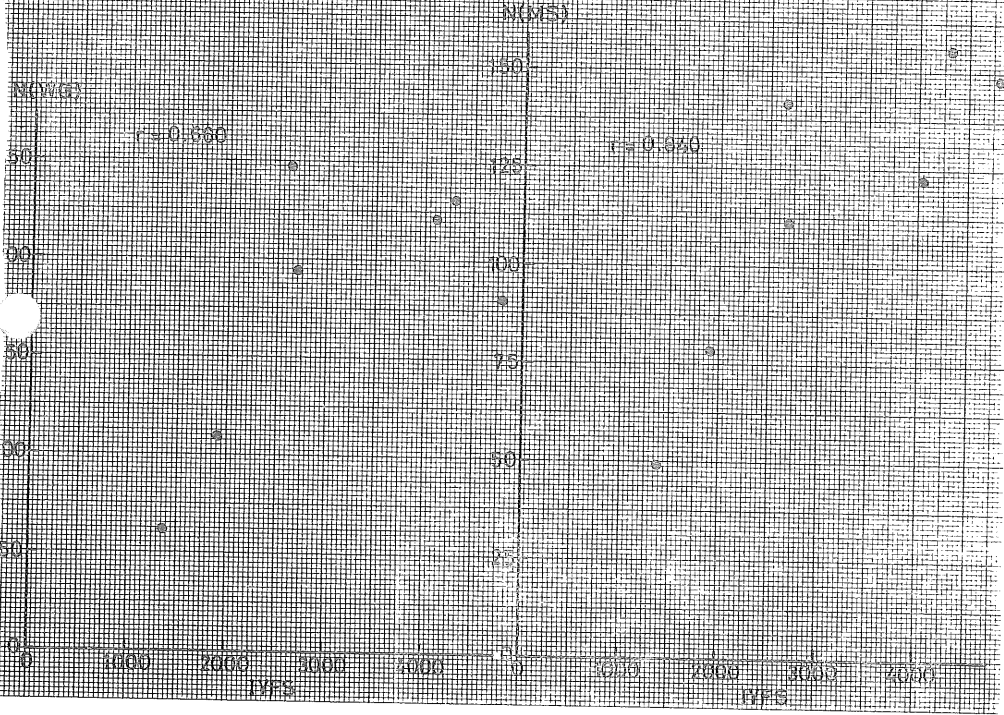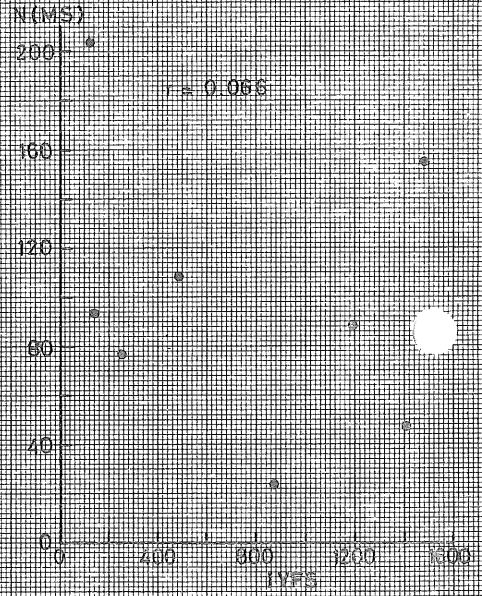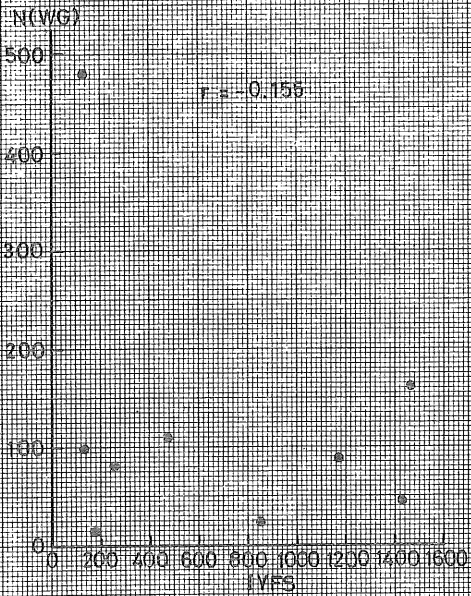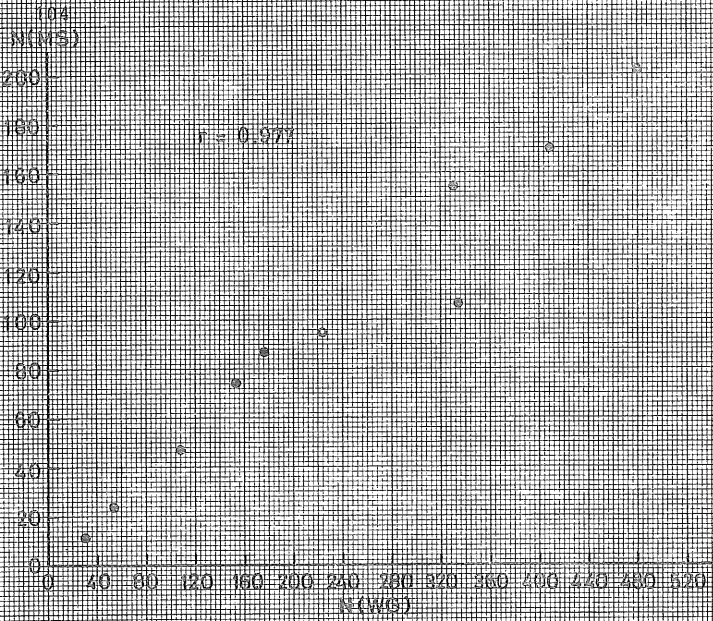
Figure 3.2.6 North Sea sprat. Correlations between MSVPA, WG and TYFS estimates of 1 year old fish.
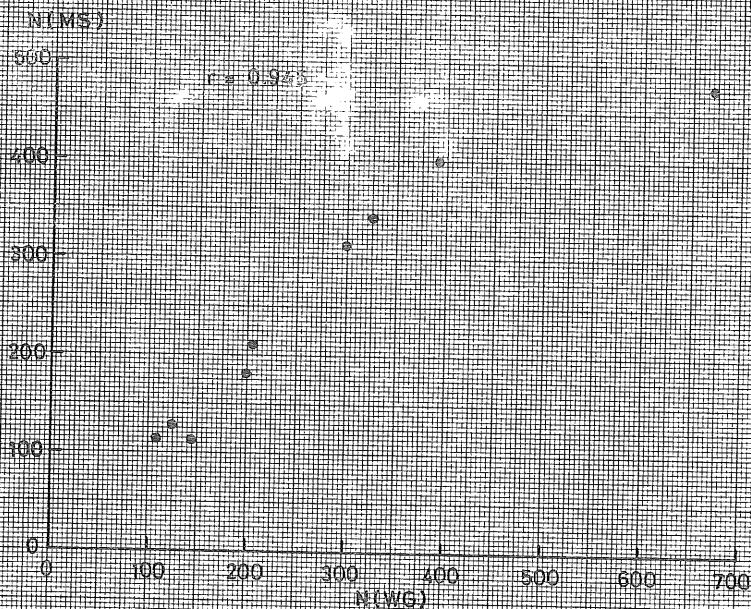
Figure 3.2.7 North Sea saithe. Correlations between MSVPA and WG estimates of 1-year old fish.

Figure 3.2.8 Sandeel (total of all three stocks). Correlation between MSVPA and WG estimates of 1-year-old fish.
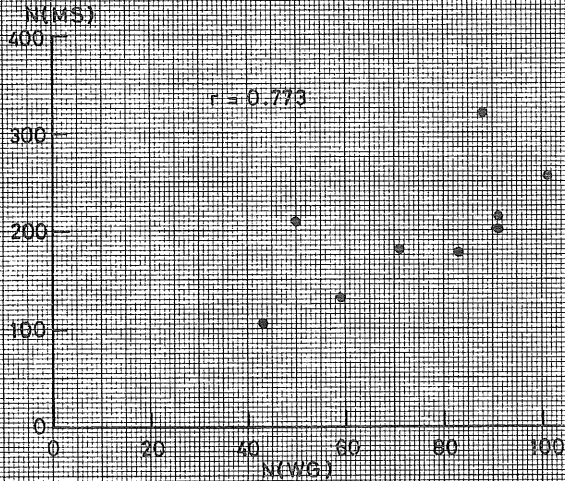
Figure 3.2.9 Mackerel. Correlation between MSVPA and WG estimates of 1-year-old fish.
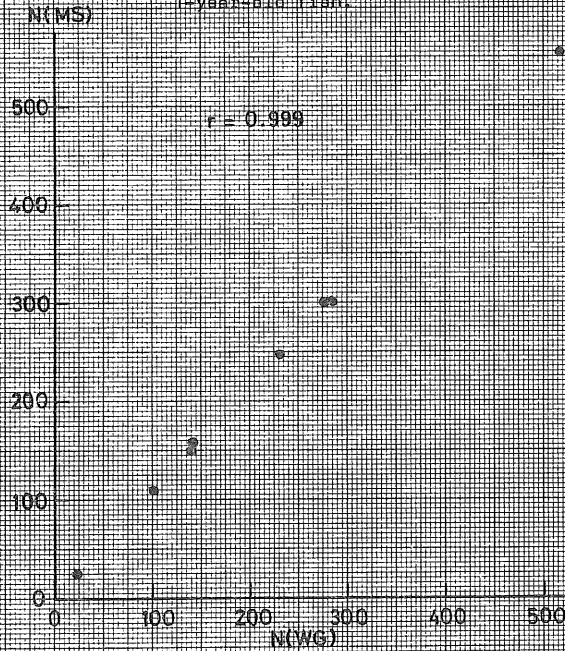
Figure 4.3.1a

HRMSJ : YIELD

Legend:
◇ COD
□ WHITING
△ SAITHE
⋈ HADDOCK
▽ HERRING
⋈ SPRAT
✕ NORWAY POUT
+ SANDEEL

TOTAL YIELD (KTONNE) vs REL F : ROUNDFISH HC FISHERY
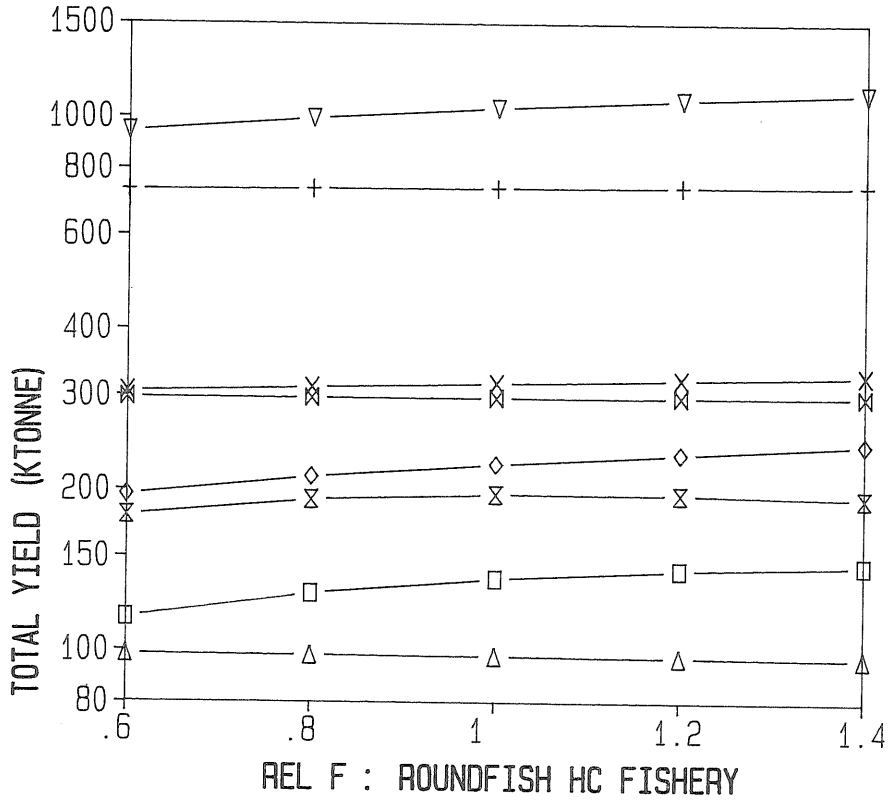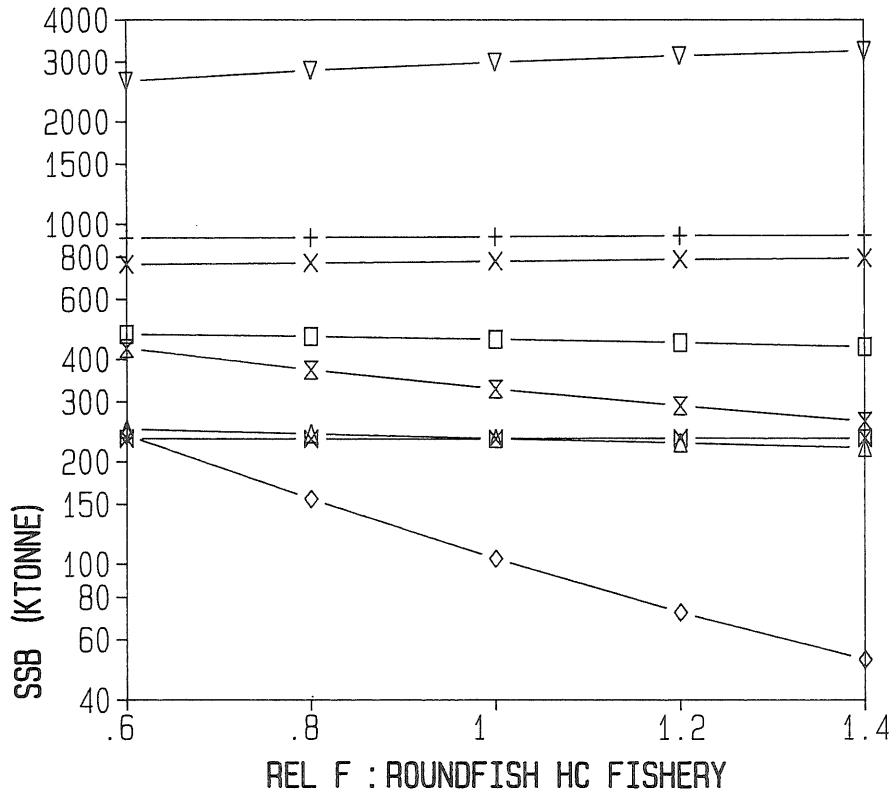
Figure 4.3.1b

HRMSJ : SSB

Figure 4.3.2a

HRMSJ : YIELD

COD
WHITING
SAITHE
HADDOCK
HERRING
SPRAT
NORWAY POUT
SANDEEL

TOTAL YIELD (KTONNE)

REL F : INDUST DEM FISHERY

Figure 4.3.2b

HRMSJ : SSB
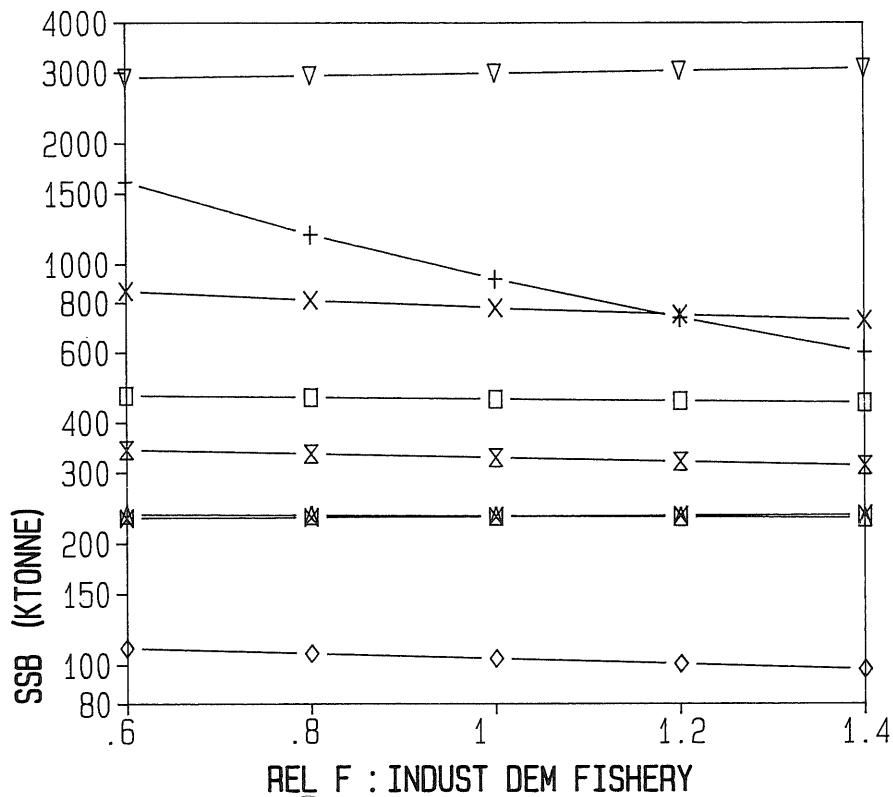
SSB (KTONNE)

REL F : INDUST DEM FISHERY

◇ COD
□ WHITING
△ SAITHE
⊠ HADDOCK
▽ HERRING
⋈ SPRAT
✕ NORWAY POUT
+ SANDEEL

110

Figure 4.3.3a

HRMSJ : YIELD
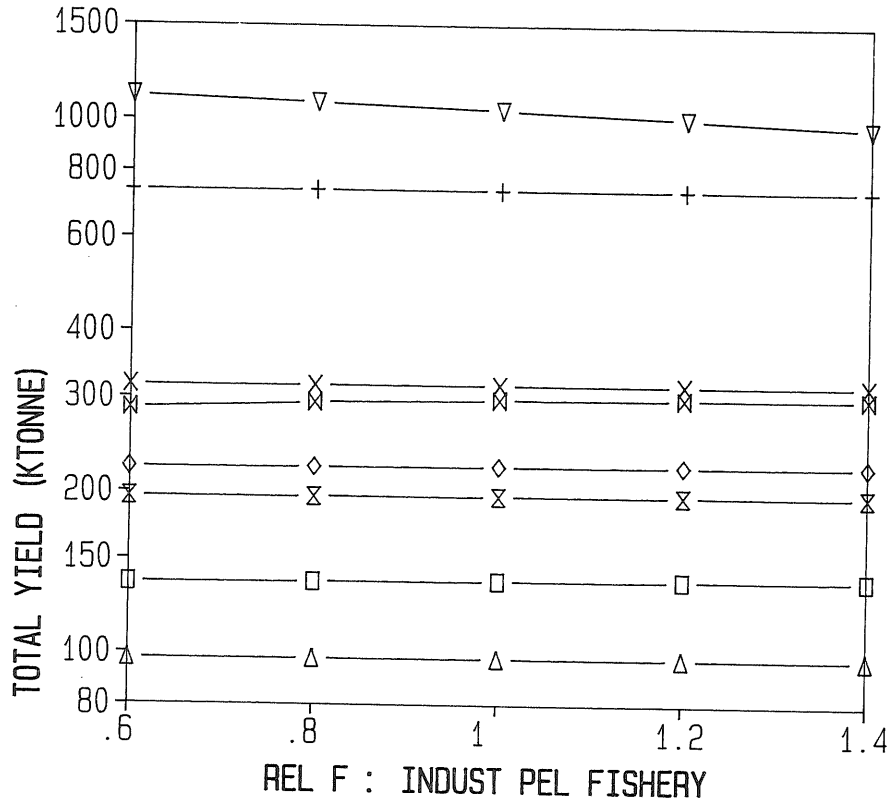
Legend:
◇ COD
□ WHITING
△ SAITHE
⋈ HADDOCK
▽ HERRING
⋈ SPRAT
✕ NORWAY POUT
+ SANDEEL

Y-axis: TOTAL YIELD (KTONNE)
X-axis: REL F : INDUST PEL FISHERY

Figure 4.3.3b

HRMSJ : SSB

Legend:
◇ COD
□ WHITING
△ SAITHE
⋈ HADDOCK
▽ HERRING
⋈ SPRAT
✕ NORWAY POUT
+ SANDEEL
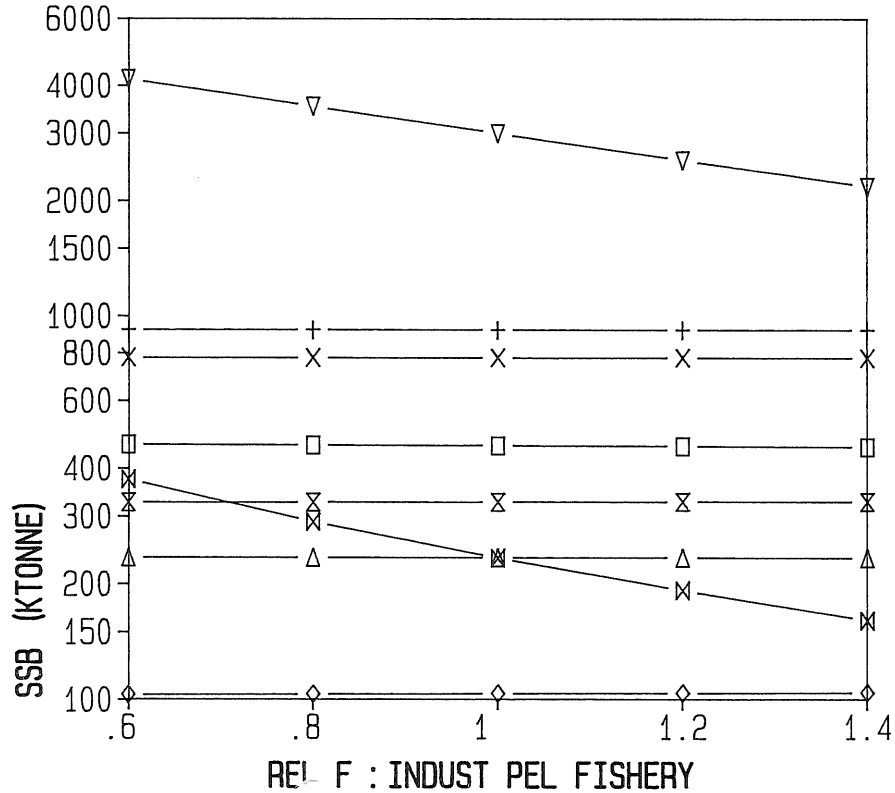
Figure 4.3.4a
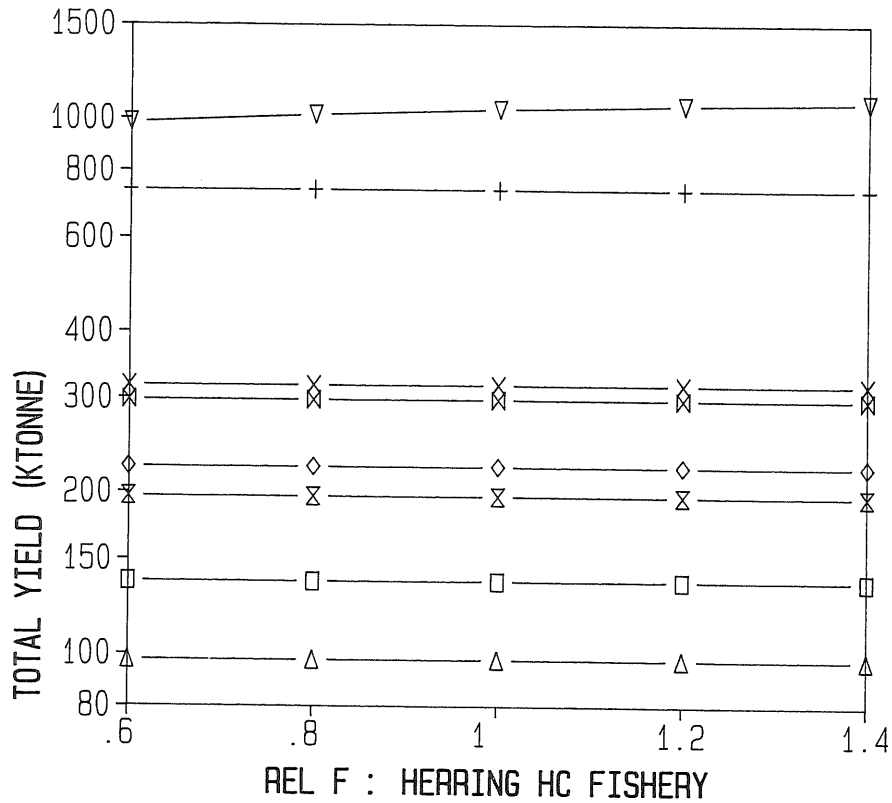
HRMSJ : YIELD

◇ COD
□ WHITING
△ SAITHE
⊠ HADDOCK
▽ HERRING
⋈ SPRAT
✕ NORWAY POUT
+ SANDEEL

Figure 4.3.4b

HRMSJ : SSB
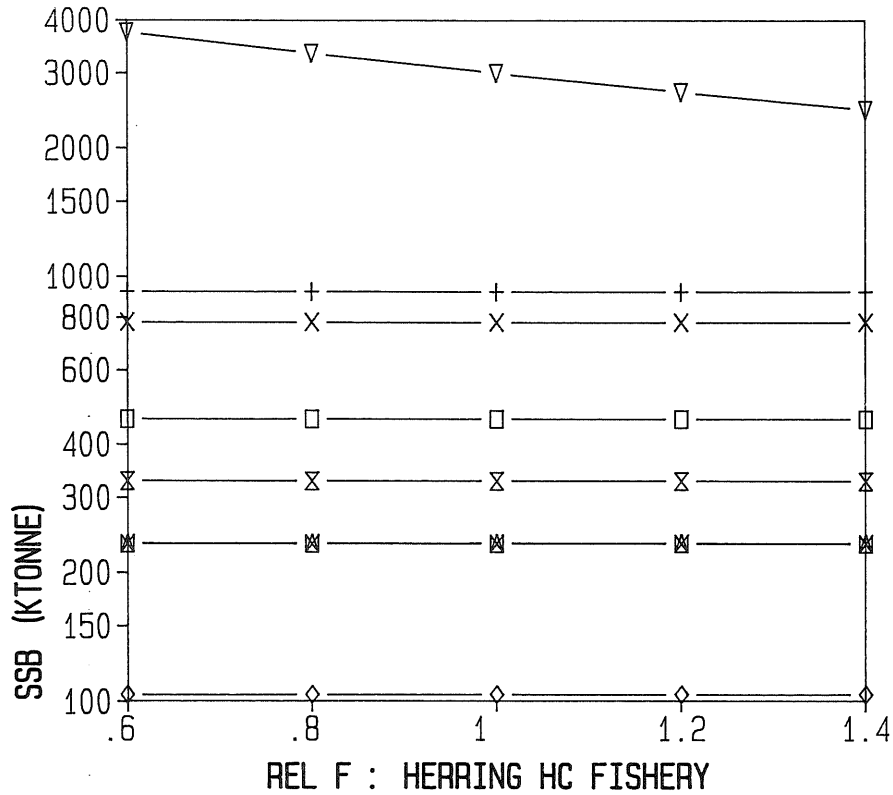
◇ COD
□ WHITING
△ SAITHE
⊠ HADDOCK
▽ HERRING
⋈ SPRAT
× NORWAY POUT
+ SANDEEL
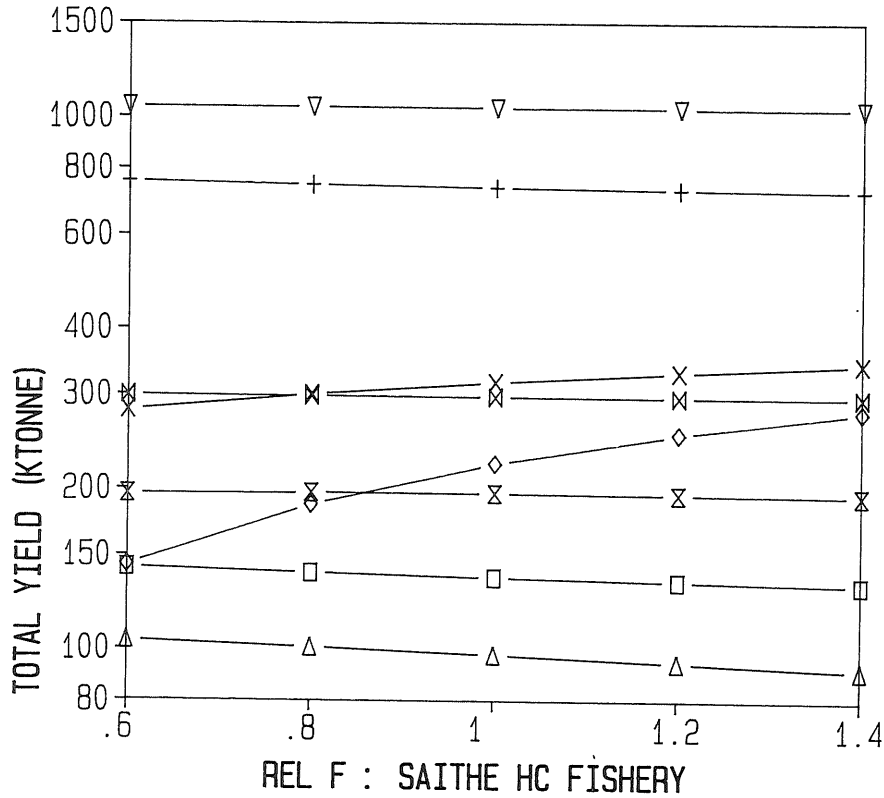
114

SSB (KTONNE)

REL F : HERRING HC FISHERY

Figure 4.3.5a

HRMSJ : YIELD

Figure 4.3.5b

HRMSJ : SSB

Legend:
- ◇ COD
- □ WHITING
- △ SAITHE
- ⊠ HADDOCK
- ▽ HERRING
- ⋈ SPRAT
- × NORWAY POUT
- + SANDEEL

Y-axis: SSB (KTONNE)
X-axis: REL F : SAITHE HC FISHERY
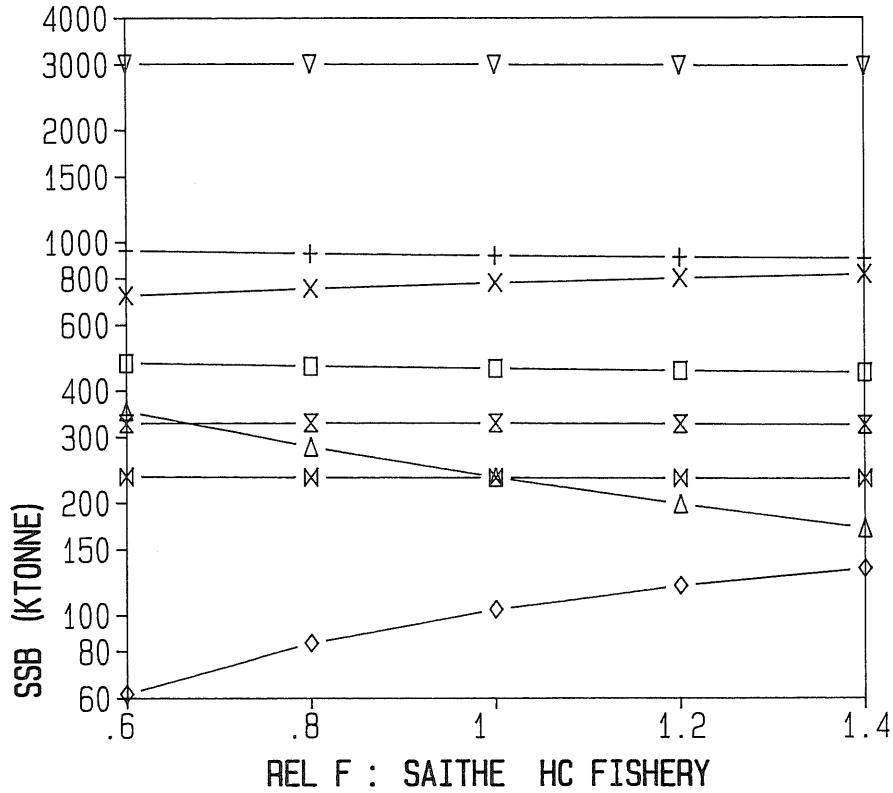
Figure 4.3.6a

HRMSJ : YIELD

◇ COD
□ WHITING
△ SAITHE
⧖ HADDOCK
▽ HERRING
⋈ SPRAT
✕ NORWAY POUT
+ MACKEREL

TOTAL YIELD (KTONNE)

REL F : MACKEREL HC FISHERY

Figure 4.3.6b

HRMSJ : SSB

REL F : MACKEREL HC FISHERY

SSB (KTONNE)
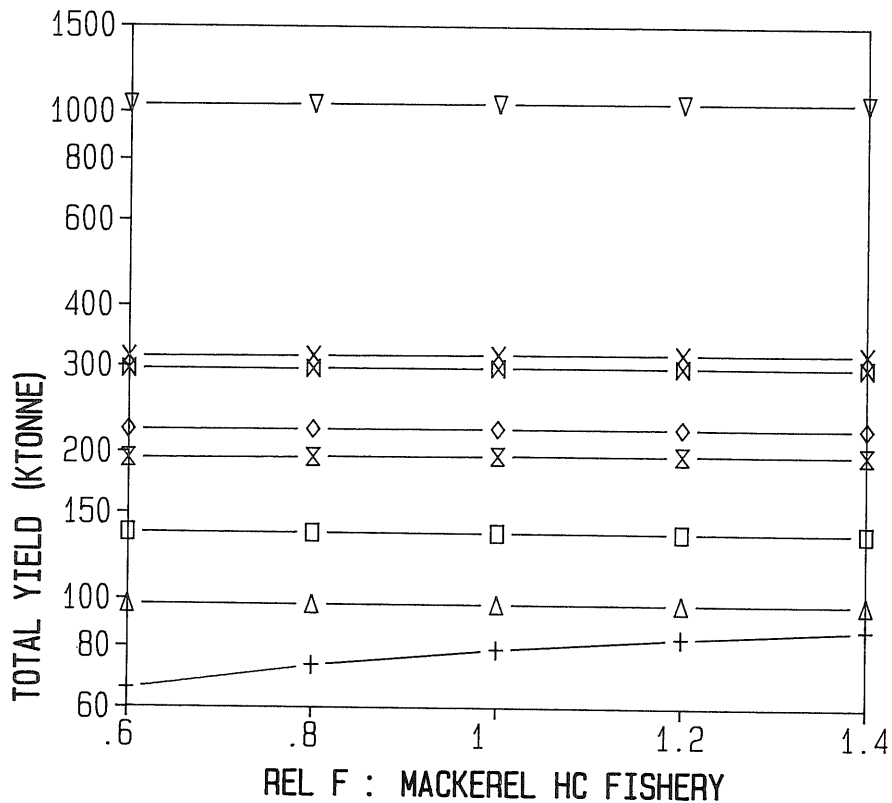
◇ COD
□ WHITING
△ SAITHE
⧓ HADDOCK
▽ HERRING
⋈ SPRAT
× NORWAY POUT
+ MACKEREL

Figure 4.3.7a

HRMSJ
EXC PRED
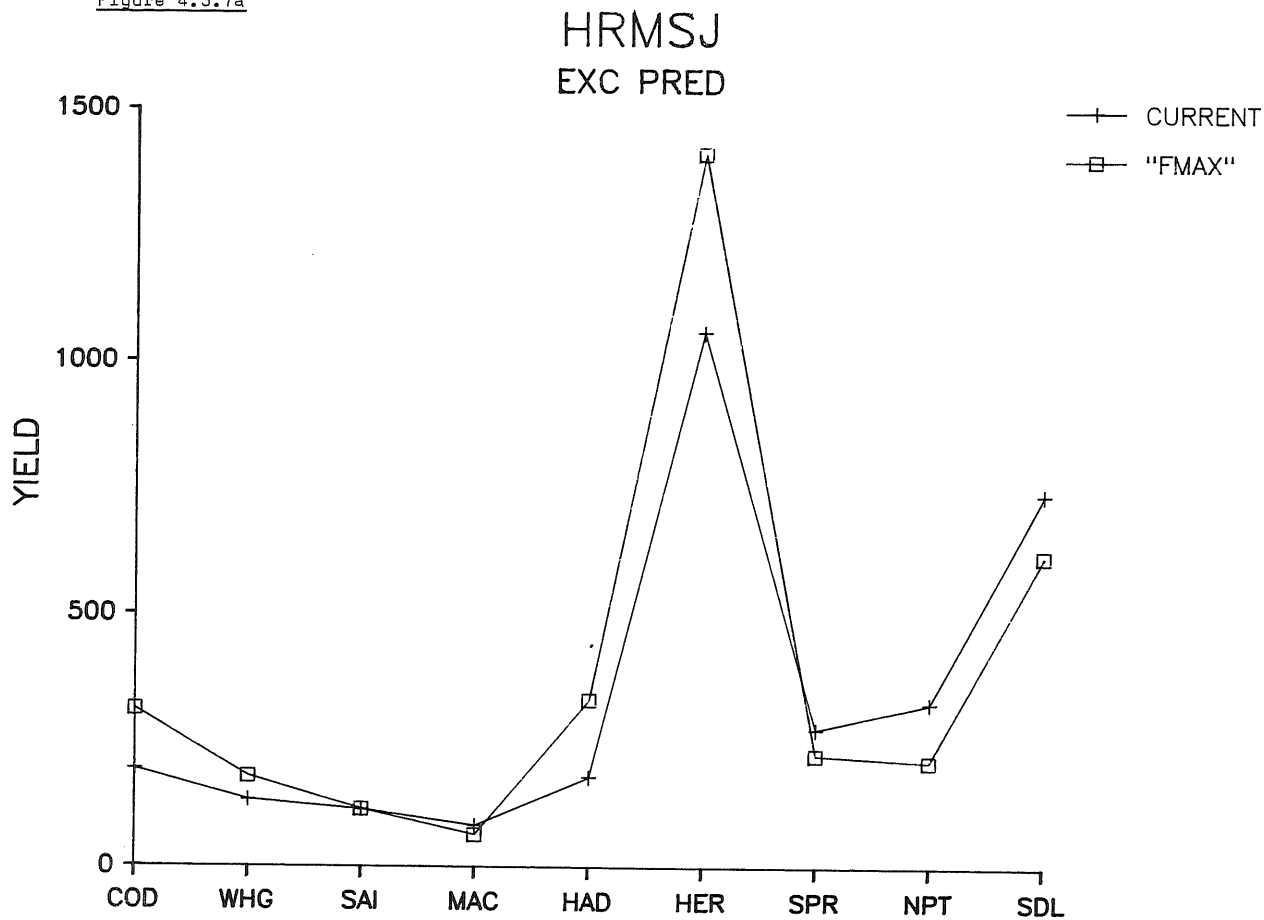
Figure 4.3.7b
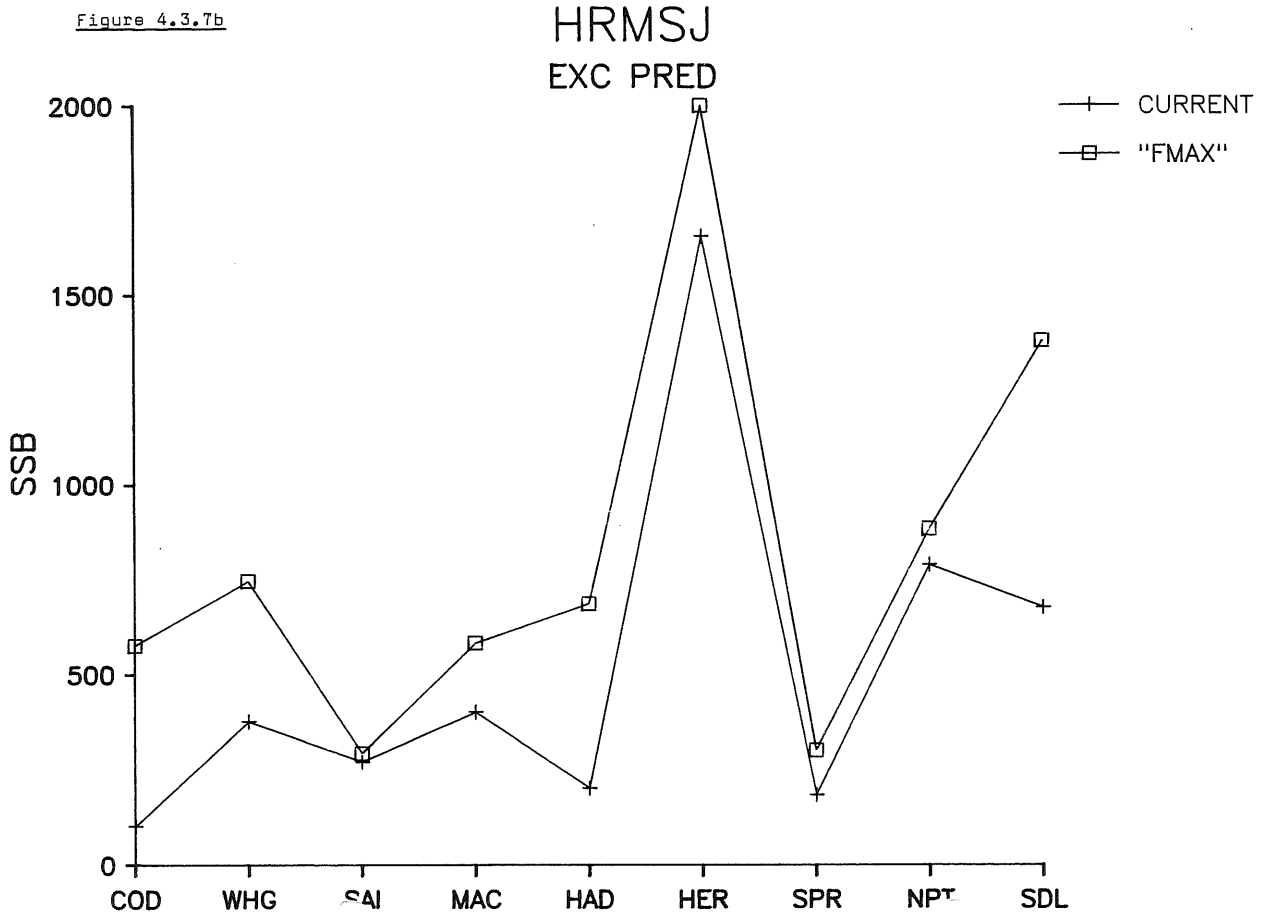
HRMSJ
EXC PRED

Figure 4.3.8a

HRMSJ
INC PRED

CURRENT
"FMAX"

YIELD

1500

1000

500

0

COD   WHG   SAI   MAC   HAD   HER   SPR   NPT   SDL
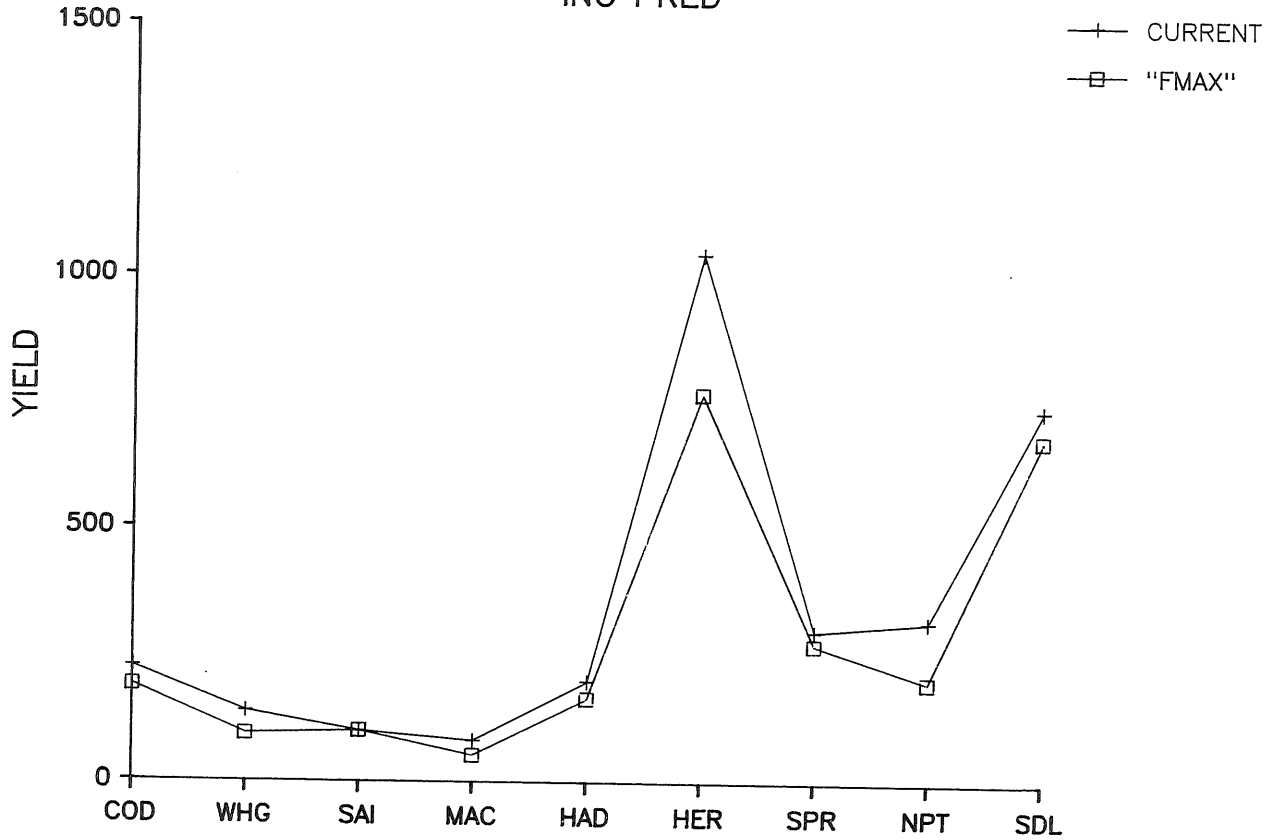
Figure 4.3.8b

HRMSJ
INC PRED

Figure 4.3.9

HRMSJ
Predation Mortalities

Legend:
- ◇ COD
- □ WHITING
- △ MACKEREL
- ⋈ HADDOCK
- ▽ HERRING
- ⋈ SPRAT
- × NORWAY POUT
- + SANDEEL
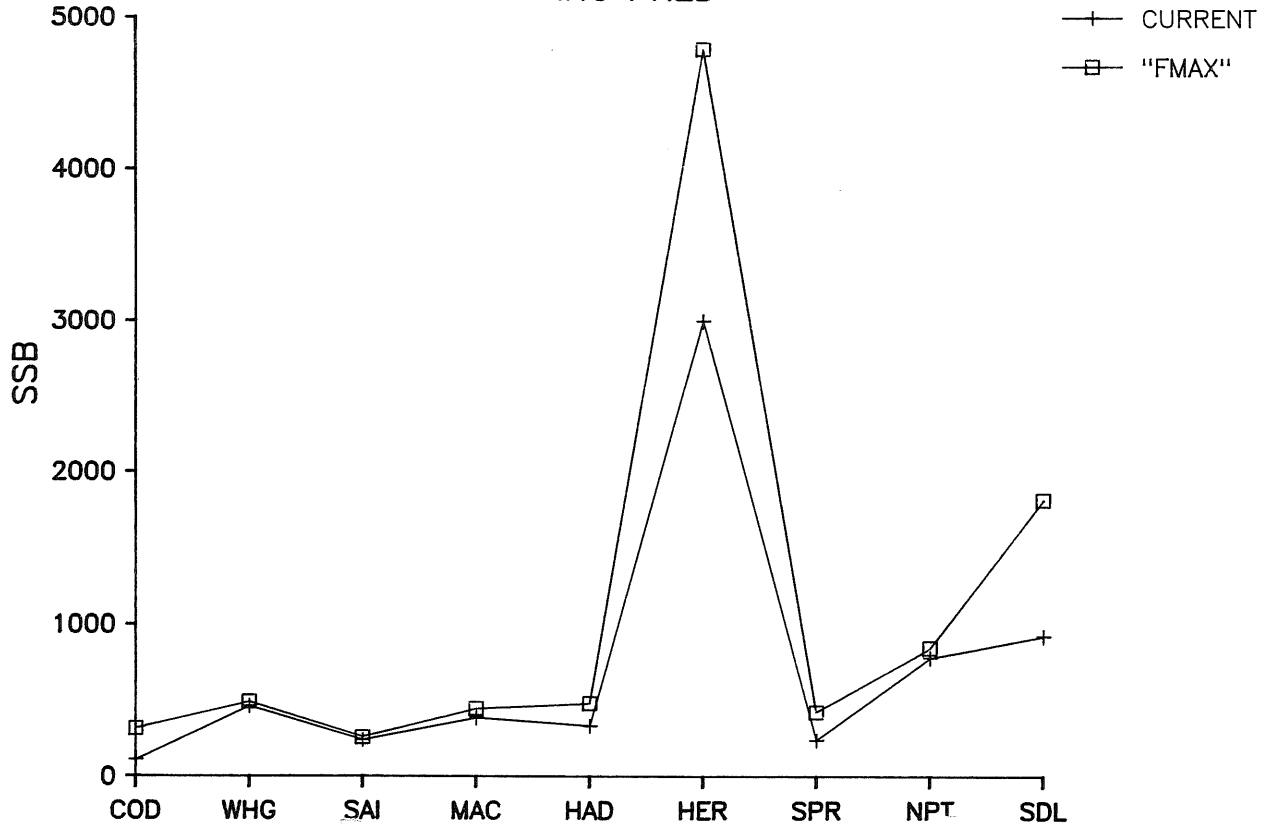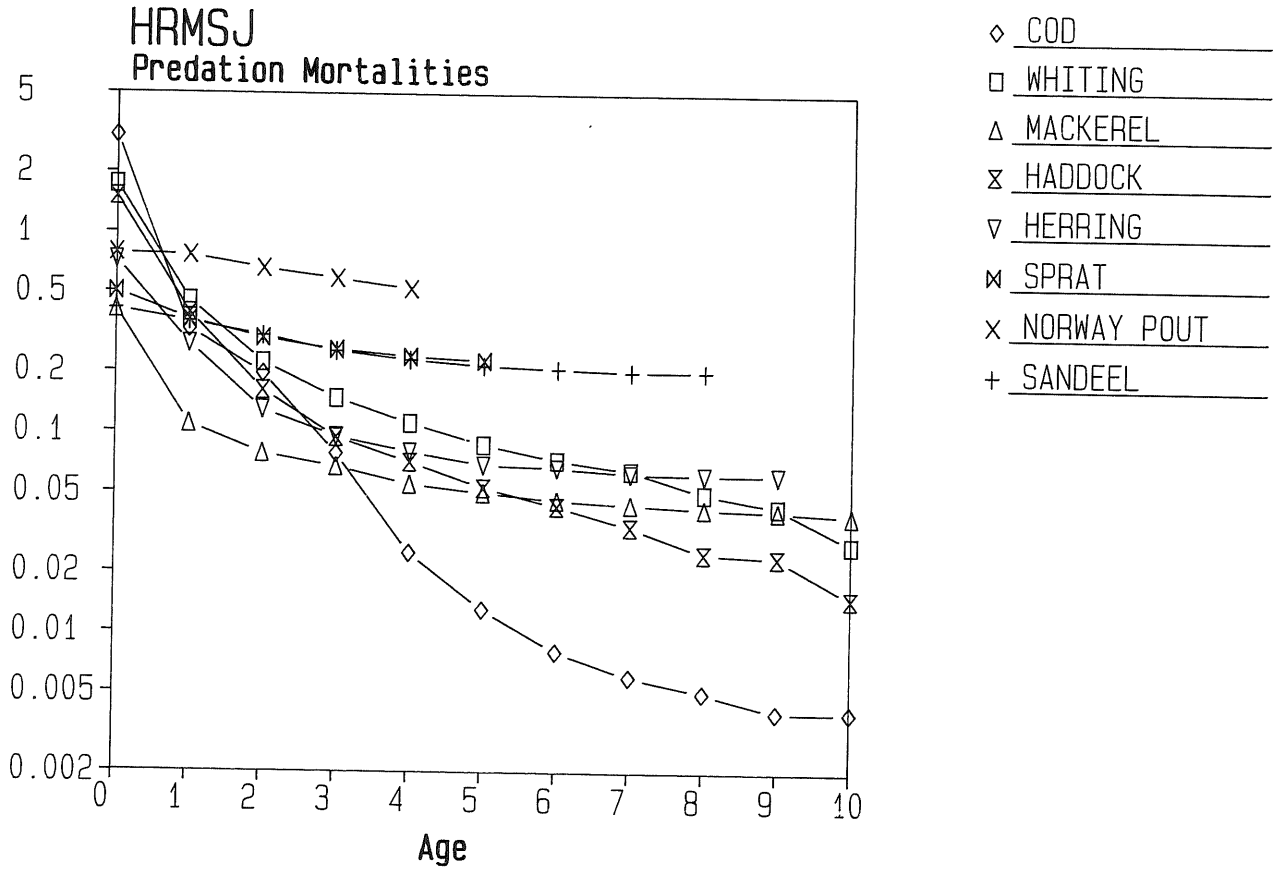
Figure 6.2.1a-g Biomass consumed by predators.

    C = cod
    W = whiting
    S = saithe
    M = mackerel
    H = haddock
    T = total
    B = standing biomass
    Y = yield

Figure 6.2.1a (see legend page)

COD CONSUMED (PER PREDATOR AND TOTAL), BIOMASS AND YIELD
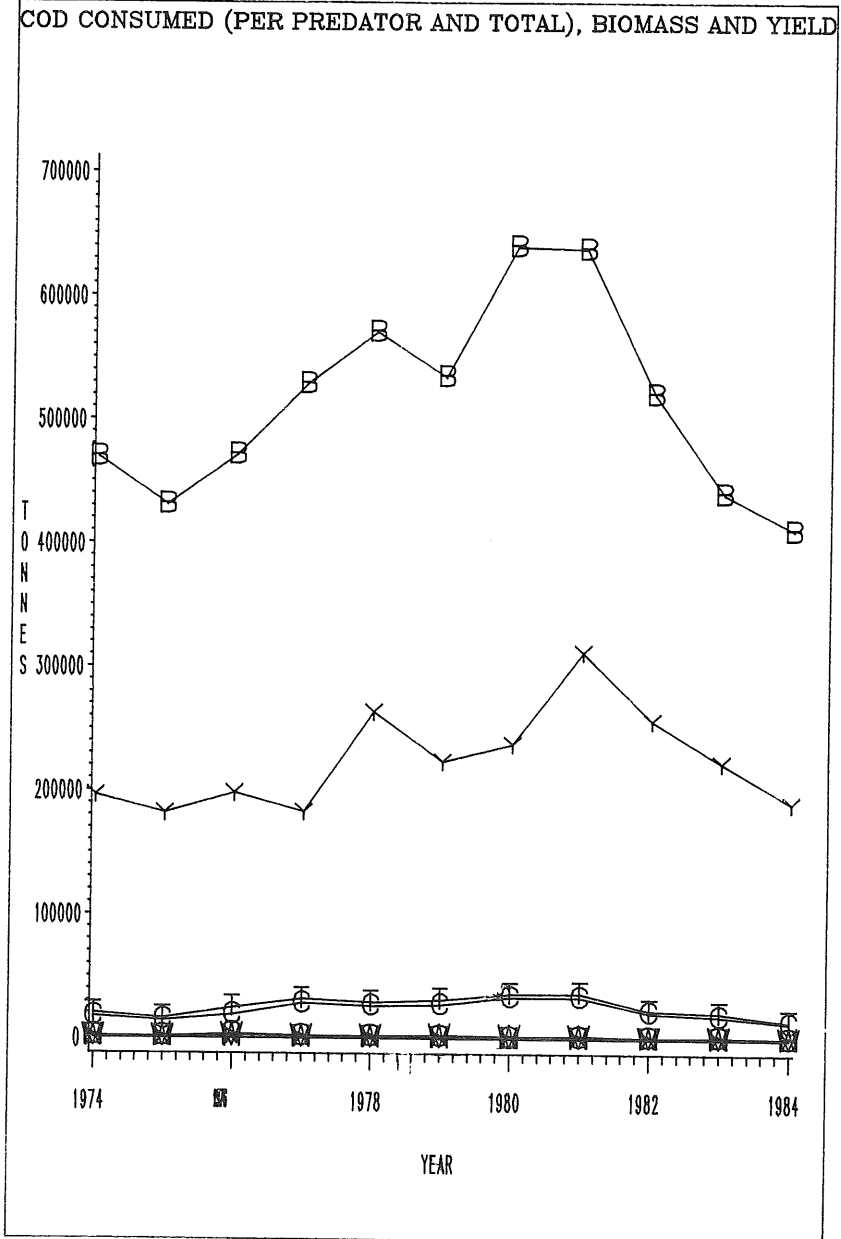
Figure 6.2.1b (see legend page)

WHITING CONSUMED (PER PREDATOR AND TOTAL), BIOMASS AND YIELD
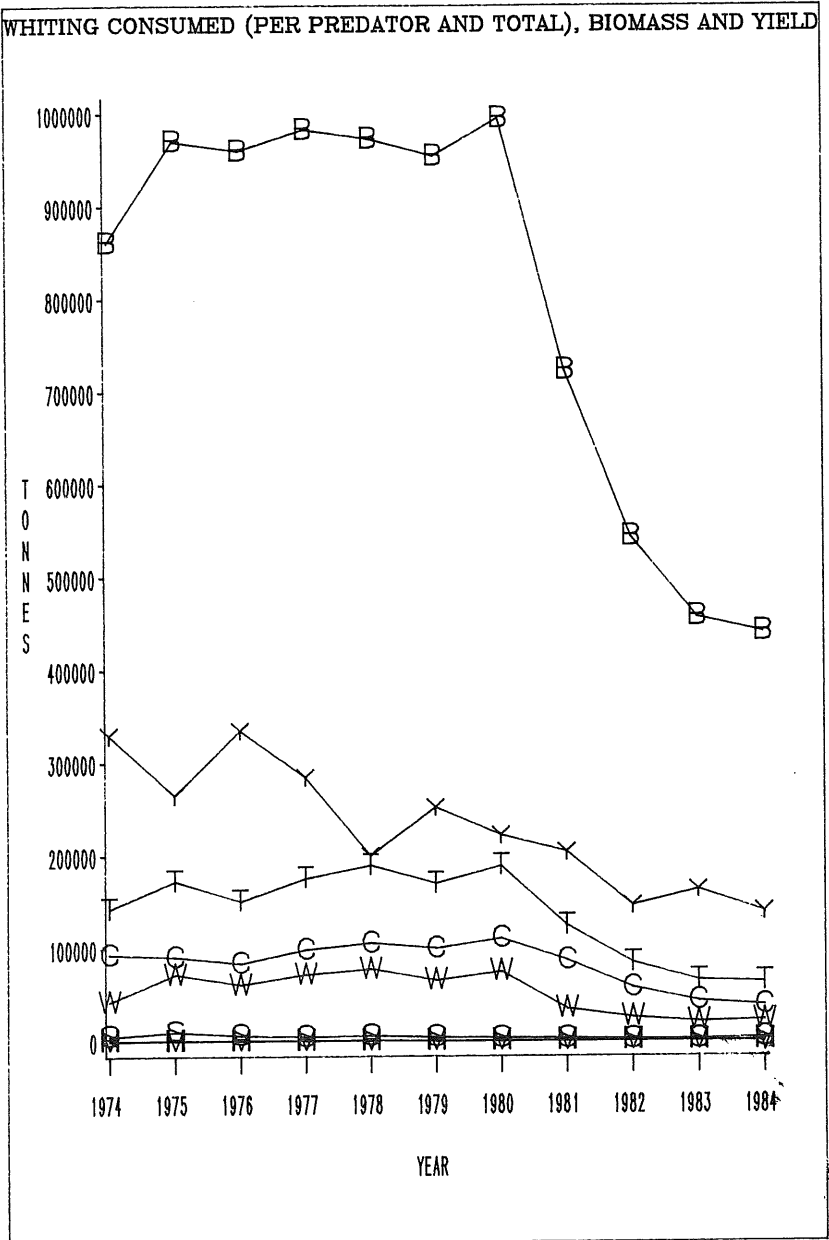
Figure 6.2.1c (see legend page)

HADDOCK CONSUMED (PER PREDATOR AND TOTAL), BIOMASS AND YIELD
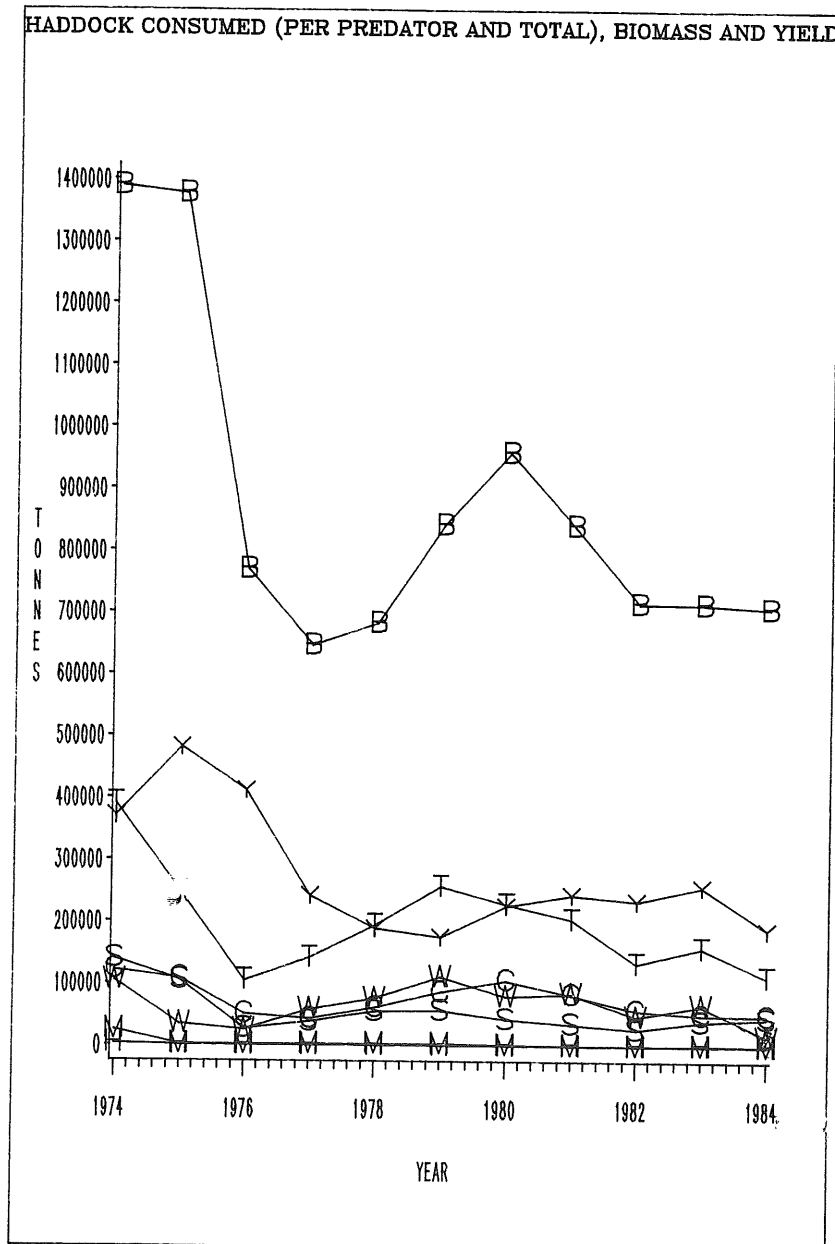
Figure 6.2.1d (see legend page)

HERRING CONSUMED (PER PREDATOR AND TOTAL), BIOMASS AND YIELD
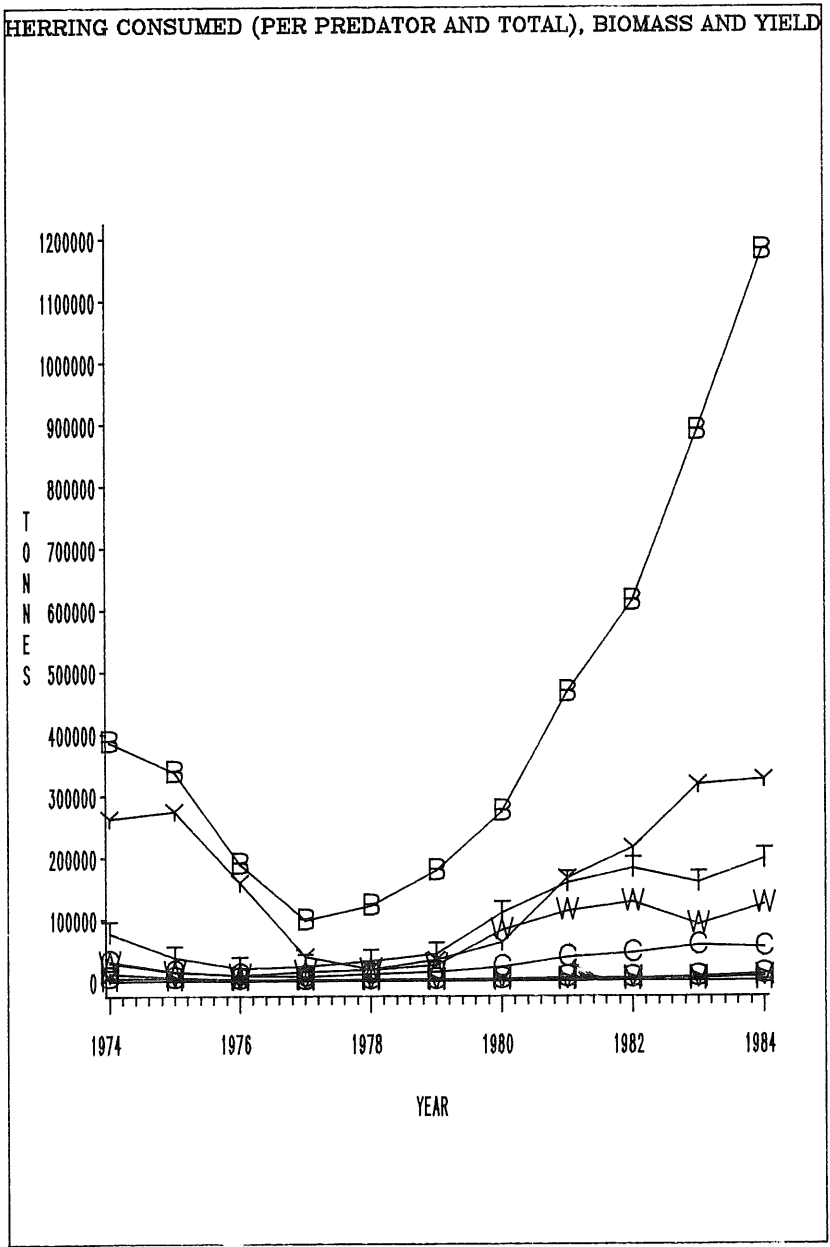
Figure 6.2.1e (see legend page)

SPRAT CONSUMED (PER PREDATOR AND TOTAL), BIOMASS AND YIELD
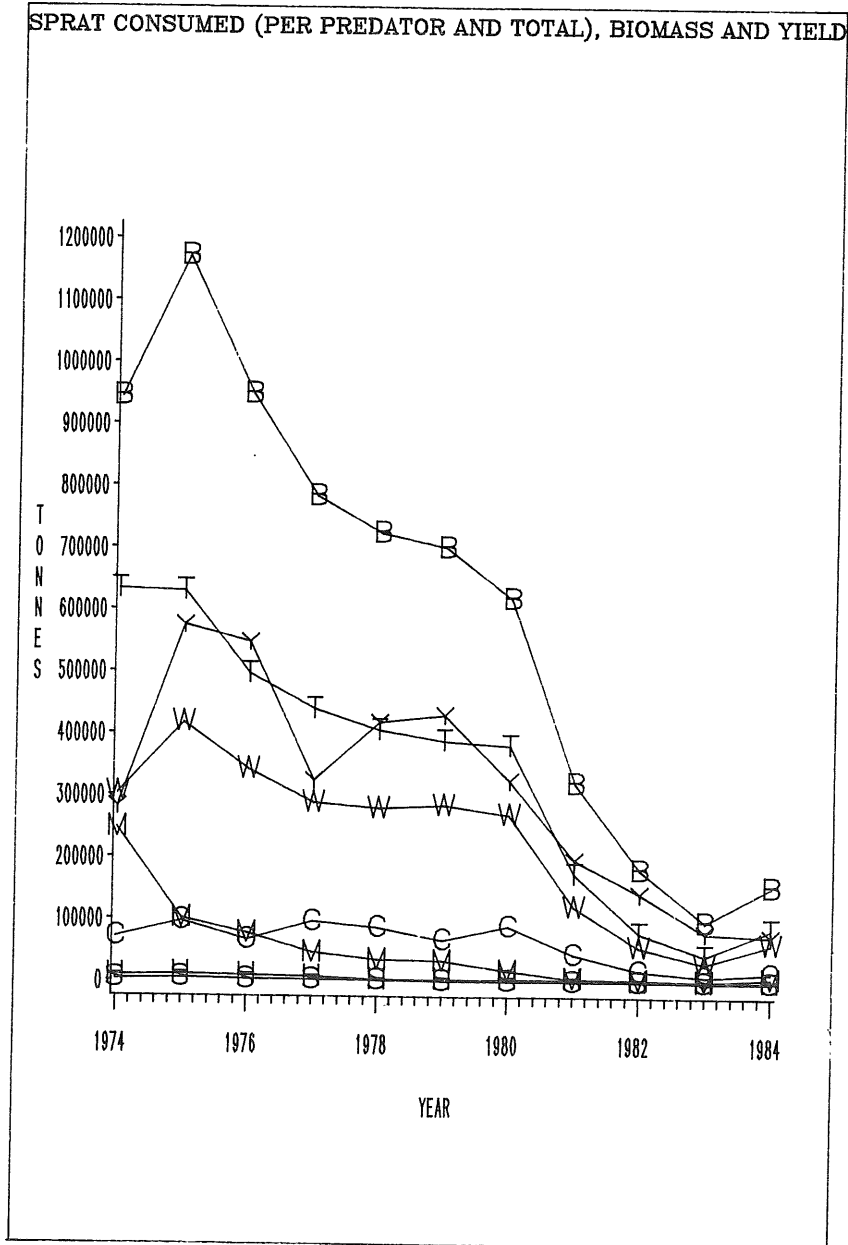
Figure 6.2.1f (see legend page)

NORWAY POUT CONSUMED (PER PREDATOR AND TOTAL), BIOMASS AND YIELD
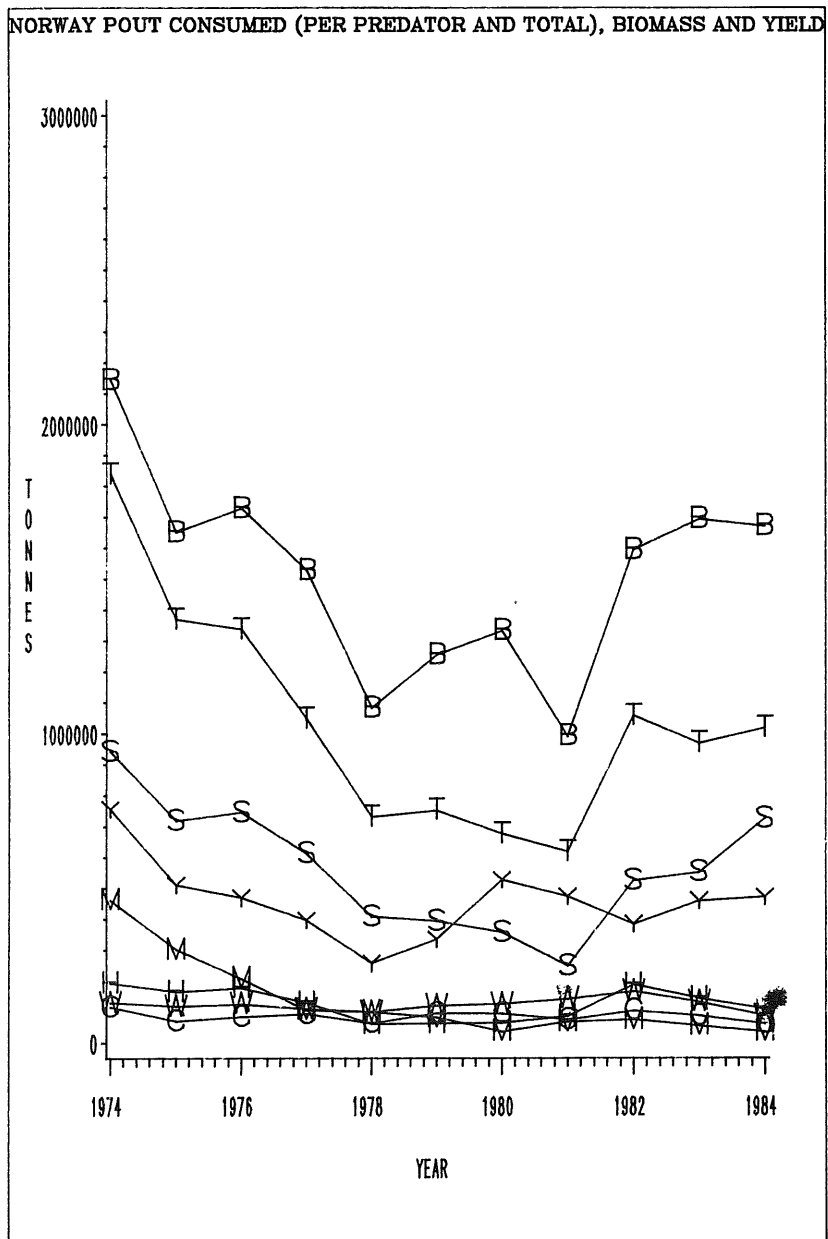
Figure 6.2.1g (see legend page)

SANDEEL CONSUMED (PER PREDATOR AND TOTAL), BIOMASS AND YIELD

132
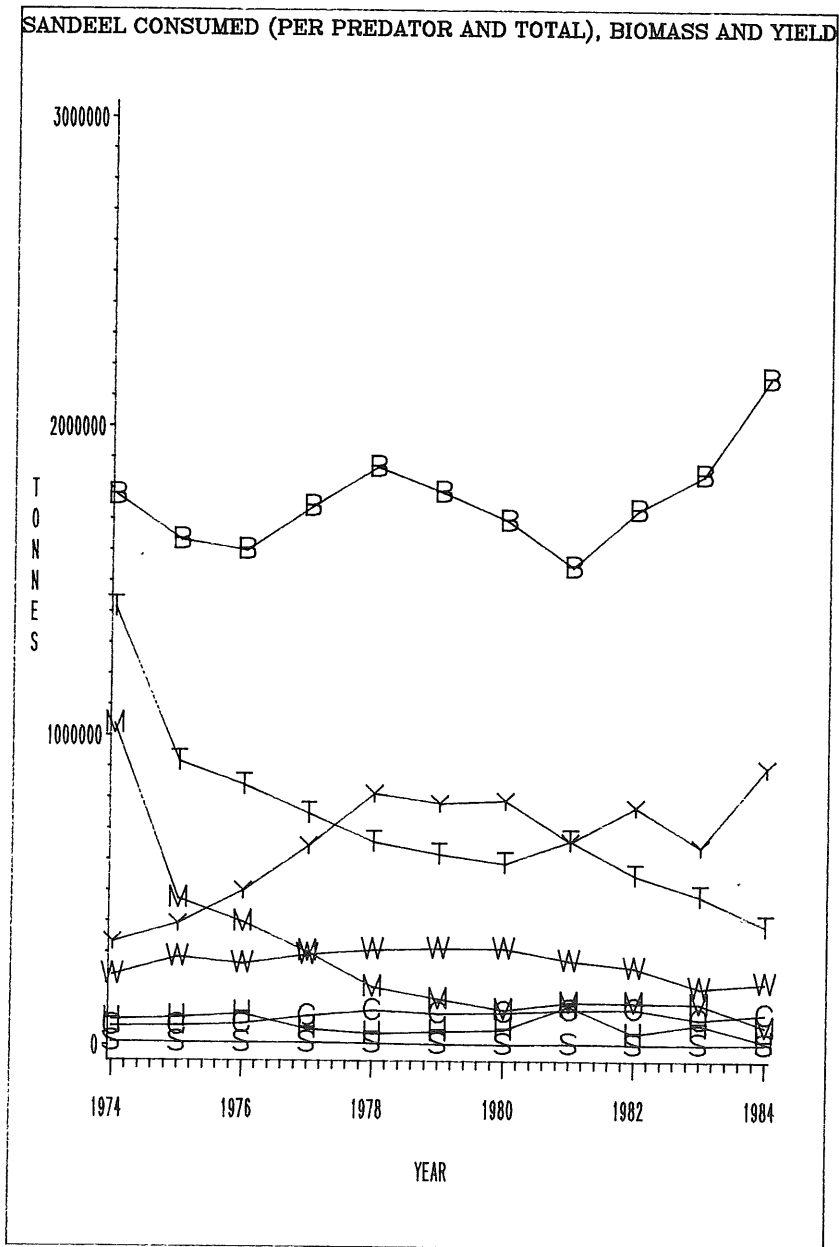
Figure 6.2.2a-e   Biomass of prey species consumed.

C = cod
W = whiting
H = haddock
1 = herring
2 = sprat
3 = Norway pout
4 = sandeel
T = total
B = standing biomass
Y = yield

Figure 6.2.2a (see legend page)

COD CONSUMPTION (PER PREY AND TOTAL), BIOMASS AND YIELD
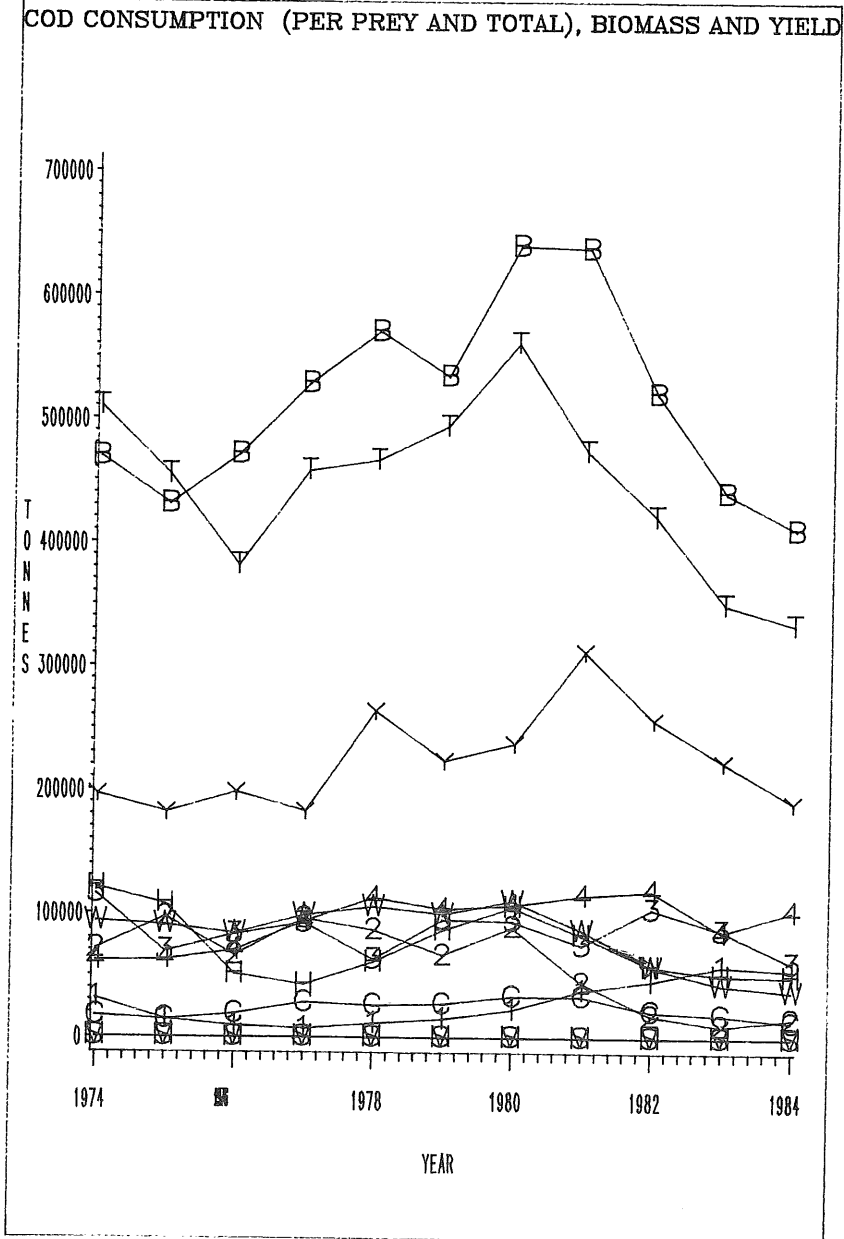
Figure 6.2.2b (see legend page)

WHITING CONSUMPTION (PER PREY AND TOTAL), BIOMASS AND YIELD
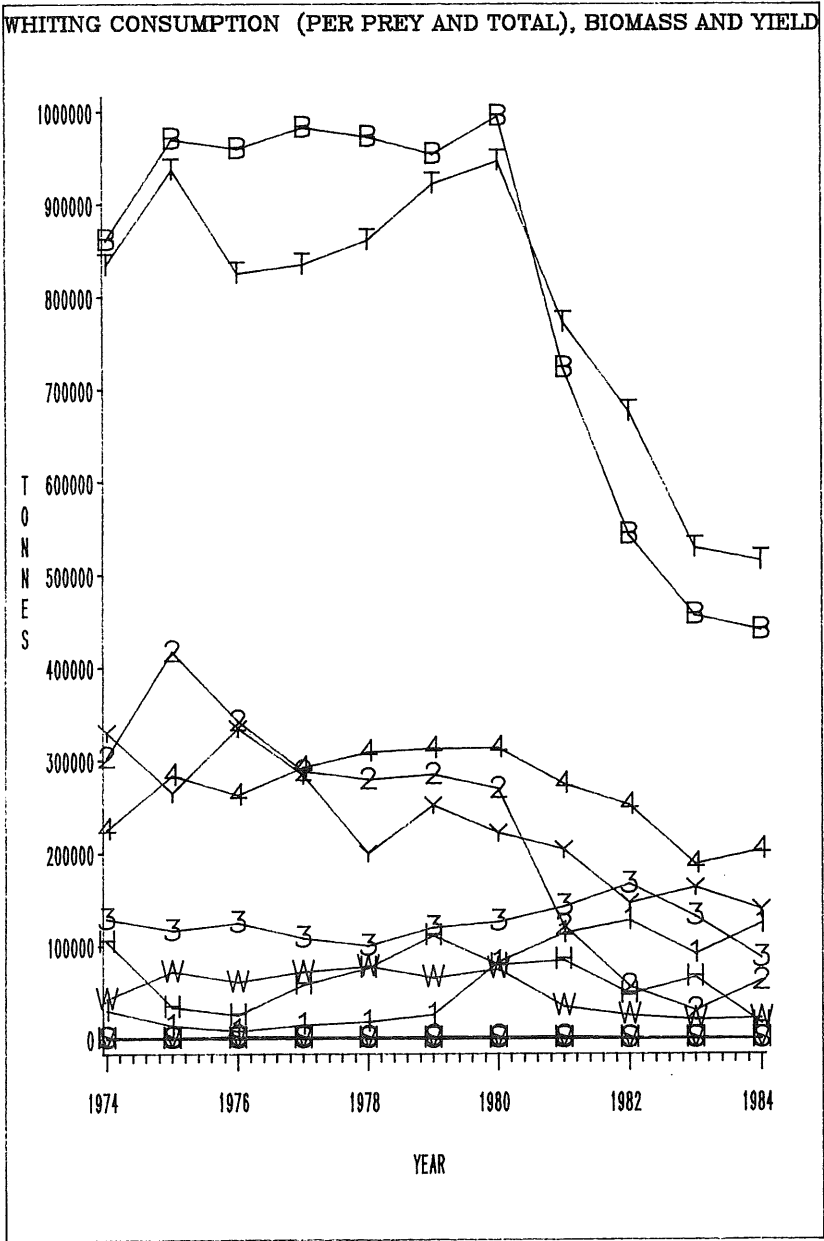
Figure 6.2.2c (see legend page)

HADDOCK CONSUMPTION (PER PREY AND TOTAL), BIOMASS AND YIELD
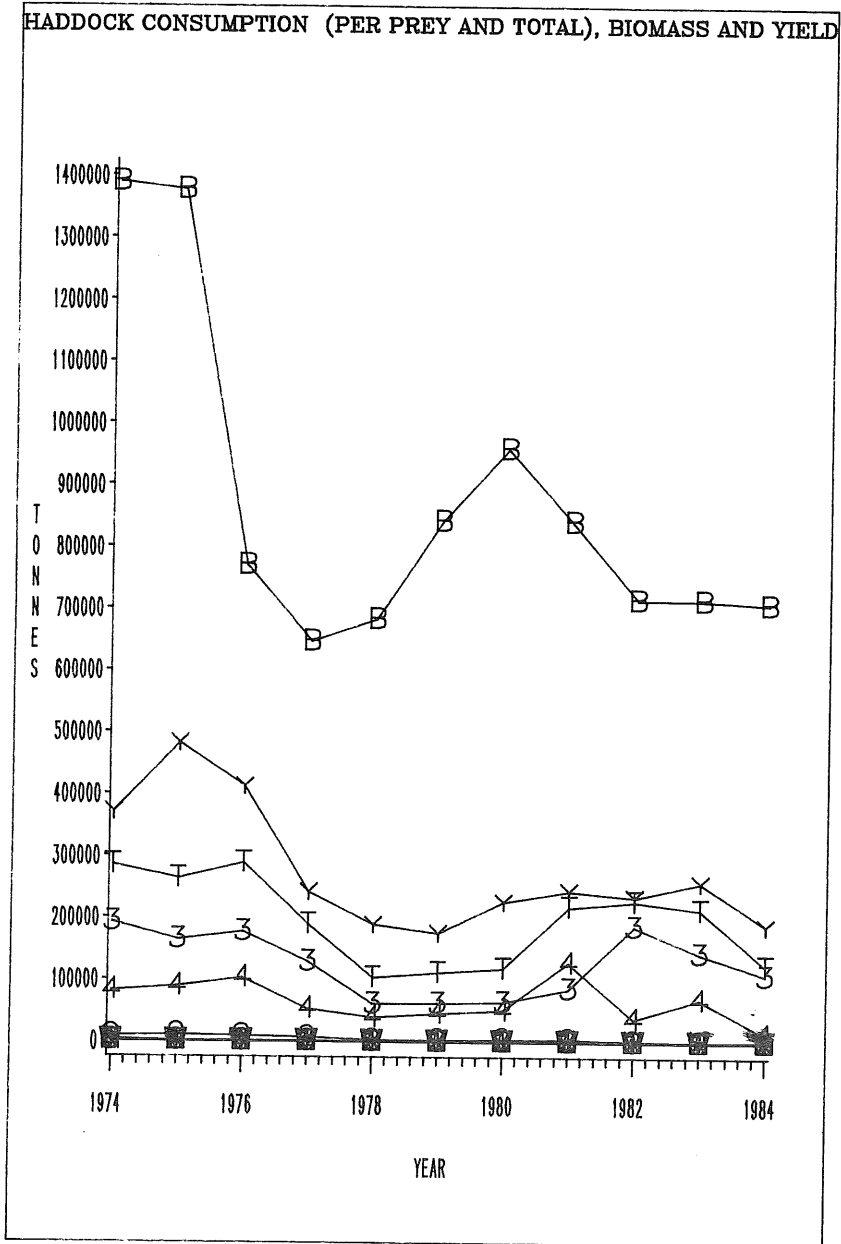
Figure 6.2.2d (see legend page)

SAITHE CONSUMPTION (PER PREY AND TOTAL), BIOMASS AND YIELD
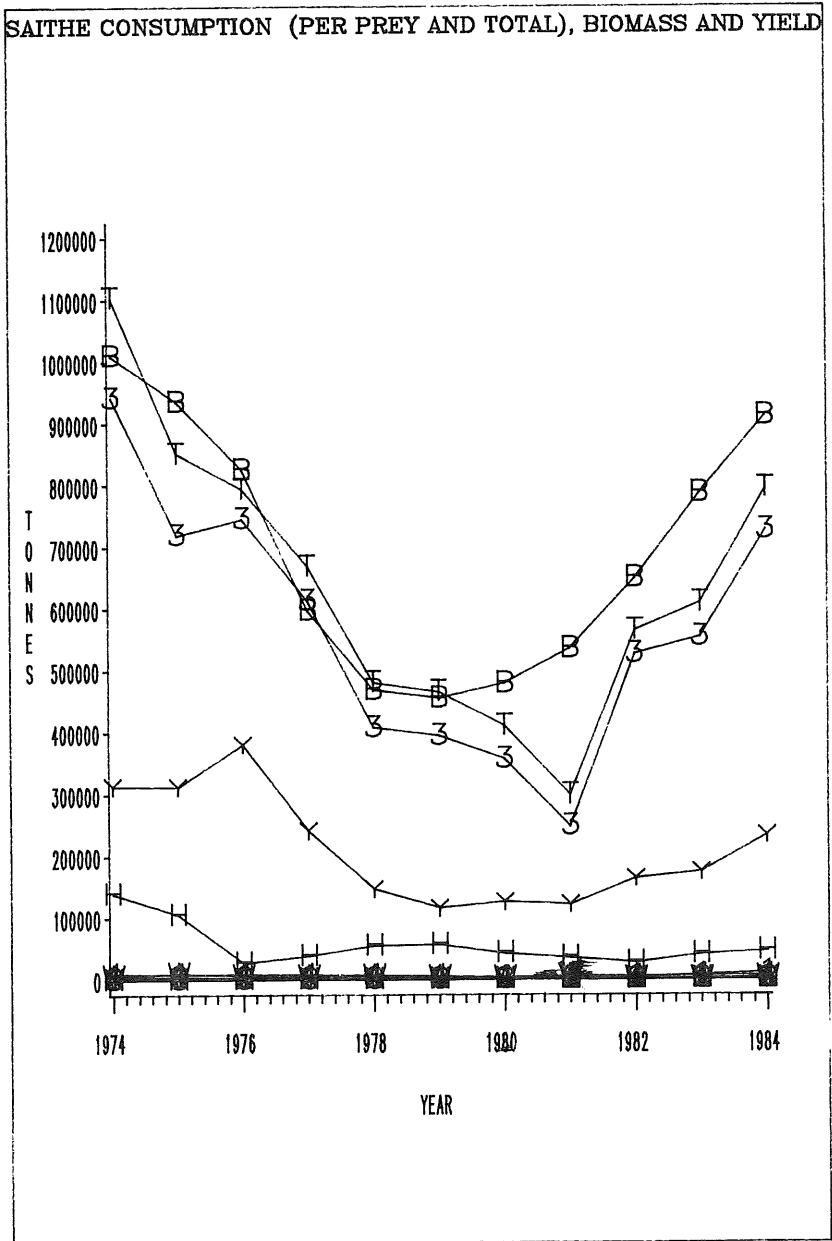
Figure 6.2.2e (see legend page)

MACKEREL CONSUMPTION (PER PREY AND TOTAL), BIOMASS AND YIELD
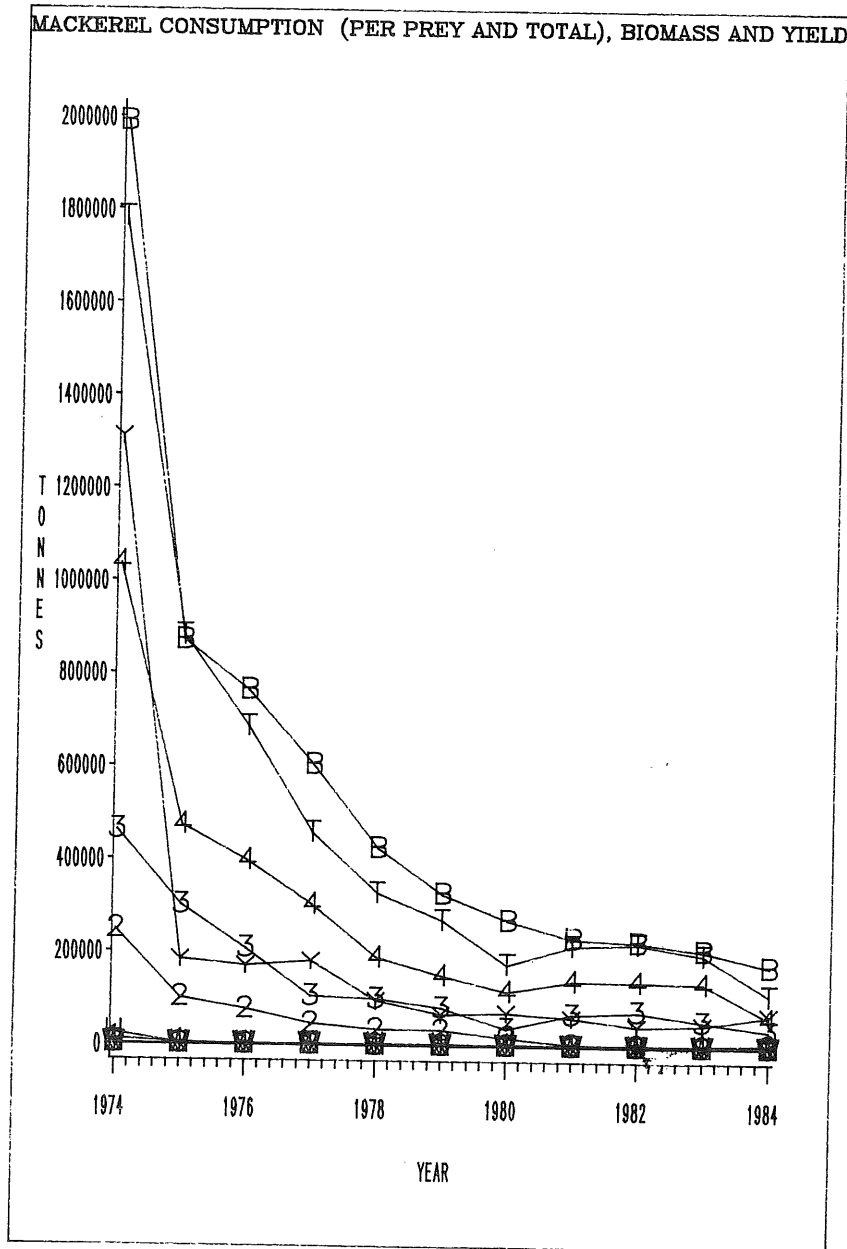
Figure 6.3.1 Plot of the ratios of assumed stock weights at age of
prey to observed mean weights of prey items in stomachs
(STOCK/STOM) from 1981 sampling in the North Sea. Predator
is cod, prey is sandeel. Data are plotted quarterly for
ages 0-6 for cod and sandeel. Note that maximum values
of RATIO generally occur during the second quarter for
cod ages (0.5, 1.5, 2.5 ...) consuming all ages of sandeel
prey. Note that data presented here have not been corrected
for the anomalies noted in Section 2.3.
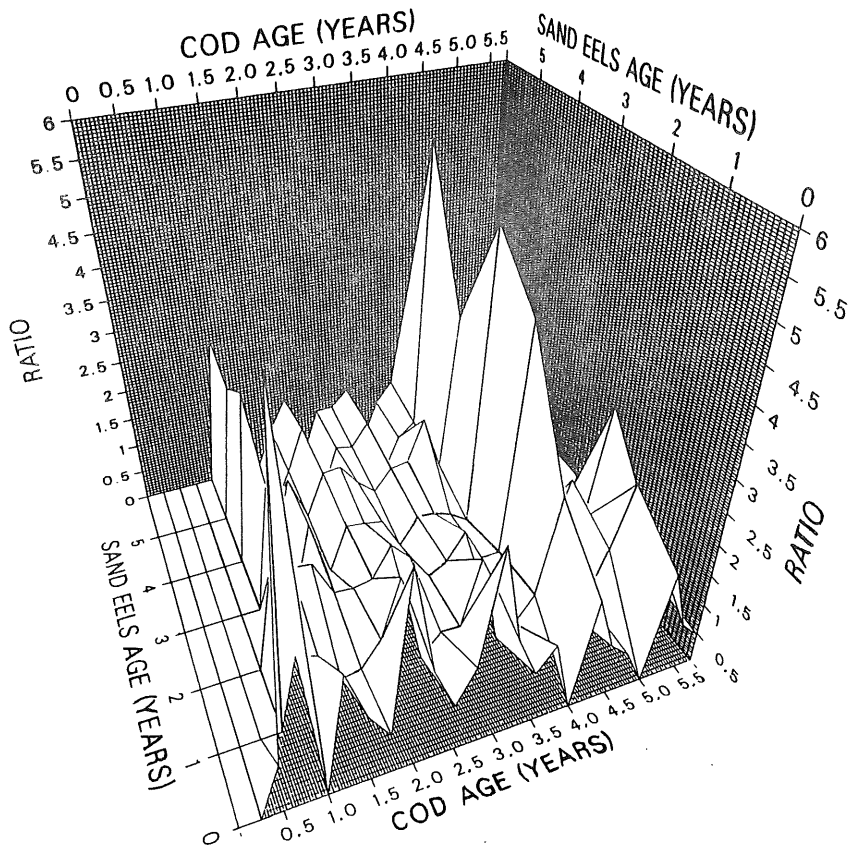
Figure 6.3.2 Plot of residuals of regression of weight at age
of sandeel preyed upon by whiting against stock.
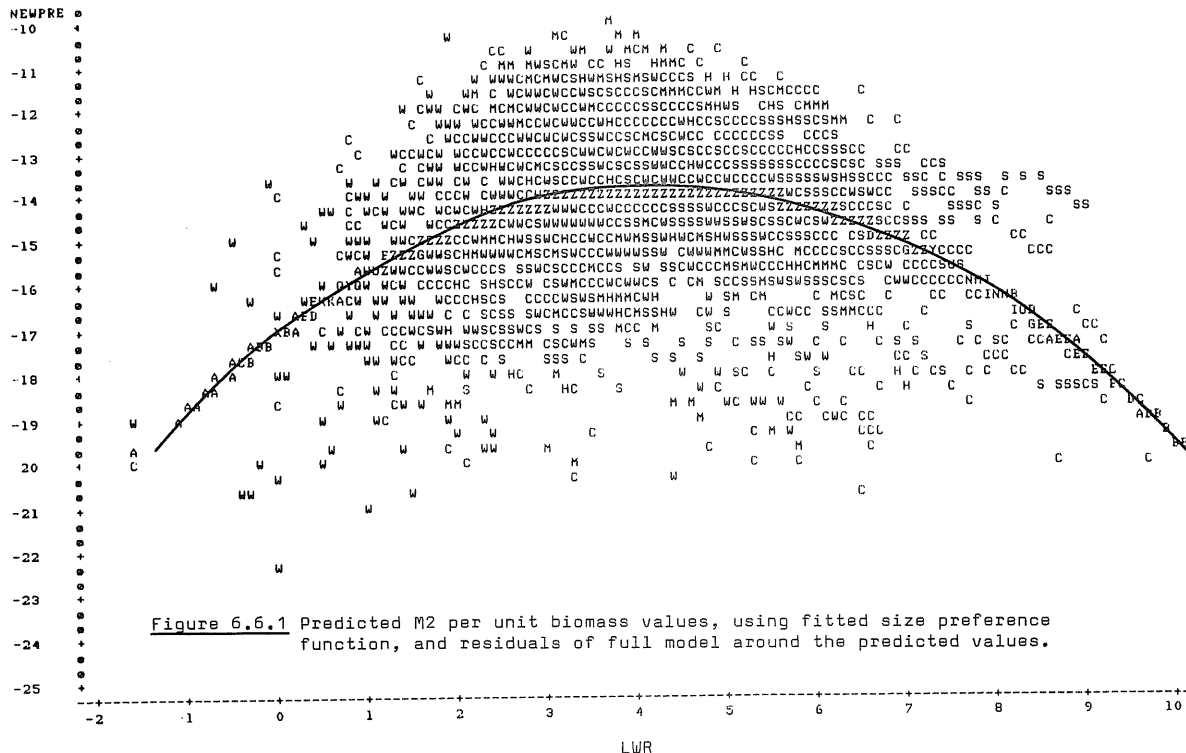Weights at age of sandeel and weights at age of whiting.
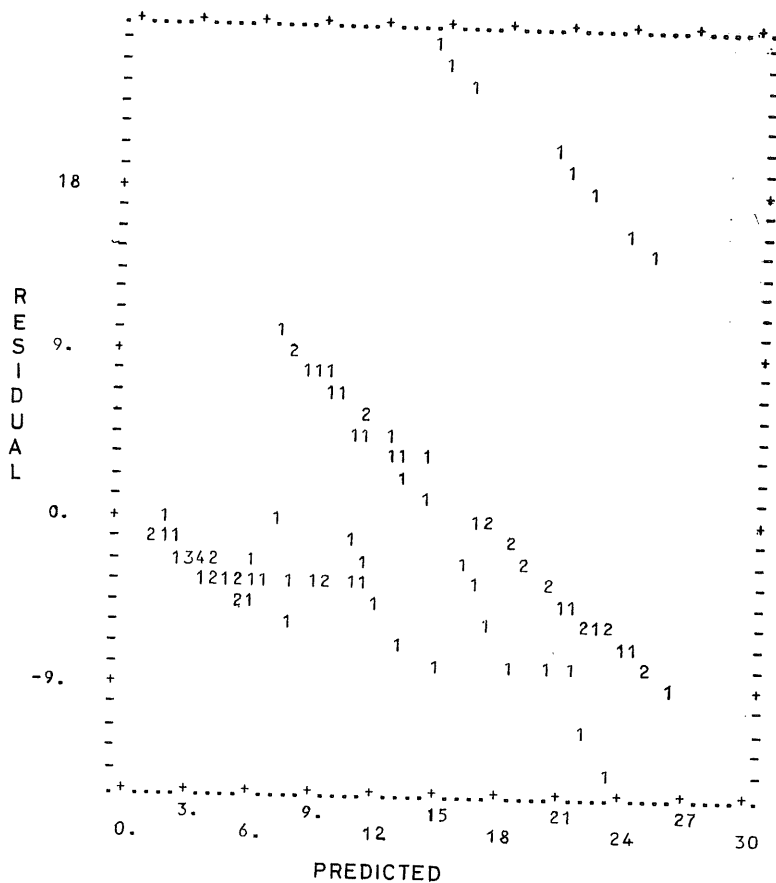
Figure 6.6.1 Predicted M2 per unit biomass values, using fitted size preference function, and residuals of full model around the predicted values.

NOTE: 2519 OBS HAD MISSING VALUES   5904 OBS HIDDEN

APPENDIX A

The Working Group encountered considerable difficulty with carrying out the computations required, mainly because of problems of transferring data and programs between machines. This arose because not all the work could be carried out on a single machine. There are, for example, no graphics or generalised linear modelling facilities on the ICES computer. The problem was exacerbated because it was not possible to run MSVPA on the ICES machine reliably because of hardware problems, so that all results from this were on the Danish Institute machine, and there was no means of transferring them elsewhere.

In the future, this latter problem should not arise, but the former remains. The Working Group wishes to point out that the work of ICES requires the detailed analysis of large data sets, and it is essential that all data, programs, packages and peripherals must either be on a single machine or there must be _excellent_ facilities for transferring programs and data between machines. This includes the transfer of large data files at high baud rates (1,200 minimum) between ICES and elsewhere (including national laboratories). As an example, the M2 data set from MSVPA is about 500 kbyte and would take about 2 hours to transfer from one machine to another, even at 1,200 baud.

In addition, various programs, data sets and other software (e.g., graphics, statistics) were available on microcomputers which some members had brought to the meeting, but there was no way to pass data between these and the ICES computer even though the necessary software was available on the micros. It would have expedited the work of the Group greatly if connection (e.g., as a terminal) had been possible. Indeed, for the present, the easiest and fastest way to transport data to ICES would be IBM-format floppy disks. It would be highly desirable for ICES to acquire at least one fully IBM-XT-compatible microcomputer to be connected to the NORD machine as a terminal, and for an RS232 serial interface to be acquired to allow for the connection of other machines. In this way, Working Group members could bring data and or working programs on disks, without the necessity of transporting the computers themselves. Indeed, the old-fashioned terminals available to Working Group members are unsuitable for the use of the new editor and spreadsheet packages, and it would probably even be cost-effective to replace them by microcomputers with suitable terminal emulation software.

Finally, it is very necessary for ICES to acquire some form of plotting device (and an appropriate graphics package), since the existent facilities for plotting at RECKU are inadequate in a Working Group context. The software should be well adapted to the statistics package in use to allow easy plotting of both data and results.