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REPORT OF THE AD HOC MULTISPECIES ASSESSMENT WORKING GROUP

Copenhagen, 18 - 22 June 1984

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TABLE OF CONTENTS

Table of Contents (Continued) Page

- o - o -

REPORT OF THE AD-HOC MULTISPECIES ASSESSMENT WORKING GROUP

1. INTRODUCTION

1.1 Participants

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H-P Cornus	Federal Republic of Germany
N Daan	Netherlands
W Dekker	Netherlands
J-E Eliassen	Norway
P Grotnes	Norway
H Hansen	Denmark
T Helgason	Iceland
J-P Lussiaá-Berdou	Canada
J J Maguire	Canada
S Murawski	USA
E Nielsen	Denmark
R O'Boyle	Canada
J G Pope (Chairman)	UK
J G Shepherd	UK
H Sparholt	Denmark
P Sparre	Denmark
Ø Ulltang	Norway
E Ursin	Denmark
T Westgård	Norway

The ICES Statistician, K. Hoydal, also participated in the meeting.

1.2 Terms of Reference

It was decided at the 71st Statutory Meeting of ICES (C.Res.1983/2:7) that an ad hoc Multispecies Assessment Working Group should be set up, which would meet at ICES headquarters from 18-22 June 1984 (after the routine Assessment Working Groups dealing with North Sea fish species have been convened), under the chairmanship of Mr J G Pope in order to:

(i) start trial runs with MSVPA models,

(ii) discuss the implication of their results of multispecies assessments in the formulation of management advice,

(iii) provide advice on possible further needs in relation to collection of stomach content data.

1.3 Background to the Working Group Meeting

Following the pioneering work of multispecies modelling of the North Sea by Andersen and Ursin, 1977, it became apparent that the problem of predation mortality was not a trivial one in the North Sea. This problem was further addressed in two papers to the 1979 Statutory Meeting of ICES by Helgason and Gislason, 1979, and by Pope, 1979. Both describe multispecies extensions of the familiar VPA techniques used by Working Groups and thus gave an approach to estimating predation mortality which was:

1. "Charmingly simple" (Ursin, 1982)
2. Which being retrospective enabled some of the problems inherent in a prospective model to be ignored (e.g., recruitment levels).

An ad hoc ICES Working Group was set up to consider the data requirements for multispecies assessment. The results of the ICES programme of stomach sampling (the 1981 Year of the Stomach) which that Working Group set up became available to the 1983 Statutory Meeting (Daan 1983, Armstrong, 1983 Mehl and Westgård 1983 and Gislason 1983).

The results caused considerable interest and led to the setting up of the present Ad hoc Working Group on Multispecies Assessments.

Clearly the immediate tasks for the Group has been to use the stomach data finalised in the report of the coordinators of the 1981 stomach sampling programme, Anon.1984, to make preliminary multispecies (VPA) (MSVPA) runs. This has been successfully achieved and the more obvious consequences of the results discussed. The results of such a large and complex undertaking are, however, necessarily provisional and a further meeting of the Ad hoc Working Group will certainly be needed next year to consolidate the advances made at this meeting and to develop means of giving long-term multispecies assessment advice.

The Ad hoc Working Group therefore recommends that it meet again at about the same time in 1985.

2. TEST RUNS WITH THE MULTISPECIES VPA (MSVPA)

2.1 FORTRAN Program

Before the Working Group meeting, a FORTRAN 77 program was developed for the VAX/11/750 computer at the Danish Institute for Fisheries and Marine Research. A listing of the program will appear in an ICES paper this year (Sparre,1984).

The program is based on the MSVPA models of Pope (1979) and Helgason and Gislason (1979). The estimation of suitability indices are based on Sparre (1980). A description of the computational procedure is given in Sparre (1980), Appendices A, B and C. A flow chart of the MSVPA procedure is shown in Figure 2.1.1. The program differs from the one described in Sparre (1980), only with respect to the time unit. The MSVPA used by the Working Group is based on quarterly data, whereas Sparre (1980) used annual data. A run with one particular set of parameters takes about 5 minutes on the VAX-computer.

2.2 Catch at Age Data for MSVPA

To satisfy the requirements of MSVPA it is neccessary to input quarterly catch at age data for each of the species to be considered. For most fish stocks definitive versions of these are not available. To test the program, preliminary estimates of these quarterly catch at age data had been derived in advance of the meeting from annual data available in various Working Group documents.

Quarterly catch at age data were estimated, assuming that fishing mortality does not vary appreciably between quarters within years. In the time available to it the Working Group were clearly unable to produce precise quarterly catch at age data.

More-over it was felt that the production of definitive quarterly catch at age data is the responsibility of the various species Working Groups who have the required data and experience. The Working Group therefore decided to check that the test quarterly catch at age data were broadly sensible in order that MSVPA results should not be greatly altered when the definitive data become available.

In the case of cod, haddock and whiting, the test data were found to be reasonable. Explicit quarterly data for England, Denmark, Netherlands, Norway and Scotland for the period 1981-1983 were made available to the Group. The data for 1981 were worked up on a quarterly basis and the resultant age frequencies were compared with those used in the trial MSVPA runs.

For ages 1 and older in the case of haddock and whiting and for ages 2 and older in the case of cod it was found that the age frequencies derived from the explicit data were reasonably similar to those used in the trial MSVPAs. It was apparent, however, from the explicit data that no 0-group haddock and whiting or 1-group cod are caught in the first and second quarters.

Because, however, only a partial data set was available for the explicit calculation of quarterly age frequencies it was not possible to work up definitive data for all years over which MSVPA was to be run. It was therefore decided to retain the data used in the trial MSVPAs for ages 1 and older in the case of haddock and whiting and for ages 2 and older in the case of cod. For 0-group haddock and whiting and for 1-group cod it was decided to partition the estimated annual catch equally between quarters III and IV.

Also for saithe, the quarterly catch data from the trial runs of MSVPA were accepted.

In the case of Norway pout and sprat, the quarterly data given in reports of the Industrial Fisheries Working Group were used.

For sandeel, Working Group reports showed No/month for years 1979 to 1983 and No/half-year for years 1974 to 1978. Catch numbers were combined to quarterly values for years 1979 to 1983. From that, a mean percentage distribution was calculated for half-year catch numbers per age:

Age	0	1	2	3	4	5	6+
Q1	0	3	3	1	0	1	0
Q2	100	97	97	99	100	99	100
Q3	89	98	99	100	99	100	100
Q4	11	2	1	0	1	0	0

The reported half-year catch numbers for years 1974 to 1978 were converted to No/quarter using the distribution pattern above.

For mackerel, the quarterly catch in number by age was estimated from Norwegian data by quarter for 1982 and 1983, and from Norwegian and Scottish data for 1981. For years prior to 1981, the quarterly data estimated in trial MSVPAs were used.

In the case of adult herring (2+), in 1981-1983, 80% of the catches in Divisions IVc - VIId was allocated to the 4th quarter each year, and the rest was allocated to the 1st quarter. In Divisions IVa - IVb, catches were assumed to be equally divided between the 2nd and 3rd quarters. Again for years prior to 1981, the catch data in the trial MSVPA were used. The seasonal distribution of 1-group catches was estimated from Danish data from 1983, applying the same percentage distribution to earlier years. 75% of the 0-group was assumed to be caught in the 3rd quarter, and 25% in the 4th quarter.

The catch data used for the different species are given in Table 2.2.1.

The Stomach Sampling Project was limited to ICES Sub-area IV, and Sub-area IV was taken as the appropriate area for a North Sea multi-species model.

The Working Group recognised in this connection two problems. Firstly, for some stocks (e.g. mackerel), catches in Division IIIa are included in the assessment, and estimated stock sizes will, therefore, include some fish not present in the North Sea. No attempt was made to correct for this at the present meeting. Secondly, there are stocks which at certain times of the year, or during certain life stages, are partly outside the North Sea proper. One example is mackerel, which during summer and autumn is partly in Division IIa, and during winter partly in Division VIa. Another example is saithe. The youngest age groups of saithe are to a large extent distributed in Norwegian coastal waters and should therefore not be included in a North Sea multispecies model.

The problem with the saithe was considered the most serious. By including the youngest age groups one would heavily overestimate predation by saithe in the North Sea. It was therefore decided to exclude age groups 0-3 when calculating saithe predation.

The best way of dealing with such problems as mentioned above in the future would be that the relevant Assessment Working Groups gave some guidance, trying to quantify the proportions being outside the North Sea.

Recommendation: The different Assessment Working Groups should at future meetings supply quarterly catch at age data for use in a MSVPA. They should also try to give some guidance concerning the proportions of different fish stocks included in the MSVPA which are outside the North Sea at different ages or different times of the year.

2.3 Relative Food Compositions

The input on the relative stomach contents in weight units by prey age group, and predator age group and quarter for cod, whiting, saithe and mackerel from the stomach sampling project 1981 were derived from Anon. (1984), Tables 5.2.1.a-d, 5.4.1.a-d, 5.5.1.a-d and 7.5.3). Haddock data were not yet available in the proper format and this predator had to be excluded from the MSVPA.

Although mackerel, plaice and sole had been recorded in cod stomachs, there is evidence on the basis of the size distribution of these species in the stomachs that they represent discarded fish from the commercial fisheries and therefore they have been excluded as prey.

For cod and whiting, estimates of average prey weights at time of ingestion had also been provided by Anon. (1984), which deviated in some cases considerably from the average weights by age group in the various fish stocks.

It was realised that this discrepancy between the whole weight of fish found in predators' stomachs and the mean weight of fish of the same age in the sea might bias the results of MSVPA. To attempt to compensate for this, bias estimates of whole weight of fish in stomachs were used as additional inputs to some runs of the MSVPA. A more detailed discussion of this problem will be found in Section 2.7.

2.4 Estimates of Ration Used in MSVPA Runs

What was actually done. The total rations by quarter for the various predators entering the MSVPA as input were derived from the report of the Coordinators of the Stomach Sampling Project (Anon.,1984). It should be noted that in their report there is no consistency in the models used to estimate the consumption by the various fish species.

For cod and whiting the method of Daan (1973) has been applied according to a linear model of the equation:

$$\bar{R} = 2 * S/\rho$$

where $\bar{R}$ represents daily food consumption, S average stomach contents in weight and ρ the digestion time in days. For whiting a constant digestion time of 2.5 days was applied over all age groups. For cod allowance has been made for digestion time to vary with size of predator in view of the larger prey items consumed according to the equation

$$\rho = \sigma * L^2$$

where L is the mean length per age group and σ is a digestion constant which has been estimated for cod at 0.06 by Daan (1973).

For saithe and mackerel exponential digestion models have been applied, taking into account the ambient temperature (T). The model used for saithe has been given by Gislason (1983):

$$R = 0.0266 * EXP\ (0.096 * T) * W^{0.74}$$

where W represents the average weight of an age group. For mackerel a slightly different formulation is used where the ration is directly derived from the stomach content weights (Mehl and Westgård, 1983):

$$R = 0.005 * EXP\ (0.2 * T) * S$$

Various other possible approaches

A. Some guesses

1. Estimates of ration assuming ration proportional to body weight

Rations of 1-2% bodyweight per day is often found only in the summer half year. The range of ration per year could thus be from $1.8\bar{w}$ to $7.3\bar{w}$.

2. Estimates of ration based on requirements to be met

Growth, spawning, metabolic losses (routine metabolism).

If the efficiency of food conversion is assumed known: range 0.1 - 0.5 and:

a) spawning and metabolic losses disregarded. In this case ration per year could be from 2 x growth increment to 10 x growth increment.

b) Spawning accounted for: the weight of eggs, adjusted for calorific contents, included in growth (male losses to be disregarded ?).This would give rations larger than a by 2 - 10 times calorific content of eggs.

c) Routine metabolic losses included: the weight loss of a fasting fish;this could be established by experiments, and would add a further increment to the estimate of ration.

B. Feeding experiments

1. One possibility would be to feed the fish so much that they grow as in nature. It should then be possible to express food consumption as a function of body-weight. The risk in this is that the fish might not behave naturally.

2. Estimate rates of digestion (or time to digest). Calculate ration from stomach contents and coefficient of digestion. There are unsolved problems: Cod on Georges Bank and in the North Sea seem to have the same growth rate and live at similar temperatures. Yet, North Sea cod has twice as much in the stomach as Georges Bank cod. Many approaches to the estimation of digestion rates have been published, ranging from linear models to expontential models to more complicated models, yet, it does not seem well known what determines the rate of digestion in a given situation.

C. Calculation of requirements from the growth equation

Another possibility is to estimate ration from consideration of the growth equation: Consider the expression

$$dw/dt = Hw^{2/3} - kw$$

The positive term can be perceived as proportional to the ration dR/dt. Some food is not digested and the equivalent of some is spent on energy for processes of feeding, digestion, etc. ("apparent specific dynamics action"). Thus:

$$Hw^{2/3} = v\frac{dR}{dt}$$

$$\frac{dR}{dt} = \frac{H}{v}w^{2/3}$$

where $H = 3KW_{\infty}^{1/3}$. If 90% of the food is assimilated and 15% of this covers "expenses" we have $v = 0.9\ (1-0.15) = 0.765$. As an example, take the growth parameters of cod in the North Sea as estimated by Beverton and Holt 1957:

$W_{\infty} = 20\ 000g$, $K = 0.2$. We have

$$H = 3 \times 0.2 \times 20\ 000^{1/3} = 16.29$$

$$\frac{dR}{dt} = \frac{H}{v}w^{2/3} = 21.3w^{2/3}.$$

w(g)	Annual cons. (g)
10	99
100	459
1 000	2 130
10 000	9 887

Different sets of the four parameters of the growth equation $Hw^m - kw^n$ may represent the observed growth equally well.

Consider the ratio of annual consumption to body-weight for three such parameter sets shown in the text table below:

w	$16.29w^{2/3} - 0.6w$	$30w^{0.58} - 2.0w^{0.78}$	$26w^{0.69} - 5.1w^{0.84}$
100	4.6	5.7	8.2
1 000	2.1	2.2	4.0
10 000	1.0	0.8	2.0

The two right-hand columns represent attempts at finding physiologically plausible parameter values. The left-hand column is the standard growth equation with parameters as estimated above. The middle column parameters were adopted by Andersen and Ursin 1977 (cf.6.4). For comparison, the computer output presented at the beginning of the meeting produces the following values for four species:

Ratio = annual consumption/body-weight

COD		WHITING		SAITHE		MACKEREL	
w	ratio	w	ratio	w	ratio	w	ratio
520	4.2	100	2.4	330	3.9	200	4.8
13 500	1.6	780	1.7	8 700	2.1	680	2.1

The value for cod of 520 g is similar to that obtained with the standard growth equation. The value for large cod compares better to the right-hand column of the previous table, whose parameters were estimated from metabolic rates of fed and fasting cod in aquaria. The parameters of the other two columns were estimated from field data on size-at-age. Generally, the consumptions calculated by the Stomach Group are in fair agreement with the more theoretical approach. It does not seem likely that the actual food consumption can have been less than half the values estimated by the Stomach Group. Such halved values would give the lower range of believable values.

2.5 M1 Levels Used in Runs

The MSVPA model partitions natural mortality into two components.

M 1 = "other cause" natural mortality

M 2 = natural mortality caused by predation by species included in the MSVPA

Some sources of M1 mortality are:

1. Diseases
2. Physiologically-based mortality (higher metabolic rates giving high mortality)
3. Spawning strain
4. Senility
5. Starvation
6. Emigration (immigration: negative M1)
7. Predation by species not included in the MSVPA

Traditionally, we assume sources of mortality independent of each other (F + M = Z). The possibility that a fish is caught because it was dying from "natural" causes is disregarded. The problem may be more important when it comes to separate M1 and M2 putting M1 + M2 = M. R Jones (1982) suggests that fish consumed are "displaced" specimens, weaker than others. Predation mortality might therefore be overestimated when all fish in the stomach are assumed to be viable in the absence of predation. Some may have been eaten because they were damaged (even killed) by fishing gear. The choice of M1 is thus a difficult one.

At the present stage of multispecies modelling it seems advisable not to diverge from assumptions made by the Assessment Working Groups unless species interactions clearly indicate changes. Therefore, the natural mortality of large fish which are not preyed upon should be close to the constant M adopted by the Assessment Working Groups. For old age groups of smaller species on which there is still some predation, M1 should be chosen such that M1 + M2 approximately equal the M of the Assessment Working Groups.

One precaution seems pertinent: in order not to overestimate predator stocks, M1 for these should perhaps be chosen smaller than tradition indicates.

The text table below shows:

A. M1 values used to produce preliminary test in the computer output available at the beginning of the meeting.

B. M2 as an average for the two oldest age groups in the same output

C. M1 + M2 = M, (A+B)

D. M as adopted by recent Assessment Working Groups

Species	Natural Mortalities			Working Group
	M1	M2	M	M
	A	B	C	D
Cod	0.1	0	0.1	0.2
Haddock	0.1	0	0.1	0.2
Whiting	0.1	0	0.1	0.2
Saithe	0.1	0	0.1	0.2
Sprat	0.2	0.76	0.96	0.8
Norway pout	0.2	0.62	0.82	1.6
Sandeels	0.2	0.60	0.80	0.5
Mackerel	0.08	0	0.08	0.15
Herring	0.024	0	0.024	0.1

Thus, estimates of M for old age groups should approximate the values in column D. The values of M1 finally used in the MSVPA runs are shown in Table 2.5.1. In one run these were halved to investigate the effect of the assumed value of M1.

C. Theoretical Approaches

Jones and Johnston (1977) and Myers and Doyle (1983) relate adult mortality to spawning strategies. These papers are of similar importance to single species and multi-species assessment and seem to provide improved estimates of M for mature fish. It seems appropriate to leave the possible application of such methods to the Assessment Working Groups, who should be best able to estimate sensible levels of total M on older ages.

2.6 Feeding Models Used in MSVPA and Assumptions about External Food

The MSVPA programme works with three models of feeding. The models are of Pope (1979), Helgason and Gislason (1979) and Sparre (1980). They differ mainly in the way external food is treated.

Pope (1979) explicitly ignores external food but assumes that a certain fraction of the total food consumed by a given fish is obtained from external source. Thus, it can be said that external or other food is directly proportional to the food supply consisting of fish within the model. So if a certain prey stock increases so does also the external biomass.

In Sparre's model (1980), he assumes the total biomass in the corresponding ecosystem to be constant. Thus, an increase in the biomass of fish included in the system results in a corresponding decrease of other external biomass.

The treatment of other biomass in Helgason and Gislason (1979) can be regarded as a compromise since they basically assume external food to be constant independent of the biomass of fish.

2.7 Problems With the Choice of Appropriate Mean Weights at Age for Prey Items in MSVPA

Background. Results of the MSVPA are doubtlessly sensitive to the mean stock weights at age used in the analysis. Underestimates of weights will result in a larger number of individuals being eaten from a cohort and vice versa. Preliminary analyses of the stomach contents data bases (Anon., 1984) indicate that mean weights at age of prey in the stomachs of cod and whiting were, in some cases, significantly different from the assumed mean stock weights at age. These discrepancies were often substantial (mean prey weights at age in cod stomachs ranged from 0.01 to 15 times the assumed stock weights at age for those prey items; whiting prey weights in stomachs ranged from 0.01 to 6 times the assumed stock weights). Thus, there is a potential for bias in MSVPA estimates of predation mortality unless some adjustments are made to the MSVPA model to deal with the differences in prey weights found in stomachs and in the sea. Two approaches were proposed, and it was not possible in the course of the meeting to resolve which was the more proper adjustment to the MSVPA model. The two methods of adjustment suggested involved:

1) Adjusting the suitability index for weight differences
2) Directly adjusting M2 estimates for weight differences.

These are described in Section 6.8.

In practice only the former method was investigated on an MSVPA run. An attempt to run the second method failed due to lack of convergence of the MSVPA when using this option. In the circumstances therefore all other runs were made using unadjusted stock weights for prey. Clearly further work is required on this problem.

It was pointed out that regardless of observed differences in mean-weight-at-age in the catch and in the stomachs it would be consistent to stick to the same weights-at-age throughout the models. Indeed one point of view was that what really matters is the balances of biomasses. Natural mortality (including predation mortality) is used to describe the disappearance of biomass which otherwise could be fished. On the other hand, a standardisation of mean-weight-at-age might introduce a bias in the observed growth rate of fish. The ultimate cure to these problems might ultimately be to base the MSVPA on length and age classes.

Studies of the Relationship of the Discrepancy Between Prey Weight in the Stomach and in the Sea, to Other Factors

The second approach to adjusting for the bias suggested that the logarithm of the adjustment factor AF might be linearly related to the logarithm of the ratios of predator to prey weight in the sea. This proved a useful starting point for a more detailed study of the discrepancies between weight of prey in the stomach and weight of prey in the sea.

This relationship between the ratio of weight of the predator to the assumed mean prey stock weights and the ratio of prey weight in stomachs to prey stock weights are illustrated in Figures 2.7.1 and 2.7.2, where:

$$AF = \ln\left(\frac{Wprey\ (stomach)}{Wprey\ (stock)}\right)$$

$$Ratio = \ln\left(\frac{Wpredator}{Wprey\ (stock)}\right)$$

Prey species of cod exhibiting AF values greater than 0 (and thus ratios of prey weights in stomachs to those in the stock greater than one) were primarily some age groups of sprat, sandeel, herring, and Norway pout. Conversely, AF values for cod eating cod, haddock, and whiting were generally less than 0. Prey species of whiting exhibiting AF values greater than 0 were primarily sprat and sandeel, with virtually all other prey items giving negative AF values.

The differences in mean prey weights in the stomachs from the assumed mean prey weights can potentially arise from two circumstances:

1. the assumed stock weights-at-age of the prey are in error;

2. the predator species selects only a portion of the size range of the prey available.

It is quite possible, particularly for the industrial species, and for young age groups of all species, that the assumed mean stock weights may not be representative of the population. Generally, these species/age groups are minimally sampled, and the timing of these samples during the quarter may be critical since growth rates may be quite rapid.

If the size distribution of prey items is roughly equal to the optimum prey size distribution of a predator, then the values of AF should be centered at 0 with some negative and positive values. As can be seen in Figures 2.7.1 and 2.7.2, some extremely low AF values are apparent, particularly for the larger prey items (e.g., cod, haddock, whiting). These data imply that only the lower portion of the size distribution of these prey items is suitable as prey.

Further analysis was undertaken to define those variables likely to influence the log-ratio of prey weights estimated from stomach contents data to prey stock weights (defined as AF). Prey weights are utilized in the MSVPA program by predator type, prey type, predator age, prey age, and calendar quarter. Some prey species were considered: cod, haddock, whiting, Norway pout, herring, sprat, and sandeels. Overall ANOVAs were conducted with AF as the dependent variable and prey type, and quarter as the categorical variables. The log-ratio of predator weight to prey stock weight was taken as a covariate in the ANOVA to remove the effects of scale. Separate analyses were conducted for the two predator species (cod, whiting) for which data were available. Results of the two overall ANOVA analyses are presented in Tables 2.7.1 and 2.7.2.

These analyses generally indicated significant prey species, quarter, and interaction (prey/quarter) effects. Most of the variation in the ratio was explained by prey species, followed by the prey/quarter interaction. The significance of the prey/quarter interaction implies relatively rapid growth ratios of prey and thus changing size selection by predators during the year. The main

quarter effect was significant in both ANOVA analyses, but explained relatively little of the total variability. The ratio covariate was significant for the cod analysis, but non-significant in the whiting case.

Thus correction factors for differences between prey weights observed in stomachs and those in the stock should be calculated for all prey types, quarters, and interactions. The Working Group did not analyse age effects for predators or prey. Continued research on the analyses of these data are suggested.

2.8 The Key Run of the MSVPA

A number of runs of the MSVPA were needed in order to test the effects of various of the assumptions made. Since the MSVPA generates considerable amounts of output it was decided to provide detailed output for one key run and to make all other runs differing from this on the various assumptions taken one at a time. The results from these could then be described by simple comparisons with the key run.

The "key run" adopted for purposes of comparison was based on

- the Helgason-Gislason feeding relationship
- the consumption figures as estimated by the coordinators of the stomach sampling programme
- residual natural mortalities to fit the standard Working Group assumptions on the oldest ages
- no correction for the difference between weights of prey in stomachs and in the stock.

Some of the central results from the key run are presented for the species considered (cod, whiting, saithe, mackerel, haddock, herring, sprat, Norway pout and sandeels) in Table 2.8.1 which give the multispecies equivalents of conventional VPA tables, i.e., fishing mortality, population numbers, and predation mortality (total due to all predators considered). (NB. These do not include M1).

As further discussed in Section 3.1, the results do not contain any major surprises. The levels of fishing mortality are very close indeed to those obtained by the single-species Working Groups. There are substantial predation mortalities on younger age groups, mostly in the range 0 to 1, and the numbers-at-age of the youngest age groups, estimated year class strengths, and stock biomass estimates are therefore higher than the traditional estimates by factors of up to 2 or thereabouts. These factors are not, however, very variable for a particular stock.

The average fishing mortality, predation mortality and number in the stock at age for each stock are given in Table 2.9.1. (a comparison of different MSVPA runs), and these are plotted together with the estimates made by the most recent Working Group in Figures 2.8.1(a)-(j). The close agreement is clearly apparent.

The discrepancies for fishing mortality on the older ages in Figures 2.8.1.f, g,h and j are very probably due to different assumptions concerning terminal mortality, since the MSVPA was not "tuned" in any way.

Note that in these runs the predation mortality on saithe and mackerel has not been estimated, because of the difficulties discussed above concerning their distributions outside the North Sea, and the zero estimates should therefore be disregarded.

2.9 Comparing Runs Under Different Assumptions With the Key Run

Additional to the key run, time permitted a number of other runs to be made. In each of these one of the assumptions was changed. The runs are specified in the text table below:

1. Key run. No adjustment factor.
   Helgason-Gislason "Other Food" model
   M1 as in Assessment Working Groups
   Feeding level = 1

2. As 1, but feeding level = 0.5 for all predators

3. As 1, but total biomass assumed constant (Sparre, 1980).

4. As 1, but ignoring other food (Pope, 1979).

5. As 1, but M1 halved

6. As 1, but with stomach/stock weight adjustment factor based on suitability (See Sections 2.7 and 6.8.).

7. As 1, but with stomach/stock weight adjustment factor based on M2. (See Sections 2.7 and 6.8). This run did not converge.

A comparison of the results of the different runs is given by species. The 1978-1983 average for F, N and M2 by age were calculated for each run and these averages are summarised in Table 2.9.1.

In order to make it possible to make a more easy comparison between the runs, the averages over years again were averaged over the age groups where predation mortality is important. The runs were then compared to the key run by expressing year-age averages as percentages of the estimates from the key runs. The percentages are given in Table 2.9.2.

Some preliminary conclusions can be made at this stage although the results are preliminary and a careful checking of the outcome was not possible during the meeting. These were:

1. The effect of halving the feeding level are higher estimates of F and lower estimates of N and M2
2. Ignoring "Other Food" (run 4) assumption in all cases give higher estimates of N and M2 in several cases 2 times the key run value. The largest differences seem to stem from the 0-group estimates
3. Assuming total biomass to be constant (run 3) does not make any change.
4. Halving M1 mainly affects F and hence estimates of N. For sandeel and Norway pout there are, however, major changes in all three estimates
5. Adjusting for differences between the mean-weight-at-age in the stomachs and in the sea with a suitability adjustment factor gave changes in the estimates without any pattern
6. It was not possible, during the meeting, to get any runs of the Multispecies VPA using the M2 adjustment factor.

It is interesting to note that the MSVPA responds to the changes in assumptions in a predictable and stable way. Only the use of adjustment factors seemed to cause problems.

2.10 Preliminary Advice for Single Species Assessment Working Groups

Results from the MSVPA are as yet preliminary and the Working Group could not therefore advocate any particular set of natural mortality estimates as being the "best" ones. It was felt that should natural mortality estimates from this work need to be used in the short-term assessments then the safest set to use would be those based on the ration x 0.5 run of MSVPA (Run 2).

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

3.1. Introduction

The results described in Sections 2.8 and 2.9 have been examined, in order to ascertain to what extent it is necessary and possible to advise changes to current Working Group practices to take account of multispecies effects. This advice is best considered in two parts:-

1) Short-term tactical advice (in this section)

2) Long-term strategic advice (in Section 4).

Short-term advice particularly involves the computation of short-term catch forecasts (TAC's etc.) but might also involve interim decisions, as to the direction in which fishing mortality should change, pending long-term advice becoming available.

3.2. Estimation of Recruitment at Age 1 in Various Stocks

Several runs of MSVPA were obtained. It was apparent from these that the results from MSVPA may vary depending on the assumptions referred to in Sections 2.3 - 2.7. It was therefore decided that only the "key run" would be investigated.

Estimates of the population numbers at age 1 of cod, haddock, whiting, herring, sprat and sandeel from MSVPA were plotted against corresponding Working Group estimates and against associated IYFS indices where the latter exists. Results for saithe and mackerel were not included in this procedure since, in the MSVPA, it was assumed that these species are not subject to predation. Results for Norway pout were also excluded because the Working Group series of estimates is not yet long enough.

It was found that for cod, haddock and whiting, the MSVPA results highly correlated with the Working Group results (Figures 3.2.1 - 3.2.3). For herring, sprat and sandeel, a less good but still quite strong correlation exists (Figures 3.2.4 - 3.2.6).

If the MSVPA results so far studied turn out in future to be acceptable, it appears that almost all of the single species' assessments have been remarkably or reasonably successful in obtaining a valid picture of the relative changes occurring in recruitment to many of the commercially-important fish stocks. For this reason, it is generally found that MSVPA

estimates of recruitment at age 1 do not correlate better with IYFS indices than do those obtained by the single species assessments (see Figures 3.2.1 - 3.2.6).

It thus appears on the basis of very limited experience that assessment by MSVPA is not likely to produce better relationships between recruitment indices and estimates of population number at age.

3.3. Estimates of Predation Mortality at Age

Predation mortality results from the "key run" of MSVPA are shown in Table 2.8.1.

A summary of the range of predation mortality on the three youngest age groups on which it was generally of greatest importance is shown for various species in Table 3.3.1. The results are from the "key run" MSVPA. As well as the extreme values of M2, the table shows a statistic called "upset".

This is calculated as exp ($\sqrt{}$M2(HIGH) - M2(LOW)$\sqrt{}$/2) and indicates the percentage change in survival that a half-range deviation would cause. Thus, in the case of 0-group haddock, the highest M2 is 1.77 and the lowest 1.24. If the lower value occurred, then the survival of fish might be increased by a factor of about 1.30 from the mid-range value, while if the higher value occurred, then the survival of fish might be decreased by a factor of 1/1.30 = .77 from the mid-range value.

The value of upset therefore indicates to what extent the range of M2 values might interfere with normal single species management approaches to predicting catches. Factors of less than 1.20 might perhaps be thought of as being within the noise level of catch-at-age data, but values more than this might require some adjustment of M from its average level in order to make a catch prediction. Such an adjustment should properly be made on a multispecies basis but might perhaps be "fixed up" on a single species basis given the biomass at age of important predators and perhaps of their alternative prey.

3.4. General Considerations

The results of the MSVPA runs described above all indicate substantial predation mortalities on the younger age groups of the species considered.

The effect of these on assessment calculations is not yet fully understood, and it was not possible to carry out detailed studies in the time available. The question requires careful consideration, and might be a suitable topic for studies by the Working Group on Fish Stock Assessment.

However, it is clear that the effect depends very much on the type of calculation being performed. The Working Group is reasonably confident that the effect of increasing M by a fixed amount on the younger ages (especially pre-recruits) will have little effect on the calculation of short-term catch forecasts if fishing mortalities remain close to recent levels (approximately status quo forecasts).

Conversely, increased natural mortality (especially on exploited age groups) is likely to have a substantial effect on calculations used for the evaluation of longer-term strategies and biological reference

points (such as yield per recruit calculations). However (see further discussion in Section 4), these changes are of course intimately related to the interaction of one species with another, and the Working Group considers that it would be unwise to attempt to take account of such increases of natural mortality in a single-species context, until both the levels to be used and the appropriate techniques are better understood.

The increases of natural mortality do of course increase the estimates of the actual numbers of young fish in the sea, and this will have an appreciable effect on the evaluation of the consequences of the exploitation of young fish, even in the short term. If estimates of natural mortality are required for this purpose, the Working Group considers that it would be prudent to use the estimates based on the 1/2 ration (Run No.2) for the time being, since these are unlikely to be overestimates. Such results should, however, be regarded as provisional, and it must be remembered that they may be substantially revised in the near future when the methodology for allowing for the different weight of fish in stomachs compared with the stock, and the suitability of the different forms of functional feeding relationship have been settled. It should also be remembered that the estimates made include an element which is on pre-recruits (which are either too young or too small to be fished), and this should be taken into account, since the mortality on pre-recruits should be of little consequence in practice in yield per recruit calcultations (and like egg and larval mortality, are part of the recruitment process).

Finally, the estimates of year class strength from MSVPA correlate very closely with the conventional VPA estimates, and do not improve the correlation with survey estimates (such as those from the IYFS). This is disappointing, but there are still interesting correlations between survey estimates which deserve to be examined, and further investigations are required, since the present results must not be considered as other than preliminary. The same conclusion applies to the study of stock-recruitment relationships, where some clarification by inclusion of predation is still a possibility.

4. LONG-TERM ASSESSMENTS

4.1. Introduction

The effects of including inter-species predation in assessment calculations are expected to be fully expressed only in the long-term assessments. They can therefore be examined either by repeating short-term forecast calculations for many years, or by carrying out analyses of yield-per-recruit type.

However, both types of calculations are a little more difficult than in conventional, single species calculations, because the natural mortalities depend on the absolute abundances of the predators. In order to determine these, the expected level of recruitment must be specified - the simple scaling of yield proportional to recruitment (which makes yield-per-recruit such a useful quantity) no longer holds good.

Forecasting recruitment in the long term is rather difficult. There seems at present to be only two reasonably workable alternatives, that is either holding all recruitments at some mean level, or specifying all

the stock-recruitment relationships. The first is likely to be misleading, and the second to be contentious. The results of all long-term forecast calculations should therefore be interpreted with great caution. It is however most important to appreciate that the full benefit of work aimed at allowing for inter-species interactions will only be apparent in long-term assessments, where it is inextricably linked with the stock-recruitment problem.

4.2. Previous Attempts

There have so far been relatively few investigations aimed explicitly at exploring the long-term effects of predation.

The model of Andersen and Ursin (1977) tackles this problem and particularly when a refined stock-recruitment relationship is introduced (Ursin, C.M.1978/G:47). The approach, however, is of limited applicability until the initial slopes of stock-recruitment curves for important species become known.

Calculations of repeated forecast type have been carried out by Sparre (1980), who points out that the definition of an appropriate goal function is an essential feature of longer-term strategic assessments. He also stresses the difficulties of presenting the results of any extended exploration using such models in a comprehensible way.

An example of the part of calculation which may be carried out using the yield-per-recruit approach has been given by Shepherd (1984), and the same model has been used with more realistic assumptions on a real fishery with a powerful and economically important predatory interaction by Brander (1983).

The type of calculation described by Shepherd (1984) is of a global type, i.e., designed to fully explore a wide range of fishing mortalities in a variety of competing fisheries. Such calculations are of great interest, particularly in acquiring an understanding of the way that multispecies systems work, and the implications of the assumptions made. They are, however, probably dangerous, because for choices of fishing mortalities far from current levels they are likely to involve massive extrapolations of stock size, far outside the range of recent experience. It would therefore be wise to regard the results of such calculations outside a range of about $\pm$ 2dB ($\pm$ a factor of 1.5) around the current position as being illustrative only.

In addition, Shepherd (1984) points out that it becomes extremely difficult to display the results of this type of calculation when more than about three distinct fisheries are considered. In the real situation in the North Sea and elsewhere, a reasonably precise description of the major fisheries will certainly require the identification of more fisheries than this.

4.3. Alternative Presentations

The Working Group therefore considered alternative ways of organising and presenting the results of similar calculations, allowing for only small changes of fishing mortality, but many distinct fisheries. The most promising approach was felt to be an assessment of the likely changes of yield (in all fisheries) biomass and recruitment of each species, resulting

from a small (10% increase or decrease) in the fishing mortality in each fishery. This would lead to a small stock of tables (one for each fishery), and should be relatively manageable and comprehensible.

The program used by Shepherd was available to the Working Group, and was modified by the author to permit these calculations to be carried out. Unfortunately, it was not possible in the time available to complete a working version of the program, nor to assemble the considerable amount of data necessary to describe enough recognisable fisheries to construct a worthwhile example.

A sketch of the content and layout of the results of such calculations is however, given in Tables 4.3.1 - 4.3.4, and it is recommended that work aimed at enabling this type of information to be provided should continue.

It was however apparent from the work done that the calculations could be carried out and the results presented without any particular difficulty, for up to about 30 distinct fisheries. If it were necessary to consider more fisheries than this, some careful organisation of the calculation might be necessary, but using suitable methods, hundreds of fisheries could be considered if required (and if the necessary data were available!!).

4.4. Discussion

It should be noted that the parameterisation of the feeding relationship adopted by Shepherd (1984) demands estimates of parameters not immediately available from current versions of MSVPA, and that in general formulations which are convenient for hindcasting are inconvenient for forecasting (Ursin and Sparre, pers.comm.). It would therefore be desirable if a parameterisation of the feeding relationship could be constructed which allows a realistic treatment of "other food", yet can be expressed directly in terms of prey mortality, which is most useful for prognoses. This would permit direct transfer of parameter estimates from MSVPA to forecast calculations without intermediate re-interpretation.

There do not at present seem to be any particular advantages in using either the yield-per-recruit method, or repeated time-stepping forecasts to achieve equilibrium. Both require the stocks-recruit relationship to be specified. The YPR probably requires fewer iterations (usually less than 10), whilst the time-stepped method gives potentially useful information on the dynamics of the system (or the model), since one may observe the transient approach to equilibrium, and possibly also real instabilities and cycling behaviour.

When yield curves are calculated, it should be noted that the functional feeding relationships for fish (i.e., the mortalities exerted by predators on prey as a function of predator abundance, prey abundance (all species) and external factors) are very uncertain and will be difficult to determine. The form of the feeding model is critical for long-term assessment.

5. ADVICE ON FUTURE DATA COLLECTION

5.1. Future Stomach Sampling Programmes

The results of the 1981 stomach sampling project having been implemented in the MSVPA, it is thus a suitable time to discuss the need for similar

information in future. First of all, it is clear that the extensive data collected in 1981 have actually served the original purpose to get the MSVPA going by taking account of the interactions of the exploited fish species in terms of predation. However, it is also evident that although some confidence has been gained from the general agreement between the cod results for 1981 with earlier data (Section 6), the basis for running a MSVPA over prolonged time periods is still narrow, because the tuning of the suitability matrices relies entirely on the one-year stomach content data set.

From comparing the level of intensity of sampling reached in 1981, some major differences emerge for the various species. For cod, whiting and haddock, the original aim of collecting approximately 3 000 stomachs per quarter with adequate coverage of the entire North Sea was exceeded in all instances. In contrast, for saithe and mackerel, neither the intensity nor the distribution of samples has been adequate to provide reliable figures of average consumption by age groups for the total North Sea population and samples from other years had to be added. Thus, the pre-requisite of tuning relative consumption in 1981 to the specific stock sizes in 1981 had to be violated. Obviously, the need for intensive stomach sampling of these species in order to improve the estimated suitability matrices still has a high priority. However, in practice, there are considerable logistic problems both in obtaining samples and in obtaining information on the seasonal spatial distribution for these species and it will be doubtful if at present any follow-up could be expected to meet the ultimate requirements.

One of the major underlying assumptions of the MSVPA is that the suitability by prey and predator age class and quarter is constant over time. After tuning the suitability matrices for the reference year to have the estimated stomach contents corresponding to the observed stomach contents, these indices are applied to calculate the food composition over all other years. However, there are various reasons why suitability indices may vary over time, the more likely ones being that 'prey switching' may occur when major changes in prey abundance take place or when the measure of overlap between a predator and prey population varies from year to year. Thus, there is a strong need to test the hypothesis of constant suitability, which requires that the stomach sampling program is repeated for at least some species for which 1981 has yielded a reliable estimate of suitabilities.

Since a measure of overlap could actually be estimated outside the model on the basis of research vessel data and thus used as additional input in MSVPA for years for which no stomach content data are available, it would seem appropriate to investigate possible changes in the estimated suitability matrices for individual quarters with direct estimates of the measure of overlap. This would require that stomach sampling is repeated in the same season over several years, rather than that sampling is spread over all quarters in one specific year, particularly since useful surveys for estimating measures of overlap are confined to some seasons only. Intensive surveys are carried out annually in February (IYFS), but less internationally coordinated surveys are routinely being carried out in summer as well (England, Federal Republic of Germany and Scotland). If stomach sampling were confined to these seasons, effective use could be made of existing trawl surveys and there would be no need for additional research vessel effort. It is suggested therefore that over a period of three years, intensive stomach sampling programs are continued for both

cod and whiting because these represent the two main fish predators that can be sampled adequately. However, it should be noted that with the present quarterly basis of the MSVPA, any stomach sampling program that is set up to provide an estimate of relative stomach contents for any species and quarter can be efficiently used for tuning, as long as the requirement that it reflects the total average North Sea stock is fulfilled. Thus, the continuity in sampling is a less important factor than the coverage of the total area.

There are a number of related problems, which require further research and which may affect the planning of future programs. Firstly, it has been suggested that ration may be more efficiently estimated from the means of the square root of the stomach contents than from the mean stomach contents (Pennington, 1984). In order to be able to make the necessary adjustment, information has to be collected on the frequency distribution of individual stomach content weights. This problem might be solved by analysing individual stomachs instead of grouped samples, but in view of the increased workload implied, it would seem that this problem might be more efficiently solved by collecting only a subset of all the samples on an individual basis or alternatively by creating a specific independent program.

Another problem is related to the fact that the estimated indices may reflect a real change or that they may result from sampling variance. The problem of sampling variance is dealt with in more detail in Section 6.7. One solution to this problem would be to split each sample in two fractions, which are analysed separately, so that ultimately two sets of average stomach contents will be available to estimate the inherent variances. Lastly, some revisions may be required in the sub-division of predators and preys in size classes because in some instances the classes defined in the former project appear to be too large to be used efficiently in estimating average prey weights by age and size classes, and also in size preference studies. A further break-down would facilitate the analysis. In addition, a separation of the observed prey in stomachs into two classes according to stage of digestion might result in more accurate reporting of sizes and number of prey as well as speed up the analysis. These aspects should be more closely investigated in the actual planning process for future work.

Lastly, it was stressed that the predator prey interactions taken account of in the MSVPA by no means can be expected to give the final answer to multispecies assessment. Interactions during the egg and larval phase may prove to be more important in regulating year class strength, but it seems unlikely that these earlier life phases could be effectively included in the MSVPA, because of mathematical restrictions in obtaining unique solutions as indicated by Magnus and Magnusson, 1983. It was felt, however, that, particularly in view of the expected upsurge of the North Sea herring stock in the near future, further studies on predation of eggs and larvae of this species would be extremely valuable, but, as yet, the background knowledge to set up a comprehensive project to study this aspect appears to be lacking.

5.2. Further Research

Food preference estimates

Apart from the most obvious future work detailed in Section 5.1, there are a number of problems which could usefully be addressed by field research.

The following would be particularly useful.

1. Fish as food

At present, elements of the suitability matrix are estimated empirically in the MSVPA model for each separate prey age, and predator age interaction. This creates problems with age groups poorly represented in the stomach data. For instance, the suitability of large herring becomes zero because in 1981 there were few in the North Sea and none in the stomach samples. Such problems can be overcome by estimating species-specific vulnerabilities to predation and by finding functional relations of predator size to prey size. A theory is available (Andersen, 1982). It was tentatively applied by Dekker, 1983, and by Arntz and Ursin, 1981. The model requires data on food abundance by species and size class, and corresponding stomach data. Coverage of a large area or a long time is not required. It is therefore applicable to a single effort of local sampling of stomachs with simultaneous estimates of abundances in the environment. Such work might be a useful adjunct to future stomach sampling programs.

2. Invertebrates as food

The "other food" compartment in the three feeding models applied in the MSVPA program remains an arbitrary and somewhat obscure quantity. Its real nature could be investigated if relative suitabilities of fish and benthos were estimated for demersal predators. This requires data on the abundance of fish and important invertebrates by size class and per unit area. Data might be obtained by trawling and benthos sampling in the same place and at the same time if catchability coefficients can be estimated. A comparison of prey in the stomachs of fish in a unit area (adjusted by digestion rate) might, with food abundance data, provide estimates of the mortality coefficients created upon the benthos stocks by fish.

Such sampling might be a part of a benthos monitoring scheme which would disclose major changes in the ratio of invertebrate predators to detritus and plankton feeding in the benthos. This relates to the conceptional background of the assumption on "other food" that this is always available. The assumption is that with increased fish predation, the invertebrate predator biomass would be reduced so that the fish could feed on, for instance, what the crabs would normally eat. This phenomenon is known from cage experiments (Arntz and Brunswig, 1976; and Reise, 1977), but remains conjectural in the field.

Ration estimates

Digestion experiments have often been performed, also in connection with the ICES Stomach Sampling Program, yet it seems that some decisive factor in the determination of digestion rates in nature has been overlooked. The difference in digestion rates estimated for cod in the North Sea and on Georges Bank are worrying (Ursin *et al*, 1984). The only way open to solve this problem appears to be by digestion experiments with natural foods of different species, sizes, etc. A considerable difference in food item sizes between Georges Bank and the North Sea points to item size as a possible cause, effects of which are at present poorly described in literature.

Observations on efficiencies of food conversion for different natural foods are also needed. The difference between cod in the two areas might be at least partly described as differences in food conversion. These might even be due to physiological differences in cod stocks, although this seems perhaps far-fetched. Some clear advice on how to proceed with research on this topic needs to be given by an expert.

6. OTHER MATTERS

In the course of work on the MSVPA, the Working Group raised various problems and made various analyses. These may well prove the basis of further studies by individuals in the Working Group. They are presented here to stimulate these studies.

6.1. Comparison of the 1981 Stomach Sampling Results with Earlier Data

Since for cod extensive data on stomach contents have been collected in earlier years, it is possible to make a comparison between those earlier results and the results for 1981. However, there are considerable differences in the raising procedures from primary analysis to ultimate figures of total consumption, which have to be taken into account when comparing such figures.

Table 6.1.1. presents the estimated consumption in weights of various exploited fish species for 1981 with the estimates given by Daan, 1973. The values for 1981 have been obtained by multiplying the percentage weights of the different prey by age group (Daan, 1983; Table 7) with the estimated consumption for the total year (Anon., 1984; Table 7-1-2) times the estimated average stock size in 1981 from traditional VPA (Daan, 1983; Table 9). For reasons of comparability, the effect of MSVPA on the estimates of cod stock consumption has not been taken into account.

From the Table, the estimates for individual species appear to be in the same order of magnitude, and even if ranked according to importance, the two sets appear to be very close. This suggests that the two data sets are fairly consistent and that even over a period of 10 years, no major differences in the food spectrum of a predator may occur.

Daan (1983) made a comparison between the estimated feeding coefficients from three sampling programs, and the essential values are given in Table 6.1.2. These feeding coefficients are based on regressions of log transformed stomach content weights against log transformed length of cod. Since the exponent of the underlying relationship $S = a L^b$ did not deviate significantly from 3 in any of the data sets, the model has been changed to $S = \emptyset L^3$, where the parameter $\emptyset$ represents an index of stomach fullness and thus can be interpreted as an index of feeding level.

The values of the feeding coefficient $\emptyset$ are very close for all the three data sets (coefficient of variation 4%), which seems to indicate that over a prolonged period, no major changes in the rate of food intake have occurred.

6.2. Who Eats Who?

The standard output tables from MSVPA provide detailed information on the weights and numbers consumed of each prey age group by each predator age group during each quarter of all the years included in the VPA. A major logistic problem arose when this information had to be reduced to a tractable format. Since a more comprehensive summary would have required additional programing, only some aspects could be explored.

Since all predation is tuned to 1981 and estimates for other years reflect extrapolations, it appeared appropriate to compare the overall predation in 1981 and 1974, being the year most remote from 1981. Table 6.2.1. summarises the total weights of the various prey stocks consumed by the four predators with the estimated stock biomasses (including 0-group) in the two years. From this Table, it would appear that the percentage of the stocks removed by predation may easily double from one year to another. Still, the relative pressure of individual predator species is even more variable, indicating that total predation is considerably buffered by differential trends in predator stock sizes.

In order to obtain a general idea of the impact of various predator age groups on different prey age groups in any particular year, the partial predation coefficients can be calculated according to:

$$M2\ (i,a,j,b) = M2\ (i,a) \times \frac{D(i,a,j,b)}{\sum\sum_{jb} D(i,a,j,b)}$$

where D(i,a,j,b) represents the total predation in numbers of prey i, age a by predator j, age b. The thus estimated partial mortalities will clearly be strongly depending on the predator stock sizes and, more interesting, division by the average number of the specified age in the predator stock should represent the chance of a prey being consumed by the average predator. It is thus analogous to a catchability coefficient.

As an example in Table 6.2.2, the estimated partial predation mortalities and the mortality coefficients relating to the individual predator are given for haddock as prey. In general, the impact appears to increase with age of predator and decrease with age of prey, but particularly for cod eating haddock, the peaks appear to shift in much the same way as can be expected from a size preference.

If predators are treated like fleet operations and the assumption is made that 'catchability' by a predator is independent of prey stock size, such estimates might provide a useful starting point for short-term predictions of expected predation mortalities given the predator stock size. Although it is not intended that the data presented here should be used in this fashion, this approach would appear to present an interesting field for further studies.

6.3. Biological Considerations and the Problems of "Other Food" and Suitability

The three feeding models (Helgason and Gislason, Sparre, and Pope) handle the role of "other foods" in different ways. These differences

may produce important differences in predictions from the same starting data (Ursin, 1982; Section 2.6 of this Report). Biological considerations may provide some guidance for decisions, when the predictions of the feeding models differ. These considerations would be particularly important when models allow "other food" to support a substantial portion of predator populations in model runs.

To make biologically sound conclusions about the true role of other foods, we must know something about them. On biological grounds, one might expect to recognise years when predators had to rely on "other foods" as years when the predators had low growth rates. Historical data from North Sea stocks might be examined for such patterns. Interestingly, in the northwest Atlantic, examination of cod growth over several years of differing capelin abundance and cod feeding habits showed no relationship between cod growth and capelin abundance (Akenhead et al., 1982). It has also been suggested that because other foods are generally of sizes most appropriate for smaller size groups of predators, the true role of other food may appear as faster growth and/or higher survivorship of younger age groups than of older ages. However, even this relationship could be absent, because if older predators are finding few prey at a time when their younger age groups are doing relatively better, it is quite plausible that older ages increase cannibalism, and obscure the suggested differences among age groups.

Although biological thinking can suggest possible roles for other food, the examples above imply that expected relationships are not present, unconvincing, or both. Long-term studies of stomach contents do, however, demonstrate great variation in use of different prey among years (Lilly, 1984; Maurer and Bowman, 1975). To clarify the role of other foods in the multispecies system, directed research efforts will probably be required. This may be possible for the demersal species, but assessing availability of other foods for pelagic species is less possible.

Because of its role in the various feeding models, other food warranted specific consideration. However, it may be a special case of a more general concern, regarding the reality of the suitability coefficients in the model. The single parameter set "suitability" is intended to reflect behavioural aspects of predation (for example, prey-palatability), local availability of prey to predators, and larger-scale distributional overlap of predator and prey stocks (Ursin, 1982). Requiring a single parameter to do several jobs at once, presents a number of modelling difficulties, but there are, however, even more aspects of predator-prey interactions which possibly need to be represented in multispecies models, rather than fewer.

The suitability coefficients should be, and are, independent of prey abundance (as long as some predator is using each prey); and they do reflect size selectivity of both predators and prey. The size preference is based on predator and prey ages though, rather than sizes, and this had led to some modelling difficulties. For reasons of both theory of predator behaviour and practical model structure, it may be desirable to develop a size-structured model of multispecies interactions and dynamics.

Currently, the suitability coefficients do not provide for responses of predator feeding to prey abundance. There are theoretical and behavioural reasons to expect such density dependent relationships on both the increasing and decreasing phases of changes in prey abundance (Dill, 1983).

Predators apparently stick with a previously abundant prey as it becomes rarer than alternative foods. They also may not commence feeding on a previously rare food, until that species' biomass is much higher than foods which were more common earlier. Models lacking these density dependent relationships between predators and prey, may smooth pulses in prey abundance artificially. When prey in the model begins to increase, the suitability-prey biomass product tracks that change, whereas the predator's response may be more abrupt. Likewise, predators in models may switch from a prey of decreasing abundance more quickly than actual predators do, so in real systems, prey biomasses may become more depressed than occurs in models. If additional sampling is carried out synchronously with prey biomass assessments (Section 5.1), it will be possible to look for such smoothing of prey abundance changes in model predictions when compared with observed predator behaviour.

Current models treat the entire North Sea as if it were homogeneous. Realistic future models may need to address problems of spatial overlap of predators and prey. Individual age classes of both predators and prey are known to school together, at least in some cases. Such age, and by inference, size separation of prey stocks especially, would accentuate the lags in predator responses to changes in prey abundance discussed earlier. Such size separation, and larger-scale geographic limitations of distributions of some species (saithe, for example) could make the use of a single suitability measure for each predator-age group, prey age group unrealistic. In this context, it would be interesting to attempt to model multispecies interactions of a spatially, much more restricted, fisheries area, where the assumption of spatial homogeneity was met more closely. For such a system, model accuracy should be greater.

6.4. Comparison of Predation Mortalities with Earlier Estimates

The results of the extensive exercises with the North Sea echosystem model by Andersen & Ursin (1977) were compared with estimates from MSVPA. As an example, the estimated predation mortalities for 1976 from the two models are compared in Table 6.4.1 (all model-unpublished run). In this comparison, it should be taken into account that both models assume very similar feeding mechanisms and total consumption rates. On the other hand, the basic information on feeding available to the Andersen and Ursin model was very limited, and the input was to a large extent based on logic inferences from the available literature, whereas the MSVPA is entirely dependent on the information collected in 1981.

Inspection of the differences between the two data sets reveals two major differences: (1) The predation mortalities on saithe and mackerel are estimated at zero value in the MSVPA, since they were not recorded as prey in 1981. This is now being interpreted as young fish of at least saithe, being almost completely outside the North Sea. (2) For older sprat, the estimates from the ecosystem model have been largely underestimated. In spite of these differences, the close agreement between both the estimated trends in mortality with age and the actual

levels, indicates that the impact of predation in both exercises is virtually the same.

6.5. Catchability Coefficients

Age-specific catchability coefficients to the fishing gear of research vessel surveys have been calculated on a single species basis by the "Survivor" method (Doubleday, 1981) for the North Sea cod, haddock and whiting stocks.

The results showed that the catchability coefficients were higher on younger ages. This could result from the design of the survey or from the gear used. However, it could also be interpreted as meaning that there were more fish of these ages in the sea than estimated by single species VPA, assuming constant natural mortality rate on all age groups. Thus, one conclusion could be that M on these younger age groups is higher than on older age groups. Estimates equivalent to M2 values are given in the text-table below, calculated as $\ln\{q(i)/q(i+1)$.

	North Sea Cod		North Sea Haddock		North Sea Whiting	
Age	q(i)	M2 Equivalent	q(i)	M2 Equivalent	q(i)	M2 Equivalent
1	1.217×10^{-2}	0.66	2.840×10^{-2}	-0.01	1.840×10^{-2}	0.45
2	6.263×10^{-3}	0.21	2.876×10^{-2}	0.53	1.179×10^{-2}	0.44
3	5.091×10^{-3}		1.700×10^{-2}		7.561×10^{-3}	

This suggests that to a limited extent we may be able to directly observe the high levels for predation mortality that MSVPA calculates on younger ages of fish.

6.6. Existence and Uniqueness of MSVPA Solutions

To run a MSVPA requires the solution of a system of non-linear equations. This is done in the available computer programs with a natural iterative approximation. Questions regarding existence, uniqueness and stability are a matter of concern to the Working Group.

The Working Group has mainly focussed on the Helgason-Gislason version of MSVPA. For that, and other reasons, the following discussion is limited to that version, although some, but not all, of the following remarks apply to the versions of Pope and of Sparre. Furthermore, the following discussion relies upon the original formulae of Helgason and Gislason (1979). The computer program developed by Sparre (1984) and used in the present study, differs in the suitability coefficients. These are assumed fixed by Helgason and Gislason, whereas Sparre derives them (in an initial phase) from observed stomach contents in the year 1981. It is most likely that the following remarks apply just as much to the Sparre program.

Dekker (1982) raised these questions but was not able to prove nor disprove uniqueness of the (Helgason-Gislason) equations when used, as in the present study of the Working Group, in retrospective mode. On the other hand, he produced a simple example showing that existence and uniqueness are not guaranteed when the model is used for predictions, i.e., in forward mode.

Magnus and Magnusson (1983) tackle the problem from a mathematical standpoint. They make, in general, the so-called "triangular assumption", i.e., that no fish preys on a fish equal or larger than itself, or more precisely, that the cohorts can be linearily ordered in such a way that a particular fish only predates upon fish in cohorts with a lower number than the number of its own cohort. Their findings can be summarised as follows:

1. There always exists a solution. This statement is also true when the triangular assumption does not hold.

2. If there are no more than 4 cohorts in the system and the triangular assumption holds, the solution is unique.

3. If (suitable) external food is sufficiently plentiful, uniqueness is guaranteed. This is not surprising, as the MSVPA approaches traditional VPA as the quantity of other food approaches infinity. On the other hand, this observation is not very useful, since a numeric value cannot be assigned to the "sufficient" quantity of external food.

4. If certain inequalities involving the data alone are true, then uniqueness holds. Here again the triangular property is assumed. These inequalities could be verified by the computer, but a corresponding sub-routine has not yet been incorporated into the program package.

5. A set of inequalities are given that guarantee the existence of a solution to the multi-species model when used for predictions. These inequalities basically require the existence of sufficient food for the fish stocks entering the model.

It should be stressed that the mentioned conditions guarantee uniqueness if fulfilled. Nevertheless, uniqueness may hold even when none of these conditions is satisfied. Thus, it still may be true that there is a unique solution in all sensible cases. The Working Group expresses the hope that further progress will soon be made in clarifying this issue.

In order to illustrate the uniqueness property, let us consider the following example.

Two species preying on each other and having the parameters:

$N_1(1)$	= 823.87	$N_2(1)$	= 1.24	
W_1	= 10	W_2	= 10	
R_1	= 10	R_2	= 10	(Food cons. ration)
	M1 = 0			
G_1^1	= 0	G_1^2	= 1	)
G_2^1	= 1	G_2^2	= 0	) Suitability coefficients
C_1	= 100	C_2	= 100	(catch)
F_1	= 5 000	F_2	= 0	(external food)

In this simple case, it is easy to derive functional relationships between the average stock size of each species $\bar{N}_1$ and $\bar{N}_2$. Let these be

$$\bar{N}_1 = f_1(\bar{N}_2)$$
$$\bar{N}_2 = f_2(\bar{N}_1)$$

Table 6.6.1. shows solutions for $\bar{N}_1$ given $\bar{N}_2$ at $\bar{N}_2$ given $\bar{N}_1$, and Figure 6.6.1. shows these two curves.

The MSVPA solutions are the intersections between f_1 and f_2.

It can be demonstrated that the two curves shown in the Figure intersect only at the point shown. This proves that there is only one solution to the MSVPA in this example. This cannot, however, be concluded from the conditions of Magnus and Magnusson (1983) since the triangular assumption is not satisfied. It should be pointed out that in the real data used in the main study of the Working Group, the triangular assumption is not satisfied. It is therefore of great importance to expand Magnus and Magnusson's conditions so that they apply to real-world situations.

6.7. Sources of Variance of Consumption Estimates

The Report of the ad hoc Working Group on Multispecies Assessment Model Testing (Anon., 1980) recognises the many sources of variation and systematic error that stomach content data and consumption estimates are hampered with. However, since optimal stratification and sample size were impossible to evaluate at that moment, the Group did not give any requirements of confidence limits in their recommendations to the North Sea Stomach Sampling Program, 1981. Due to other priorities, the coordinators of the Stomach Sampling Program did not pay much attention to these problems in their report (Anon., 1984), and no indication of the likely confidence limits of the results is given. Such estimates will also be extremely difficult to obtain since both random sampling

variance (e.g., introduced by individual sampling of stomachs from a trawl haul) and systematic errors of unknown size due to raising factors and uncertainties in respect of digestion models, temporarily emigration of fish out of the North Sea (ref. 2.2., page 4), etc., operate simultaneously. The likely errors of the consumption estimates will also vary between species. Cod, for instance, is probably adequately sampled by bottom trawl, while several years' work had to be applied to sample the whole population of pelagic species like saithe and mackerel.

Pennington, Bowman and Langton (1980) evaluated the variability in the weight of the stomach content of cod sampled at the east coast of the USA by trawl. The general conclusion was that the individual variance within a haul is larger than variance between season, time of day, etc. The coefficient of variation was about 1.4 for all size classes of cod. If the stomach contents were to be split into individual prey categories, the coefficient of variation would become even larger.

J. Pope (unpublished data) investigated the number of 0-group Norway pout in the stomachs of 30-34 cm whiting sampled haphazardly throughout the North Sea in 1978, and obtained a coefficient of variation of 1.1, being the same size range as the American cod data.

Pennington (1981) sets up formulae to estimate variance of the consumption estimates when random samples are taken from a population. He gives results for silver hake indicating a standard error of 30% of the estimated total consumption. Again, a higher value might be expected if the stomach content were split into several prey species.

The present Working Group had only the data for cod in hand and there was not sufficient time to explore these data in any detail. However, some trial runs were set-up to come to grips with the problem.

No conclusive results were obtained, but the Working Group suspects, however, that the confidence limits for the consumption estimates on any one single prey species size group has rather wide limits and that if possible a higher number of stations is required than the number taken in the 1981 project.

If a new sampling scheme is to be set-up in the North Sea, a careful stratification of sampling effort should be set-up, based on the experience derived from the total data base of the 1981 program, aiming at keeping the coefficient of variation of consumption estimates of each prey species at a reasonable level. A first step should be an analysis of the variation exhibited by the 1981 stomach content data.

6.8. Two Possible Ways of Correcting the Bias in MSVPA Results due to Systematic Differences between Weights of Prey in the Sea and in Predators' Stomachs

Section 2.7 describes the discrepancies found between the weight of some prey species in the sea and in predators' stomachs. This effect seems to be systematically related to predator size with larger predators taking larger individuals from a prey cohort and smaller predators taking smaller individuals. Two approaches were developed to deal with the resulting bias in the MSVPA, but in the time available

to the Working Group, only the former could be inserted in the program, which if either is the appropriate form of correction, has to be resolved, and it is hoped that the following expositions of the alternative approaches will stimulate further work on this subject.

Correcting for bias by adjusting the suitability estimates

Let $\overline{W}_{sea}$ (s,a) be the mean weight of age group a of species s in the sea (the population mean). Let $\overline{W}_{stom}$ (j,b,s,a) be the mean weight of prey s age group a observed in the stomach of predator j age group b.

The model presented in Sparre (1980) assumes that

$$\overline{W}_{sea}(s,a) = \overline{W}_{stom}(j,b,s,a) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 6.8.1.$$

However, as demonstrated in Section 2.7, great deviations from assumption (1) were observed. This is likely to give biassed estimates of predation mortalities, and it was attempted to correct for that. To circumvent the bias problem, a 'correction factor' was derived as follows.

Ideally, the suitability concept SUIT (j,b,s,a) based on age groups should be replaced by a suitability concept based on lengths.

$$\text{SUIT}(j,b,s,a) = \sum_{l} \text{SUIT}_L(j,b,s,a,l) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 6.8.2.$$

where l is index of prey length group.

Let $\emptyset$ (s,a,l) be the relative length distribution of prey (s,a) in the sea (lengths are used rather than weights to match the actual observations of the stomach content sampling scheme).

Thus

$$\overline{W}_{sea}(s,a) = \sum_{l} \phi(s,a,l)\, W_{sea}(s,a,l) \quad \ldots\ldots \quad 6.8.3.$$

where W_{sea}(s,a,l) is the weight of prey (s,a) of length l in the sea.

The expected mean length of (s,a) in the stomach of (j,b) is

$$\overline{W}_{stom}(j,b,s,a) = \sum_{l} \frac{SUIT_L(j,b,s,a,l)}{SUIT(j,b,s,a)} \phi(s,a,l)\, W_{sea}(s,a,l) \quad 6.8.4.$$

(see Figure 6.8.1 and compare Equation 6.8.1).

Ideally, the formula

$$M2(s,a) = \frac{1}{\bar{N}(s,a)\bar{W}_{sea}(s,a)} \sum_{jb} \bar{N}(j,b)R(j,b) \frac{\bar{N}(s,a)SUIT(j,b,s,a)\,\bar{W}_{sea}(s,a)}{\sum_{di} \bar{N}(d,i)SUIT(j,b,d,i)\,\bar{W}_{sea}(d,i)} \qquad 6.8.5.$$

should be replaced by $M2(s,a) =$ 6.8.6.

$$\frac{1}{\bar{N}(s,a)\bar{W}_{sea}(s,a)} \sum_{jb} \bar{N}(j,b)R(j,b) \frac{\sum_{\ell} \bar{N}(s,a)SUIT_L(j,b,s,a,\ell)\phi(s,a,\ell)\,W_{sea}(s,a,\ell)}{\sum_{di}\sum_{\ell} \bar{N}(d,i)SUIT_L(j,b,d,i,\ell)\phi(d,i,\ell)W_{sea}(d,i,\ell)}$$

Thus, the correction factor becomes

$$C.F. = \frac{\sum_{\ell} \bar{N}(s,a)\,SUIT_L(j,b,s,a,\ell)\phi(s,a,\ell)\,W_{sea}(s,a,\ell)}{\bar{N}(s,a)\,SUIT(j,b,s,a)\,\bar{W}_{sea}(s,a)} \quad \ldots\ldots \quad 6.8.7.$$

C.F. is to be applied both to the nominator and the denominator in Equation 6.8.6.

Inserting Equation 6.8.4 into Equation 6.8.7, we get

$$C.F. = \frac{\bar{W}_{stom.}(j,b,s,a)}{\bar{W}_{sea}(s,a)} \quad \ldots\ldots\ldots\ldots \quad 6.8.8.$$

Thus, to repair for the bias, $\bar{W}_{sea}(s,a)$ in Equation 6.8.5 should be replaced by $\bar{W}_{stom}(j,b,s,a)$.

Note that an unbiassed estimate is obtained only if the condition (Equation 6.8.4) is fulfilled.

The correction for bias is to change the SUIT-values by the correction factor.

The main reason for this particular way of repairing for bias stems from the iterative manner in which the suitability coefficients are calculated in the FORTRAN program.

The mathematical equivalence:

relative stomach content =

$$CON\ (j,b,s,a) = \frac{\bar{N}(s,a)\ \bar{W}(s,a)\ SUIT\ (j,b,s,a)}{\sum_{di} \bar{N}(d,i)\ \bar{W}\ (d,i)\ SUIT\ (j,b,d,i)} \qquad 6.8.9.$$

$$\Longleftrightarrow$$

$$SUIT\ (j,b,s,a) = \frac{\dfrac{CON\ (j,b,s,a)}{\bar{N}(s,a)\ \ \bar{W}(s,a)}}{\sum_{di} \dfrac{CON\ (j,b,d,i)}{\bar{N}\ (d,i,)\ \bar{W}(d,i)}} \qquad 6.8.10.$$

must be fulfilled to secure that the iterative process converges. To replace SUIT by SUIT x C.F. does not change/spoil the equivalence.

Another approach would be to run the iterative process and afterwards repair for bias in M2 by multiplying M2 by

$$\frac{\bar{W}_{sea}}{\bar{W}_{stomach}}$$

This idea is developed in the next Sub-section.

Correcting for bias by adjusting the M2 estimate

A second approach to this problem studied was by specifying some theoretical function for $\emptyset\ (s,a,l)$ and

$\frac{SUIT_L\ (j,b,s,a,l)}{SUIT\ (j,b,s,a)}$ in Equation 6.8.4, and from this

derive a regression function for the data presented on prey weights in stomachs of the report of the Meeting of the Coordinators of the Stomach Sampling Project, 1981 (Anon, 1984). The success of this regression can be used as a test on the assumption that the observed differences in weight are the results of the predators having a size preference for certain prey sizes within one prey year class. On the other side, the estimated regression function can be used as a predictor for the best correction factor.

Following the lines of reasoning of Andersen (1982), it was assumed that:

a) the weight of a prey in the population within one year class has a log-normal distribution (with mean μ and variance τ^2).

b) the size preference of a predator has the shape of a log-normal frequency distribution (with log mean/(prey to predator weight ratio) = η, and variance σ^2, i.e., mean log (preferred prey weight) = η + log W_{pred}).

If the fraction of a year class removed by predation is not too large, it follows that the weight of a prey in a predator stomach within one year class is log-normally distributed with mean

$$Co \times \eta + Co \times \ln W_{pred} - Co \times \mu + \mu \quad \ldots\ldots\ldots\ldots \quad 6.8.11$$

$$\text{where } Co = \frac{\tau^2 \times \sigma^2}{\tau^2 + \sigma^2}$$

$$\text{and variance } Co \times \sigma^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 6.8.12$$

Assuming that η, σ^2 and τ^2 are independent of prey and predator age group, the different age groups were treated as multiple observations of one and the same regression function (6.8.11).

The log of the mean weight at age given by the various Assessment Working Groups was used as an estimate of μ. Taking the value for σ^2 estimated in Dekker (1983) for cod eating gadoids as a reasonable estimate for any prey category for any predator ($\sigma^2 \approx 1$), and the estimated values of the slope of the regression lines given below, it follows that the log of the mean prey weight in the predator stomach does not deviate from the mean of the log very significantly. Furthermore, the intercept of the regression (6.8.11) divided by its slope, should be an estimate of η. Comparing these η-estimates (given in Tables 6.8.1 and 6.8.2) to Dekker (1983), it is obvious that some η-values estimated here are utterly wrong but the general trend is in reasonable agreement.

7. CONCLUSIONS AND RECOMMENDATIONS

Broad conclusions and recommendations are summarised below. To aid clarity, these are cross-referenced to the relevant report section.

Section 1

7.1.a. The ad hoc Working Group had a successful and productive first meeting. The results detailed, however, are necessarily provisional and a further meeting of the ad hoc Working Group will certainly be needed to consolidate the advances made at this meeting and to develop means of giving long-term multispecies assessment advice.

The ad hoc Working Group on Multispecies Assessment therefore recommends that it meet again at about the same time in 1985.

Section 2

7.2.a. A number of the inputs to MSVPA need to be estimated more precisely than was currently possible. This may be partly achieved by further research by members of the ad hoc Working Group but specific advice on quarterly catch-at-age data and proportions of the fish stocks outside the North Sea would best be provided by the relevant Assessment Working Groups. The ad hoc Working Group therefore recommend that the various Assessment Working Groups should at future meetings supply quarterly catch-at-age data for use in a MSVPA. They should also try to give some guidance concerning the proportions of different fish stocks included in the MSVPA which are outside the North Sea at different ages and different times of the year.

7.2.b. It would also be helpful if they could advise on suitable levels at natural mortality (M1 + M2) to apply to the oldest ages of each fish stock.

7.2.c. The problem of how best to adapt MSVPA to allow for differences in the weight of fish found in stomachs and in the sea, needs further research.

7.2.d. The results of the MSVPA runs all indicate substantial predation mortalities on the younger age groups of the species considered.

Section 3

7.3.a. The effect of including these mortalities in assessment calculations depends very much on the calculation being carried out.

7.3.b. It is the considered opinion of the Working Group that the effect of increasing M by a fixed amount on younger ages will have little effect on short-term catch forecasts if fishing mortalities remain close to current levels.

7.3.c. The effect on long-term assessments (e.g., yield-per-recruit) is likely to be substantial, but it would be unwise to consider these effects of predation mortalities in a single-species context, until both the levels to be used and the appropriate techniques are better understood.

7.3.d. Inclusion of predation mortalities increases estimates of the actual number of young fish in the sea, and will have an appreciable effect on the evaluation of the consequences of the exploitation of young fish, even in the short-term.

7.3.e. If revised estimates of natural mortality are required, it would be prudent to use the estimates based on the half ration assumption (Run No.2) for the time being, since these are unlikely to be overestimates.

7.3.f. Estimates of predation mortality may include an element which is on pre-recruits, which should (like egg and larval mortality) be of little consequence in practice, for making some types of calculation (e.g., yield per recruit).

7.3.g. Current estimates of year class strength from MSVPA do not correlate better with survey indices or clarify the stock-recruitment relationship, compared with traditional estimates. This may yet be because of imperfections in the estimates, and further investigations are required.

Section 4

7.4.a. The effects of including predation mortalities in assessment calculations are expected to be fully expressed only in the long-term.

7.4.b. Predation mortalities depend on absolute predator abundances, so that yield-per-recruit calculations alone are no longer adequate, and the stock-recruitment relationships become of crucial importance.

7.4.c. The form of the functional feeding relationship assumed is of great importance in long-term assessments, affecting both the stability and the validity of the results. The adequacy of current assumptions is uncertain and requires further investigation.

7.4.d. The presentation of the results of long-term assessments is not easy, particularly when many fisheries are considered, and further work is required.

7.4.e. Long-term assessments may imply fish biomasses well outside the range of recent experience. The extrapolation of present interpretations of data outside a range of ± 50% of the current situation should be regarded as illustrative only.

7.4.f. Exercises involving running the MSVPA for years earlier than 1974, going back to the middle 60's, would give indications of the robustness of the MSVPA model due to the great changes in North Sea fish biomass that occurred during that period.

Section 5

7.5.a. The ad hoc Working Group recommends that future stomach sampling should be particularly for cod and whiting, and should be carried out for particular quarters in 1985, 1986 and 1987 using existing research vessels' surveys for sampling purposes.

7.5.b. Studies of the variability of the 1981 sampling programme should be made.

7.5.c. Studies aimed at increasing our understanding of the suitability matrix should be made and would involve the joint sampling of stomach contents and prey (including invertebrate prey).

7.5.d. Studies need to be conducted on factors of importance to predator ration size. Expert help should be sought on this problem.

Section 6

7.6.a. The contents of the various sub-sections of Section 6 should form the starting point for a number of studies to be conducted during the year by individuals and presented to the next meeting of the ad hoc Working Group.

8. ACKNOWLEDGEMENTS

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EXPLANATION OF FOOTNOTES TO TABLE 2.2.1 - LAY-OUT OF THE INPUT VALUE TABLE

1) In species where no quarterly data were available to the Group, the annual catches were split by inserting the quarterly fishing mortality coefficients and the annual natural mortality coefficients given here into the appropriate equations (Sparre, 1984), i.e.

$$F_{quarterly} = 0.5 \qquad M_{year} = 0.2$$

2) Catch in numbers by age and year. The first line is the annual catch of age groups 0 to 10. The next line contains the quarterly catches of the oldest age group and the fishing mortality coefficient for the last quarter (input to the MSVPA). For species and periods for which quarterly data exist, these are given.

3) Quarterly fishing mortality coefficients for the last year.

4) Quarterly weight by age in the stock (weight at age in the catch assumed to be the same).

Please note that the lay-out is only shown for cod, but applies to all species in Table 2.2.1.

Table 2.2.1. Number of years with quarterly data.

```
COD CATCH NUMBER                                                        !
0                                                                       ! 0 : ANNUAL CATCH
0.5  0.5  0.5  0.5  0.2      1)                                         ! FACTORS TO SPLIT ON QUARTERS
 0    14677  55431  10716  14869  4392  920  417  373  313  75 ! YEAR 1974
           71    54     26     28     0.19                            ! LAST AGE GR. F(OLDEST)
 0    30305  48051  18232   4220  6484 1732  377  149  180  80 ! YEAR 1975
           14    10      5      4     0.19
 0     6238  93083  17584   6608  1589 2439  770   98   49  49 ! YEAR 1976
           13     9      4      3     0.19
 0    60267  48281  23082   4307  2190  675  926  307  223  20 ! YEAR 1977
           32    24     12     13     0.19
 0    28358 156890  14231   8469  2884  961  371  364  131  32 ! YEAR 1978
           15    11      5      7     0.19                                  } 2
 0    36314  86741  39700   3596  3061  660  342  113  127  34 ! YEAR 1979
            7     5      3      3     0.20
 0    55522  94284  29942   9702  1523 1037  384  159   69  46 ! YEAR 1980
            9     7      3      4     0.20
 0    21829 187169  27318   7627  3777  757  546  136   62  33 ! YEAR 1981
            9     7      3      3     0.20
 0    64659  57307  51770   6424  2939 1662  321  197   62  24 ! YEAR 1982
            9     7      3      4     0.20
 1.1  28193 105022  25680   9443  2705 1053  424  118   54   8 ! YEAR 1983
            4     3      1      1     0.20
0.0001 .068 .20    .37      .19    .23   .19  .17  .22   .23  .20 ! TERM. FS  } 3
```

```
      COD                                                   ! NAME OF SPECIES NO. 1.
          12        3                                       ! NUMBER OF AGE GR., AGE AT MATURITY
Age
        .01       .05      .10      .20     .05
        .30       .40      .52      .62     .05
        .74       .85     1.06     1.35     .05
       1.64      1.93     2.36     2.91     .05     ! BODY WEIGHTS OF COD BY AGE GROUP
       3.48      4.03     4.58     5.13     .05     ! AND QUARTER OF YEAR
       5.67      6.22     6.77     7.33     .05     ! AND RESIDUAL NAT. MORTALITY          } 4
       7.87      8.42     8.87     9.31     .05
       9.54      9.88    10.21    10.52     .05
      10.84     11.16    11.48    11.81     .05
      12.14     12.47    12.70    12.83     .05
      12.97     13.10    13.30    13.66     .05
      13.98     14.31    14.47    14.47     .05
        Q1        Q2       Q3       Q4       M2
```

/Continued

Table 2.2.1. (Continued)

```
CATCH OF WHITING                                                    !
0                                                                   ! 0 : ANNUAL CATCH
0.5   0.5   0.5   0.5   0.2          !  FACTORS TO SPLIT INTO QUARTERS
570112  754672  974691  228625  330094  4876  1223  5832  352  52 ! YEAR 74
   8       6       2       3    0.25     !  LAST AGE GROUP, F(OLDEST AGE)
239142  956417  401312  299652  54982  9173  7987   [16 1385  142 ! YEAR 75
   1      .5     .25     .25    0.25
424539  478651 1114173  161154  76447 13816  2716   545   [2 291 ! YEAR 76
  10       7       3       3    0.25
664985 1017151  480400  361985  31540 18292  4637   906   167   4 ! YEAR 77
  55      41      23      30    0.25
686382 4182[2  335745  203499  69135  7618  5267  (422   745   7 ! YEAR 78
   3       2       1       1    0.25
477685  619543  466684  211648  86230 25082  3115  1179   194  15 ! YEAR 79
   2       1      .5      .5    0.25
332373  321704  437785  282591  83419 38185  8047   755   [48  45 ! YEAR 80
   7       5       4       2    0.25
543293  198342  354910  361111  93063 21701 10186  1761   340  30 ! YEAR 81
  16      11       6       9    0.25
[04919  264612  [36827  233550  82116  34309  6279  1713   365  58 ! (BAR 82
  12       9       5       4    0.25
661477  300540  167294  103070 127966  35390  7402  1367   596  78 ! YEAR 83
  19      14       7       5    0.25
 .065    .088     .16     .30     .21     .33     .28   .35   .05  .25 ! TERM. ES
```

```
WHITING                                                             !   NAME OF SPECIES NO. 2
      11      2                                                     !   NO. OF AGE GR., AGE AT MAT.
   0.01    0.015   0.028   0.045   0.05
   0.063   0.080   0.100   0.122   0.05
   0.145   0.167   0.189   0.210   0.05
   0.231   0.252   0.269   0.282   0.05   ! BODY WEIGHTS OF WHITING
   0.294   0.307   0.327   0.355   0.05   ! BY AGE GROUP AND QUARTER
   0.383   0.411   0.430   0.440   0.05   ! AND RES. NAT. MORT.
   0.451   0.461   0.476   0.495   0.05
   0.514   0.532   0.549   0.562   0.05
   0.576   0.596   0.619   0.662   0.05
   0.705   0.748   0.791   0.832   0.05
   0.875   0.917   0.940   0.950   0.05
```

/Continued

Table 2.2.1. (Continued)

```
CATCH OF SAITHE                                                    !
  0                                                                ! 0: ANNUAL CATCH
  .3     .3     .3     .3     .2                                   ! FACTORS TO SPLIT INTO QUARTERS
0  3670  14750  60680  31803  12431  20595  14504  5028  1427   809   414   222   132    30 ! YEAR 74
     11     8      4      4     .1                                ! LAST AGE GROUP . P(OLDEST AGE)
0   311  72546  51287  23585   9028   6717  12660  8656  3299  1100   616   254   275    77 ! YEAR 75
     10     8      4      3     .1
0   228  33125 233680  51407   9852   5111   3309  4842  2978  1068   420   253   121   161 ! YEAR 76
     26    20     12      8     .1
0  2586  12993  23567  51801  12914   4684   3178  2902  3466  1895   875   342   341   128 ! YEAR 77
     52    39     20     18     .1
0  1237  16970  39504  27679  17251   3787   1162  1069   907   736   640   415   213    95 ! YEAR 78
     44    34     16     14     .06
0   894  16959  10076  14756  12843   6878   2641   873   470   382   402   343   157   154 ! YEAR 79
     41    30     16     14     .06
0   974  17642  10498  11029   9601   6503   4512   985   500   406   303   254   216   147 ! YEAR 80
     36    27     14     13     .06
0  5595  17674  18941   9079   7109   4413   3207  3269   673   293   389   345   297   253 ! YEAR 81
    134   101     60     40     .06
0  1462  22474  23636  33759  10645   6466   1816  1346   978   294   108   129    98   146 ! YEAR 82
     58    44     24     20     .06
1   176  33655  19497  16454  25842   4866   4752  1360   955   318   118    80    95    38 ! YEAR 83
     35    26     15     11     .05
.001 .002  .03   .04    .06    .08    .07    .07   .08   .07   .05   .05   .05   .05   .05
```

```
SAITHE                                                             ! NAME OF SPECIES NO. 3
      16       5                                                   ! NO. OF AGE GROUPS. AGE AT MAT.
   0.010    0.050  0.100   0.150  0.05
   0.200    0.250  0.340   0.340  0.05
   0.440    0.490  0.570   0.690  0.05
   0.800    0.920  1.060   1.220  0.05   ! BODY WEIGHTS OF SAITHE
   1.39     1.55   1.71    1.88   0.05   ! BY AGE GROUP AND QUARTER
   2.05     2.22   2.41    2.62   0.05   ! AND RES. NAT. MORT.
   2.83     3.04   3.24    3.45   0.05
   3.66     3.87   4.09    4.32   0.05
   4.55     4.78   5.02    5.25   0.05
   5.49     5.73   5.94    6.15   0.05
   6.36     6.57   6.74    6.86   0.05
   7.01     7.15   7.24    7.28   0.05
   7.32     7.54   7.45    7.58   0.05
   7.71     7.84   7.98    8.13   0.05
   8.28     8.43   8.61    8.84   0.05
   9.07     9.3    9.30    9.30   0.05
```

/Continued

Table 2.2.1. (Continued)

```
MACKEREL CATCH NUMBER
  3                                    ! 01 ANNUAL CATCH DATA
.25  .25  .25  .25  .15                ! FACTORS TO SPLIT INTO QUARTERS
 0  2900  18700  23600  39900  240800  45800   7500  16100  3200   500   300  6600  6000  6000   ! YEAR 74
          2500   1500   1000   1000   .05          ! LAST AGE GROUP AND F(OLDEST)
 0 11900  10100  16200  42400  27800 193200  25600  20400 15800  5000   500   200  8200  7000   ! YEAR 75
          3000   2000   1000   1000   .05
 0  2700  73600  69700  13900  33800  19500 118600  31300  8000  9000  4000   500   100  1900   ! YEAR 76
           700    500    200    100   .05
 0  1100  19300  58900  54300   9800  26600  31600 125900 31200  8300  8800  4500   800   100   ! YEAR 77
          1000    800    400    300   .05
 0     0   8200  34700  40800  27900   6000  14200  16100 45700 14600  5500  5500  2900   600   ! YEAR 78
          1300   1000    500    400   .06
 0  2300    500  11300  21200  33300  14300   4200   9200  2000 27000  5200  2000  2000  1200   ! YEAR 79
          1000    800    300    200   .04
 0  2700   5600   2400  14300  23500  25900  15300  12300 14000  3500 19300  3800  1300  1600   ! YEAR 80
          1000    700    300    200   .04
 0     0      0     58      0    113    157    160     95    49    68    20   184    16    23    14   ! YEAR 1981 Q1
 0     0     48     12    129   1375   1914   1958   1155   594   825   242  2244   198   275   165   !           Q2
 0  3900   5952  11293    924  10263  14285  14614   8621  4433  6158  1806 16748  1478  2053  1232   !           Q3
 0     0      0    138     47    750   1044   1068    630   324   450   132  1224   108   150    90   !           Q4
.1
 0     0      0   1054    922     50    193    190    208   133    75    90    55   215    43    33   ! YEAR 1982 Q1
 0     0      0     62    126    270   1040   1026   1121   716   405   486   297  1161   230   176   !           Q2
 0  3000  14300   1330   8167   1616   6222   6141   6706  4282  2424  2909  1778  6949  1374  1050   !           Q3
 0     0   1054      0    485     68    262    258    282   180   102   122    75   292    58    44   !           Q4
.04
 0     0      0   1008    672    107     16     86    104    80    69    29    51    19   128    29   ! YEAR 1983 Q1
 0     0      0    140     66    342     51    275    332   255   219    92   163    61   408    92   !           Q2
 0   100  17000  24780  14006   6043    902   4871   5863  4510  3879  1624  2886  1082  7216  1624   !           Q3
 1     1      1   2072   1640    214     32    173    208   160   138    58   102    38   256    58   !           Q4
.07
.001   .005 .00001   .045  .0675  .0625   .0750  .0725   .0750  .0575 .0775 .0825 .080  .060  .0675
```

```
MACKEREL                                  ! NAME OF SPECIES NO. 4
   16       3                             ! NO OF AGR GR., AGE AT MAT.
  0.005   0.010   0.020   0.070   0.04
  0.100   0.150   0.260   0.280   0.04
   .30     .32     .33     .34     .04
   .35     .36     .37     .37     .04
   .38     .39     .40     .41     .04    ! BODY WEIGHTS OF MACKEREL
   .42     .43     .44     .44     .04    ! BY AGE GROUP AND QUARTER
   .45     .45     .46     .48     .04    ! AND RES. NAT. MORT.
   .50     .51     .53     .54     .04
   .56     .57     .58     .58     .04
   .58     .58     .59     .59     .04
   .60     .61     .61     .62     .04
   .63     .63     .64     .64     .04
   .65     .65     .66     .66     .04
   .66     .67     .67     .67     .04
   .67     .67     .68     .68     .04
   .68     .68     .68     .68     .04
```

Table 2.2.1. (Continued)

```
HADDOCK CATCH NUMBER                                    !
 0                                                      ! 0 : ANNUAL CATCH
 1    1     1      1      .2                           ! FACTORS TO SPLIT INTO QUARTERS
601454     1213968    174438    336841    53159    1834    1330   10583    237    22    32  ! YEAR 74
         4        2         1         1      .22
 44913     2097418    633852     57628   106044   15315     953     599   2625   255    61  ! YEAR 75
         8        6         2         2      .22
167010      167563   1045329    306721     9624   30523    4786     187     67   682    52  ! YEAR 76
       1.5        1      .25       .25      .23
115080      250416    103734    376518    39348    3949    6000    1136    115    24   163  ! YEAR 77
       1.5        1      .25       .25      .22
289807      458727    141915     28439   109212    9583    1186    1911    386   112    24  ! YEAR 78
        25       20        10         9      .22
960092      348597    198797     39750     7131   26908    2136     249     451   136    52  ! YEAR 79
         9        6         5         3      .22
388200      726409    321523     70544    10117    1826    8228     601     123   182    71  ! YEAR 80
        15       12         6         5      .22
688754      141833    408901    140766    14892    1835     342    2631     127    67    22  ! YEAR 81
        16       13         7         6      .22
355133      297376     82207    287181    41185    3160     659     187     945    31    78  ! YEAR 82
         9        6         5         3      .22
685230      229031    238103     79279   128610   19136    2215     465      57   337    74  ! YEAR 83
         3        2         2         1      .22
  .10        .10       .25       .35      .40      .26     .25      .35     .22   .25   .22  ! TERM. FS
```

```
HADDUCK                                                 ! NAME OF SPECIES NO. 5
    12        2                                         ! NO. OF AGE GR., AGE AT MAT.
    .010     .015     .026     .049     .05
    .072     .095     .125     .163     .05
    .20      .24      .28      .32      .05
    .36      .40      .44      .49      .05
    .54      .59      .63      .69      .05  ! BODY WEIGHTS OF HADDOCK
    .74      .79      .83      .89      .05  ! BY AGE GROUP AND QUARTER
    .94      .99     1.04     1.09      .05  ! AND RES. NAT. MORT.
   1.14     1.18     1.23     1.29      .05
   1.34     1.40     1.51     1.57      .05
   1.63     1.69     1.76     1.85      .05
   1.94     2.04     2.13     3.22      .05
   3.31     2.41     2.45     2.45      .05
```

/Continued

Table 2.2.1. (Continued)

```
HERRING CATCH NUMBER                                    !
 3                                                      ! 0: ANNUAL CATCH DATA
 .3      .3     .3      .3     .15                      ! FACTORS TO SPLIT INTO QUARTERS
 996100   846100   772600   362000   126000   56100   22300   5000   2000 ! YEAR 1974
    500      300      100      100     .25                                 ! LAST AGE GROUP AND F(OLDEST)
 263800  2460500   541700   259600   140500   57200   16100   9100   3400 ! YEAR 1975
      600      400      200      200     .25
 238200   126600   901500   117300    52000   34500    6100   4400   1000 ! YEAR 1976
      200      100       50       50     .20
 256800   144300    44700   186400    10800    7000    4100   1500    700 ! YEAR 1977
       20       15        8        7     .18
 130000   168000     4900     5700     5000     300     200    200    300 ! YEAR 1978
      120       90       45       45     .005
 542000   159200    34100    10000    10100    2100     200    800    600 ! YEAR 1979
       40       30       15       15     .01
 791700   161100   108000    91800    32200   21700    2300   1400    400 ! YEAR 1980
       40       30       15       15     .02
        0    14751    44500     8100     3900    1300     700    100      0      0 ! YEAR 1981 Q1
        0    26328    20900     8300    10100   10900    9700   9100   2800    600 !           Q2
5916525   355768    20900     8300    10100   10900    9700   9100   2800    600 !           Q3
1972175    50153   178100    32300    15400    5400    3600    900     10     10 !           Q4
.0001
        0    27733    40200    44300     5300    1400     400    300    100      0 ! YEAR 1982 Q1
        0    49500    38100     4400     3600    3800    2300   3200   1600    500 !           Q2
7167525   668874    38100     4400     3600    3800    2300   3200   1600    500 !           Q3
2389175    94293   161000   177100    21300    5400    1800   1200    400    100 !           Q4
.03
        0    37638    50300    21000    13900    3200     600    100    100      0 ! YEAR 1983 Q1
        0    67535   146600    55700    20300    7600    9900   6200   5500   6100 !           Q2
7522425   912579   146600    55700    20300    7600    9900   6200   5500   6100 !           Q3
2507475   128648   201400    84100    51600    8900    2400    400    400    100 !           Q4
.06
 .30      .06      .06      .06      .06      .06     .06    .06    .06 ! TERMINAL FS

HERRING                                                 ! NAME OF SPECIES NO. 6
     9      3                                           ! NO OF AGE GR., AGE AT MAT.
    .002   .005   .010   .020   .025
    .030   .045   .060   .079   .025
    .098   .13    .13    .15    .025
    .16    .17    .18    .19    .025  ! BODY WEIGHTS OF HERRING
    .20    .21    .22    .22    .025  ! BY AGE GR. AND QUARTER
    .23    .24    .24    .25    .025  ! AND RES. NAT. MORT.
    .26    .25    .26    .26    .025
    .36    .37    .37    .37    .025
    .27    .27    .27    .27    .025
```

/Continued

Table 2.2.1 (Continued)

```
SPRAT CATCH  NUMBER                                          !
 10                                                          ! 1 : QUARTERLY CATCH
   0        100000      100000      100000      100000      ! YEAR 1974 Q1 ⌘
   0        100000      100000      100000      100000      !            Q2 ⌘
 10000      100000      100000      100000      100000      !            Q3 ⌘
 10000      100000      100000      100000      100000      !            Q4 ⌘
  .25                                                        ! F(OLDEST)
   0       4096600    14973300     3929000      233700      ! YEAR 1975 Q1
   0        446200     1163200       68900        6500      !            Q2
 15000    10588100     5760000       75100        3100      !            Q3
675200     6351600     6122500      660200       57300      !            Q4
  .25
      0     9360900     9997000     6678000      373000      ! YEAR 1976 Q1
      0     2017200      964600      740100       40900      !            Q2
  79600    16536400      999400       40100           0      !            Q3
2780400     8443700     2659400      612700       37100      !            Q4
  .25                                                        ! F(OLDEST)
      0     4197200    11962600      962900     1047000      ! YEAR 1977 Q1
      0      540300      670900       52700        1500      !            Q2
  57300     2803100     3248400      165900       11100      !            Q3
1060800     4705000     3049500      311200        1500      !            Q4
  .25                                                        ! F(OLDEST)
      0     2461900     2839300     3770100      344500      ! YEAR 1978 Q1
      0     1077500      123800        3200           0      !            Q2
   6300    17785500      216500       14700         700      !            Q3
636800     6932700     3955800     1159000      214300      !            Q4
  .25                                                        ! F(OLDEST)
      0     2770000     6422200     2670600      131200      ! YEAR 1979 Q1
      0      303600      452000       14000        1100      !            Q2
      0    25379100      388300        2100           0      !            Q3
433000     8394800     1494600      122400       34900      !            Q4
  .25                                                        ! F(OLDEST)
      0     1448000    12764400     1323200      103700      ! YEAR 1980 Q1
      0      134000       84500        2400         300      !            Q2
  15100    10143300      811600        4700          00      !            Q3
515700     4518500     2767400      111800       19500      !            Q4
  .25                                                        ! F(OLDEST)
      0     2249300     5218600     1055500       22100      ! YEAR 1981 Q1
  23000       87000      169200       29100        1700      !            Q2
 192200     7626500     1140800       46100        3000      !            Q3
 158000     2326800     1448900       69900         700      !            Q4
  .25                                                        ! F(OLDEST)
      0     1020700     5877800      595100      116900      ! YEAR 1982 Q1
      0        3400       31200        5500         700      !            Q2
  30800     4813200       60800        2100          00      !            Q3
  34800     2700700      623900       10500         600      !            Q4
  .25                                                        ! F(OLDEST)
      0      357300      932900      483000       38100      ! YEAR 1983 Q1
   1700       25400       56100        5300           0      !            Q2
  10300     2665400      341100       27000           0      !            Q3
 130700     2016600      761400       46700         100      !            Q4
  .25                                                        ! F(OLDEST)
 .0088         .20         .50          .5          .5      ! TERMINAL FS
```

/Continued

⌘ (CATCH UNKNOWN)

```
    SPRAT                                                   ! NAME OF SPECIES NO. 7
     5        2                                             ! NO OF AGE GR. AND AGE AT MAT.
   .0005    .001     .0030    .0042    .025
   .0050    .0064    .0071    .0090    .025
   .0085    .0100    .0140    .0160    .025    ! BODY WEIGHTS OF SPRAT
   .018     .020     .025     .027     .025    ! BY AGE GROUP AND QUARTER
   .027     .028     .028     .028     .025    ! AND RES. NAT. MORT.
```

Table 2.2.1 (Continued)

```
NURWAY POUT CATCH NUMBER                                    !
 10                                                         ! 1 : QUARTERLY CATCH DATA
        0    13450000    414000     26000                  ! YEAR 1974 Q1
        0     7873000    193000     36000                  !           Q2
   345000     9966000    459000    145000                  !           Q3
  5700000     7809000    140000      4000                  !           Q4
     .2                                                     ! F(OLDEST)
        0     3742000   1726000     13000                  ! YEAR 1975 Q1
        0     7206000    383000      2000                  !           Q2
   889000     7117000    349000         0                  !           Q3
  9968000     3027000    461000      1000                  !           Q4
     .2                                                     ! F(OLDEST)
        0     4950000    589000     91000                  ! YEAR 1976 Q1
        0     7580000    645000     58000                  !           Q2
   197000     5349000    590000      2000                  !           Q3
  5986000     3157000    320000     15000                  !           Q4
     .2                                                     ! F(OLDEST)
        0     9171000    950000     33000                  ! YEAR 1977 Q1
        0     3577000    367000      8000                  !           Q2
    61000     3580000    861000     45000                  !           Q3
  1655000     3540000    236000      5000                  !           Q4
     .2                                                     ! F(OLDEST)
        0     2931000   1371000     93000                  ! YEAR 1978 Q1
        0     1181000    650000    194000                  !           Q2
   304000     2385000    786000     30000                  !           Q3
  1325000     1400000    332000      6000                  !           Q4
     .2                                                     ! F(OLDEST)
        0     5079000    940000    170000                  ! YEAR 1979 Q1
        0     3023000    249000     27000                  !           Q2
   968000     4243000    763000     49000                  !           Q3
   861000     2147000    166000     11000                  !           Q4
     .2                                                     ! F(OLDEST)
        0     5025000   1072000     59000                  ! YEAR 1980 Q1
        0     3576000    686000     33000                  !           Q2
    24000     7709000   1959000     18000                  !           Q3
   640000     3913000    511000      6000                  !           Q4
     .2                                                     ! F(OLDEST)
        0     3223000   1688000     76000                  ! YEAR 1981 Q1
        0     1072000    621000     77000                  !           Q2
    76000     1309000    944000     17000                  !           Q3
 36697000     1036000    301000      3000                  !           Q4
     .3                                                     ! F(OLDEST)
        0     5264000    415000    216000                  ! YEAR 1982 Q1
        0     3243000    274000     23000                  !           Q2
   151000     6563000    429000     62000                  !           Q3
  1058000     3015000     46000         1                  !           Q4
  .0000002                                                  ! F(OLDEST)
        0     3945000   1221000     14000                  ! YEAR 1983 Q1
        0     1714000   1139000      9000                  !           Q2
   420000     5485000   1477000     16000                  !           Q3
  2519000     4052000    358000      8000                  !           Q4
     .3                                                     ! F(OLDEST)
     .2          .35        .35        .2                  ! TERMINAL FS


NURWAY POUT                                                 ! NAME OF SPECIES NO. 6
     4          1                                          ! NO OF AGE GROUPS , AGE AT MAT.
   .0005      .0010      .0050      .0062      .25
   .0077      .0108      .0229      .0230      .25          ! BODY WEIGHTS OF NORWAY POUT
   .0270      .0300      .0350      .0400      .25          ! BY AGE GR. AND QUARTER
   .0450      .0500      .0570      .0650      .25          ! AND RES. NAT. MORT.
```

/Continued

Table 2.2.1 (Continued)

```
SANDEEL CATCH NUMBER                                    !
 10                                                     ! 1 : QUARTERLY CATCH DATA
      0    775000    158000    19200        0    2800       0   ! YEAR 74 Q1
1142000  25063000   5118000  1900800  2342000  275200  108000   !          Q2
8950000    598000     63400    10000    11900    6000    2000   !          Q3
1106000     12000       600        0      100       0       1   !          Q4
.0001
      0    559300    208300    43500        0    7500       0   ! YEAR 75 Q1
 100000  18084700   6733700  4302500   778000  744500   96000   !          Q2
8261000    542900   1140500   172000   249500    2000    1000   !          Q3
1021000     11100     11500        0     2500       0       1   !          Q4
.000001
      0     66200    469100    19700        0    2100       0   ! YEAR 76 Q1
 242000  21354800  15166900  1946300  1336000  207900   88000   !          Q2
5452100    878100   2417600    76000   118800   30000   82000   !          Q3
 673900     17900     24400        0     1200       0       1   !          Q4
.000001
      0   1314200    238400    68200        0    4600       0   ! YEAR 77 Q1
3686000  42491800   7709600  6747800  1090000  457400  402000   !          Q2
14533700  3063500    930600   150000   106900   30000   18000   !          Q3
1496300    62500      9400        0     1100       0       1   !          Q4
.0001
      0   1950000    578600    33700        0    3000       0   ! YEAR 78 Q1
 922000  63017000  18707400  2342300  1084000  158000   82000   !          Q2
43649300  3700500    685100   164000    99000   36000   34000   !          Q3
5394800    75500      6900        0     1000       0       1   !          Q4
.00001
      0    25900    121500        0        0       0       0   ! YEAR 79 Q1
 180700  18327400  32943400  4729500  1269600  443000  252700   !          Q2
38801700  6449700   2493700   197200   118400   29800       0   !          Q3
7347600    70100     24500     5300     1500       0       1   !          Q4
.000001
      0   3086100   1779900    21700        0       0       0   ! YEAR 80 Q1
  78800  46577200  19558900  4821900  1020800  206800   89400   !          Q2
6579900   5575700   1011900   594700    12900    3100    1100   !          Q3
1840600    334800     43300        0        0       0       1   !          Q4
.000001
      0   1499200    843900    82000    19500    7500    1800   ! YEAR 81 Q1
 428400  17321200  14624200  3255500   874700  361700  129700   !          Q2
47483900   736600   1963400   127800    41600    3400       0   !          Q3
4567800     8900      3600        0        0       0       1   !          Q4
.000001
      0    707200     57800     8300        0       0       0   ! YEAR 82 Q1
 241400  58785900   8219600  3788000  1871100  101800   31300   !          Q2
11459400  4757400    485900   340800    35700    3900      10   !          Q3
       0        0         0        0        0       0       1   !          Q4
.000001
      0     7900      7400      500      100       0       0   ! YEAR 83 Q1
 955400  7907800  36236600  1022500   242200  121600   33900   !          Q2
16633600   543100   3122000   531300     1700     100     100   !          Q3
  575200        1         1        1        1       1       1   !          Q4
00.000001
  .05     .0000001  .0000001  .0000001   .000001  .000001  .0000001 ! TERM. FS


SANDEEL                                                 ! NAME OF SPECIES NO. 9
     7        2                                         ! NO OF AGE GR.. AGE AT MAT.
     0.0008   0.0015   0.0022   0.0032   0.025
     0.0050   0.0060   0.0080   0.0100   0.025
     0.0110   0.0130   0.0140   0.0150   0.025  ! BODY WEIGHTS OF SANDEEL
     0.0170   0.0200   0.0220   0.0230   0.025  ! BY AGE GROUP AND QUARTER
     0.0250   0.0260   0.0270   0.0280   0.025  ! AND RES. NAT. MORT.
     0.0290   0.0300   0.0310   0.0320   0.025
     0.0330   0.0330   0.0330   0.0330   0.025
```

Table 2.5.1 Residual natural mortality, M1, used in MSVPA Key run.

SPECIES	AGE-gr	COEFFICIENT $Year^{-1}$
Cod	All	0.2
Saithe	"	0.2
Mackerel	"	0.16
Haddock	"	0.2
Herring	"	0.1
Sprat	"	0.1
Norway Pout	"	1.0
Sandeel	"	0.1

Table 2.7.1 ANOVA of COD log-ratio prey Weight (stomach)/Prey Weight (stock)as a function of prey type and calendar quarter. COVARIATE is the log ratio predator weight/prey weight (stock).

Source	Sum of Squares	Degree of Freedom	Mean Square	F	Tail Prob.	Regression Coefficient
Prey Species	53.87	6	8.98	24.58	0.00	
Quarter	8.17	3	2.72	7.45	0.00	
Prey/Quarter	37.17	18	2.06	5.65	0.00	
1st Covariate	7.56	1	7.56	20.70	0.00	0.1065
Error	165.13	452	0.36		0.00	

Table 2.7.2 ANOVA of WHITING log-ratio prey Weight (stomach)/Prey Weight (stock) as a function of prey type and calendar quarter. COVARIATE is the log-ratio predator weight/prey weight (stock).

Source	Sum of Squares	Degree of Freedom	Mean Square	F	Tail Prob.	Regression Coefficient
Prey Species	130.92	6	21.82	58.78	0.00	
Quarter	14.73	3	4.91	13.23	0.00	
Prey/Quarter	89.65	18	4.98	13.42	0.00	
1st Covariate	1.20	1	1.20	3.22	0.07	-0.0630
Error	104.68	282	0.37			

1 - A value for whiting eating cod in the 3rd quarter was specified in order to specify the full design.

FISHING MORTALITY COD

Table 2.8.1.

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006
1	0.1205	0.1486	0.0607	0.1827	0.1406	0.1753	0.1425	0.1495	0.2190	0.2838
2	0.8512	0.8264	1.0243	0.9736	1.1098	0.9038	1.0257	1.1031	0.8008	0.7281
3	0.7031	0.8064	0.8860	0.7973	0.9235	1.0149	0.9953	1.0313	1.1811	1.1554
4	0.6992	0.6799	0.8005	0.5608	0.7938	0.6348	0.7479	0.7599	0.7344	0.7029
5	0.6992	0.7744	0.5940	0.6864	0.9540	0.7657	0.6137	0.7529	0.7671	0.8154
6	0.5813	0.6685	0.7705	0.5463	0.7522	0.5911	0.6465	0.7232	0.9252	0.7029
7	0.6644	0.5019	0.7268	0.7728	0.6692	0.6696	0.8500	0.8779	0.7950	0.6434
8	0.5250	0.5306	0.3320	0.7347	0.8203	0.4378	0.7772	0.8663	0.9663	0.7880
9	1.0974	0.5224	0.3302	1.2904	0.8332	0.7803	0.5269	0.8204	1.4564	0.7880
10	0.8058	0.9506	0.2590	0.2170	0.6199	0.5318	0.7403	0.5196	0.9190	0.7318
11	0.8707	1.0272	1.1311	0.8558	0.7777	0.8498	0.8245	0.9683	0.8245	1.0983
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 3)										
	0.1719	0.1872	0.1997	0.1819	0.2110	0.2259	0.2165	0.2236	0.2558	0.2303

STOCK NUMBERS COD

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	512634.	249747.	797296.	490156.	576341.	970031.	403819.	853204.	274085.	10762.
1	179587.	283798.	135953.	446049.	277109.	285553.	528525.	206969.	417033.	150125.
2	109450.	96202.	162286.	86318.	260072.	162064.	163265.	311916.	115857.	236372.
3	33570.	36404.	33002.	46294.	26010.	68536.	52341.	46787.	82318.	41361.
4	32340.	9358.	13122.	10979.	16909.	8372.	20154.	15675.	13510.	30463.
5	9552.	13159.	3882.	4825.	5131.	6259.	3633.	7811.	6002.	5307.
6	3283.	3887.	4967.	1755.	1989.	1618.	2383.	1610.	3012.	2282.
7	940.	1045.	1631.	1882.	832.	767.	734.	1022.	640.	978.
8	999.	396.	518.	645.	711.	349.	322.	257.	348.	237.
9	522.	484.	191.	336.	253.	256.	184.	121.	88.	108.
10	148.	143.	235.	112.	76.	90.	96.	89.	44.	17.
11	325.	54.	45.	149.	74.	33.	43.	38.	43.	14.
TOTAL STOCK BIOMASS ON 1. JANUARY										
	395922.	379033.	356903.	390454.	448333.	420901.	493320.	505363.	465463.	413381.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 3)										
	255927.	220219.	188052.	187862.	166984.	205607.	209908.	203933.	251678.	200721.

PREDATION MORTALITY COD

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.3914	0.4081	0.3808	0.3703	0.5023	0.4073	0.4684	0.5158	0.4020	0.5059
1	0.3037	0.2102	0.1936	0.1568	0.1958	0.1837	0.1849	0.2307	0.1920	0.2345
2	0.0496	0.0434	0.0300	0.0259	0.0238	0.0264	0.0241	0.0290	0.0293	0.0302
3	0.0207	0.0140	0.0125	0.0099	0.0101	0.0090	0.0105	0.0109	0.0109	0.0127
4	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
6	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
8	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
10	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

FISHING MORTALITY — SAITHE — Table 2.8.1. (Continued)

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020
1	0.0058	0.0016	0.0016	0.0167	0.0094	0.0028	0.0050	0.0257	0.0043	0.0090
2	0.0749	0.1511	0.1574	0.1148	0.1451	0.1729	0.0693	0.1175	0.1365	0.1282
3	0.6748	0.4008	1.0255	0.2271	0.4112	0.1202	0.1540	0.0986	0.2277	0.1688
4	0.6500	0.6115	0.9246	0.6624	0.4811	0.3721	0.1872	0.1934	0.2556	0.2451
5	0.4051	0.3821	0.5625	0.6288	0.4816	0.4311	0.4435	0.1768	0.3646	0.3178
6	0.4574	0.4000	0.3882	0.5771	0.3763	0.3585	0.4054	0.3759	0.2419	0.2819
7	0.4736	0.5716	0.3509	0.4458	0.2700	0.4928	0.4239	0.3583	0.2606	0.2819
8	0.3634	0.5826	0.4468	0.5980	0.2629	0.3347	0.3428	0.6293	0.2496	0.3178
9	0.3007	0.4325	0.4039	0.6779	0.2792	0.1761	0.3259	0.4173	0.3861	0.2819
10	0.2817	0.4008	0.2408	0.4891	0.2898	0.1707	0.2271	0.3226	0.3234	0.2073
11	0.3042	0.3603	0.2613	0.3191	0.3015	0.2540	0.2801	0.2543	0.1881	0.2073
12	0.2042	0.3115	0.2455	0.3524	0.2446	0.2618	0.2525	0.5968	0.1891	0.2073
13	0.4188	0.4197	0.2391	0.6122	0.3877	0.1370	0.2616	0.3279	0.3330	0.2073
14	0.4754	0.4630	0.4666	0.4085	0.3389	0.5415	0.1838	0.5579	0.5404	0.2073
15	0.7288	0.8505	0.8453	0.7624	0.6679	0.6337	0.6131	0.7129	0.6401	0.6325
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 5)										
	0.1059	0.1163	0.1058	0.1399	0.1017	0.0954	0.1003	0.0723	0.0752	0.0762

STOCK NUMBERS — SAITHE

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	360495.	196632.	209275.	176585.	433729.	262488.	296106.	460082.	26487.	596.
1	697607.	213275.	160989.	171340.	144576.	355107.	214907.	242431.	376683.	21685.
2	224430.	367852.	174335.	131601.	137956.	117256.	289938.	175075.	193456.	307088.
3	135703.	170487.	299701.	121945.	96065.	97693.	80756.	221516.	127450.	138184.
4	73022.	56583.	93489.	117360.	79554.	52135.	70926.	56680.	164334.	83101.
5	40965.	31210.	25134.	30365.	49543.	40259.	29422.	48155.	38244.	104200.
6	61585.	22367.	17439.	11725.	13257.	25059.	21419.	15460.	23035.	21744.
7	42199.	31913.	12275.	9684.	5391.	7450.	14335.	11692.	8692.	21235.
8	18116.	31515.	14753.	7076.	5077.	3369.	3726.	7681.	6690.	5484.
9	6033.	10313.	9837.	7726.	3186.	3196.	1974.	2165.	3952.	4267.
10	3618.	3656.	5479.	5377.	3211.	1973.	2194.	1166.	1166.	1865.
11	1725.	2235.	2005.	3526.	2700.	1968.	1362.	1431.	692.	692.
12	1220.	1042.	1276.	1264.	2100.	1635.	1250.	843.	822.	469.
13	423.	881.	625.	817.	728.	1346.	1030.	795.	380.	557.
14	87.	328.	474.	403.	363.	404.	961.	649.	384.	223.
15	52.	44.	118.	243.	219.	212.	193.	655.	304.	183.
TOTAL STOCK BIOMASS ON 1. JANUARY										
	1028415.	963736.	895684.	640121.	546108.	543408.	588188.	659283.	770812.	794713.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 5)										
	577476.	454219.	334977.	285496.	264722.	367546.	251483.	272165.	279706.	429194.

Continued

PREDATION MORTALITY SAITHE Table 2.8.1. (Continued)

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	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
6	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
8	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
10	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
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

BIOMASS OF OTHER FOOD ASSUMED TO REMAIN CONSTANT

FISHING MORTALITY MACKEREL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010
1	0.0072	0.0258	0.0113	0.0095	0.0000	0.0386	0.0340	0.0317	0.0209	0.3961
2	0.1209	0.0302	0.2099	0.1000	0.0909	0.0469	0.1194	0.0968	0.1615	0.1512
3	0.0812	0.1400	0.2851	0.2475	0.2508	0.1671	0.3150	0.3750	0.0481	0.4681
4	0.2037	0.1963	0.1641	0.3590	0.2592	0.2286	0.3148	0.2274	0.5935	0.5129
5	0.2287	0.2031	0.2267	0.1596	0.3016	0.3332	0.4067	0.4901	0.7842	1.0760
6	0.2123	0.2770	0.2050	0.2679	0.1328	0.2380	0.4476	0.5888	0.6098	1.2028
7	0.0892	0.1685	0.2613	0.5665	0.2138	0.1240	0.4114	0.6249	0.5285	1.1775
8	0.2064	0.3536	0.3057	0.4652	0.6081	0.2000	0.6045	0.5420	0.6432	1.2028
9	0.0846	0.3066	0.2172	0.5416	0.2908	0.1302	0.5029	0.5740	0.5544	1.0192
10	0.0409	0.1766	0.2742	0.3500	0.5020	0.2666	0.3361	0.5437	0.7026	1.2348
11	0.0269	0.0503	0.2000	0.4494	0.3943	0.3182	0.2961	0.3580	0.5214	1.2686
12	0.2935	0.0216	0.0624	0.3457	0.5380	0.2311	0.3876	0.5730	0.7016	1.2526
13	0.4317	0.6877	0.0129	0.1289	0.3745	0.3626	0.2210	0.3130	0.4817	1.0535
14	0.3242	1.3414	0.3134	0.0153	0.1291	0.2492	0.5280	0.8427	0.5225	1.1278
15	0.5484	0.6233	1.0809	0.7170	0.7417	0.8370	0.8102	1.4137	1.5366	1.8021
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 3)										
	0.0493	0.0617	0.0628	0.0902	0.0724	0.0611	0.0989	0.1354	0.1114	0.1891

/Continued

STOCK NUMBERS MACKEREL Table 2.8.1 (Continued)

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	592649.	304768.	141594.	16223.	76836.	102302.	162090.	188147.	400.	1151.
1	433275.	505022.	259706.	120658.	13825.	65476.	87176.	138124.	160328.	341.
2	177132.	366547.	419411.	218824.	101807.	11781.	53680.	71804.	114029.	133798.
3	326627.	133752.	303065.	289744.	168727.	79216.	9579.	40595.	55541.	82677.
4	234537.	256637.	99084.	194190.	192764.	111884.	57116.	5957.	28775.	45104.
5	1270381.	163182.	179717.	71656.	115570.	126760.	75854.	35527.	4044.	11191.
6	258341.	861203.	113500.	122075.	52052.	72838.	77411.	43041.	18545.	1573.
7	94785.	178043.	556286.	78794.	79576.	38840.	48924.	42162.	20355.	8589.
8	93108.	73876.	128186.	365021.	38105.	54757.	29237.	27629.	19233.	10225.
9	42558.	64542.	44203.	80463.	195346.	17676.	38204.	13611.	13693.	8614.
10	13446.	33324.	40476.	30314.	39895.	124457.	13224.	19689.	6533.	6702.
11	12174.	10998.	23300.	26219.	18203.	20579.	81238.	8052.	9741.	2757.
12	27986.	10098.	8913.	16605.	14255.	10457.	12757.	51487.	4797.	4928.
13	18458.	17782.	8421.	7135.	10013.	7093.	7072.	7378.	24738.	2027.
14	23373.	10215.	7618.	7084.	5345.	5868.	4206.	4832.	4598.	13022.
15	13363.	14403.	2276.	4745.	5945.	4003.	3897.	2114.	1773.	2323.
TOTAL STOCK BIOMASS ON 1. JANUARY										
	1147761.	992090.	855630.	686685.	469907.	332958.	257917.	191401.	151439.	127284.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 3)										
	1048331.	830100.	703129.	608891.	437598.	322365.	232285.	155106.	101195.	87105.

PREDATION MORTALITY MACKEREL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	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
6	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
8	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
10	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
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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FISHING MORTALITY WHITING **Table 2.8.1. (Continued)**

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.0859	0.0611	0.1049	0.1519	0.1462	0.1172	0.1726	0.2871	0.0694	0.1209
1	0.4820	0.2978	0.2557	0.5667	0.2091	0.3019	0.1619	0.2567	0.3551	0.3257
2	0.9106	0.8106	1.0694	0.6134	0.4970	0.5389	0.5045	0.3748	0.8735	0.5976
3	1.0919	1.0812	1.2394	0.9734	0.6737	0.8105	0.8985	0.7735	0.5343	0.7205
4	1.0195	1.0716	1.1364	1.0389	0.8677	0.7908	1.0799	1.0352	0.6900	0.7526
5	0.3591	1.0918	0.9323	1.0546	0.8353	1.0377	1.1635	1.0574	0.9511	0.8136
6	1.9227	2.2354	1.3456	1.1162	1.1675	1.1034	1.3098	1.3295	1.1495	0.9417
7	1.1968	1.1630	1.2303	0.7429	1.4986	0.9082	0.9241	1.3149	0.8609	0.8688
8	0.9416	1.1120	0.7128	2.3601	1.6892	0.8663	1.8287	0.8916	1.1705	0.8688
9	2.7313	1.4710	0.7420	0.2626	0.6770	0.8894	0.4953	0.4306	0.5532	0.8688
10	0.9487	1.0930	1.0677	1.0033	1.0108	1.0930	1.1786	1.0635	1.0560	1.1751
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 2)										
	0.2201	0.2198	0.2529	0.1762	0.1436	0.1545	0.1611	0.1315	0.1271	0.1676

STOCK NUMBERS WHITING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	18815720.	12794668.	10553794.	12334750.	13557780.	10810565.	6326672.	5330321.	3892811.	12734853.
1	3282560.	5848661.	3421845.	3481757.	3638598.	3919540.	3450926.	1573970.	1472154.	1323191.
2	1310946.	952732.	2210849.	1308244.	1086102.	1411233.	1389260.	1462304.	518044.	488662.
3	438880.	356468.	275199.	500147.	491653.	452300.	566008.	578146.	674096.	241915.
4	61824.	99267.	132869.	56981.	138925.	185412.	148158.	169863.	195360.	287274.
5	18880.	15830.	25138.	31866.	15252.	44234.	63123.	37871.	45146.	72783.
6	1625.	10060.	4128.	7708.	8724.	5210.	13280.	15482.	10204.	13595.
7	9123.	195.	842.	847.	3002.	2161.	1369.	2632.	3244.	2576.
8	631.	2357.	47.	301.	330.	366.	713.	445.	979.	1123.
9	61.	202.	608.	19.	16.	51.	126.	94.	149.	147.
10	34.	3.	38.	237.	12.	6.	28.	63.	50.	70.
TOTAL STOCK BIOMASS ON 1. JANUARY										
	862361.	804427.	756733.	681133.	687726.	739311.	687367.	571206.	444030.	458050.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 2)										
	467603.	408014.	435619.	338435.	322917.	384274.	406693.	418743.	311356.	247340.

PREVATION MORTALITY WHITING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.8827	1.0576	0.8043	0.8689	0.8950	0.8249	1.0186	0.7996	0.8097	0.7117
1	0.5551	0.4750	0.5058	0.3982	0.5381	0.5354	0.4968	0.6546	0.5477	0.6878
2	0.3128	0.2312	0.2169	0.1653	0.1790	0.1747	0.1722	0.1996	0.1880	0.2251
3	0.1945	0.1511	0.1354	0.1076	0.1014	0.1056	0.1051	0.1115	0.1186	0.1257
4	0.1429	0.1018	0.0914	0.0791	0.0767	0.0867	0.0842	0.0899	0.0974	0.1001
5	0.0705	0.0523	0.0498	0.0409	0.0387	0.0439	0.0419	0.0442	0.0491	0.0496
6	0.0527	0.0452	0.0380	0.0321	0.0280	0.0329	0.0304	0.0333	0.0370	0.0356
7	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
9	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

/Continued

FISHING MORTALITY — HADDOCK — Table 2.8.1. (Continued)

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.0367	0.0355	0.1029	0.0432	0.0706	0.1359	0.2119	0.2135	0.1208	0.1680
1	0.4803	0.4948	0.4783	0.5231	0.5945	0.2756	0.3309	0.2969	0.3593	0.3996
2	0.9285	0.9691	0.8327	1.0519	1.0446	0.9109	0.6987	0.4753	0.4426	0.9642
3	0.9302	1.2201	1.3344	1.0180	1.1341	1.1375	1.1666	0.8744	0.8317	1.2451
4	0.9890	1.0714	0.7621	1.2281	1.0867	1.1285	1.1672	0.9488	0.7374	1.3610
5	0.5910	0.9833	1.2720	0.9511	1.1177	0.9467	1.1227	0.7062	0.5482	1.0212
6	0.8277	0.7343	1.0563	1.0015	0.8973	1.0029	0.9045	0.6540	0.6058	1.0000
7	1.1724	1.2505	0.3010	0.7851	1.1085	0.4663	0.8997	0.8543	0.9581	1.2629
8	0.4692	1.1257	0.4167	0.3062	0.6832	0.8801	0.4438	0.4727	0.8967	0.9117
9	0.2422	1.5420	1.0813	0.2564	0.5553	0.5480	1.1886	0.4647	0.1302	1.0000
10	0.6954	2.6052	2.4583	0.8414	0.4415	0.5464	0.6261	0.4114	1.8327	0.9117
11	1.0502	1.1293	1.3284	1.3284	0.9802	1.0295	1.0219	0.9711	1.0295	1.0585
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 2)										
	0.2322	0.2447	0.2217	0.2557	0.2627	0.2351	0.1931	0.1397	0.1774	0.2682

STOCK NUMBERS — HADDOCK

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	103342056.	6844834.	6039249.	9953983.	16192081.	35247328.	7854988.	14009270.	14188492.	16318359.
1	11598661.	14174803.	1077205.	1243861.	2221221.	3204233.	5216298.	1290745.	2242907.	2100361.
2	373934.	1256142.	2355660.	190119.	260432.	397050.	765023.	1298435.	278272.	469295.
3	609538.	92053.	316795.	657112.	46548.	64773.	112648.	267480.	564690.	123723.
4	94772.	181917.	20426.	62019.	182599.	11652.	16264.	26818.	87519.	191513.
5	4509.	36901.	46749.	7054.	13944.	48027.	2958.	3955.	8189.	32681.
6	3546.	1989.	7964.	10294.	2174.	3662.	15006.	774.	1575.	3804.
7	16637.	911.	782.	2268.	3096.	726.	1100.	4973.	329.	704.
8	687.	4217.	214.	474.	847.	837.	373.	366.	1733.	103.
9	111.	352.	1120.	115.	285.	350.	284.	196.	187.	579.
10	69.	71.	62.	311.	73.	134.	166.	71.	101.	134.
11	13.	28.	4.	4.	110.	38.	64.	73.	38.	13.
TOTAL STOCK BIOMASS ON 1. JANUARY										
	2239894.	1500551.	759373.	516089.	507183.	634049.	675443.	613925.	620404.	586110.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 2)										
	371359.	411522.	621422.	326991.	185334.	150870.	221319.	380899.	317029.	271751.

PREDATION MORTALITY — HADDOCK

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	1.7501	1.6136	1.2775	1.2568	1.3499	1.2416	1.3941	1.4185	1.5900	1.6219
1	1.5426	1.1432	1.0562	0.8406	0.9273	0.9568	0.8597	1.0375	1.0050	1.3392
2	0.3732	0.2085	0.2007	0.1553	0.1469	0.1489	0.1522	0.1574	0.1680	0.1839
3	0.0823	0.0855	0.0964	0.0626	0.0509	0.0445	0.0486	0.0428	0.0497	0.0523
4	0.0704	0.0841	0.1012	0.0643	0.0489	0.0425	0.0468	0.0375	0.0477	0.0466
5	0.0272	0.0338	0.0412	0.0259	0.0195	0.0166	0.0185	0.0146	0.0182	0.0182
6	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
8	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
10	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

/Continued

FISHING MORTALITY — HERRING — Table 2.8.1. (Continued)

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.1533	0.3442	0.3610	0.2396	0.0907	0.1187	0.1214	0.6623	1.0013	0.6071
1	0.6548	0.9955	0.4070	0.4923	0.3132	0.1947	0.0583	0.1296	0.1720	0.4253
2	0.9882	1.2306	1.3353	0.2324	0.0253	0.0910	0.1849	0.1230	0.1027	0.1505
3	0.8480	1.4280	1.2024	1.4016	0.0437	0.0728	0.4108	0.1718	0.1844	0.1318
4	0.9120	1.3572	1.8248	0.3256	0.1108	0.1096	0.3716	0.3383	0.1455	0.1159
5	1.2266	1.8695	2.0351	1.7342	0.0129	0.0598	0.3422	0.6457	0.1893	0.1638
6	1.1230	1.4475	1.0424	2.0767	0.1596	0.0095	0.0774	0.6447	0.2747	0.4494
7	1.1538	2.7291	3.9877	0.6914	0.4725	1.4474	0.0765	1.3079	0.4289	1.0719
8	1.3308	1.0837	1.1089	1.0082	0.2086	0.3371	0.4912	0.4343	0.7697	1.8120
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 3)										
	0.2030	0.3137	0.3088	0.2694	0.0143	0.0204	0.0881	0.0707	0.0392	0.0334

STOCK NUMBERS — HERRING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	18838768.	2698898.	2014706.	3181711.	3913619.	11725483.	20425526.	41869764.	40705400.	48882488.
1	2847537.	5618455.	579177.	505054.	879492.	1296656.	4004819.	5736201.	7564271.	4957013.
2	1334810.	822774.	1312361.	230007.	209339.	419270.	682446.	2506336.	3109824.	4263174.
3	888112.	430899.	210541.	303336.	161411.	180382.	338142.	501916.	1952020.	2474681.
4	334830.	206446.	67182.	41542.	50943.	103914.	110493.	149436.	271995.	1060744.
5	100357.	80161.	46127.	9469.	26600.	40430.	82602.	67797.	94347.	208647.
6	34620.	22045.	9870.	4908.	1420.	22243.	32343.	50362.	30000.	66395.
7	7660.	10189.	4690.	3148.	557.	1095.	19931.	27078.	23909.	20620.
8	1398.	2183.	602.	79.	1427.	314.	233.	16707.	6625.	14088.
TOTAL STOCK BIOMASS ON 1. JANUARY										
	486616.	391993.	211597.	105142.	97744.	168315.	336406.	651375.	1017029.	1346117.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 3)										
	123167.	137420.	61581.	61087.	43017.	64873.	108530.	149929.	403927.	681851.

PREVATION MORTALITY — HERRING

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	1.1833	1.0929	0.9231	0.9464	0.9146	0.8562	1.0488	0.9488	1.0043	0.8263
1	0.4867	0.3586	0.4164	0.2884	0.3276	0.3472	0.3103	0.3827	0.3014	0.3713
2	0.0421	0.0324	0.0294	0.0218	0.0235	0.0241	0.0223	0.0269	0.0258	0.0322
3	0.5111	0.3305	0.3206	0.2826	0.2967	0.3173	0.3058	0.3409	0.3255	0.3796
4	0.0628	0.0414	0.0347	0.0202	0.0203	0.0199	0.0168	0.0216	0.0198	0.0369
5	0.1891	0.1251	0.1055	0.0628	0.0660	0.0634	0.0526	0.0696	0.0620	0.1211
6	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0003	0.0003	0.0003
7	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

/Continued

FISHING MORTALITY NORWAY POUT Table 2.8.1 (Continued)

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.0392	0.0625	0.0495	0.0261	0.0120	0.0018	0.0079	0.2236	0.0072	0.2202
1	0.9586	0.8792	0.7581	0.6889	0.5416	0.5217	0.0787	0.2713	0.6033	0.6658
2	2.0159	0.7855	1.2257	0.7274	0.8744	1.1767	1.5834	0.0484	0.2772	1.4296
3	1.7623	0.5847	0.5437	0.9796	1.3729	0.9014	0.7892	1.3839	0.0227	0.4172
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 1)										
	0.1300	0.1435	0.1340	0.1462	0.1221	0.1129	0.0187	0.0273	0.0834	0.1100

STOCK NUMBERS NORWAY POUT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	930970240.	851525376.	534479904.	249875776.	432158656.	3039867904.	283406752.	607993920.	568583488.	43912880.
1	391510944.	187218240.	142543328.	106474128.	56886668.	103549016.	774175232.	73968816.	126052840.	142896704.
2	2703816.	8806204.	5446292.	7817074.	8720719.	5014788.	9438303.	121353392.	7906907.	9913181.
3	3142553.	107357.	1264951.	515271.	1271032.	1214864.	517604.	656337.	38340256.	1995579.
TOTAL STOCK BIOMASS ON 1. JANUARY										
	1695078.	1724942.	1568796.	1179037.	946763.	2507330.	6380709.	4179634.	3209097.	1479718.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 1)										
	3229592.	1299179.	1301556.	1054099.	730683.	987396.	6239006.	3875637.	2924805.	1457762.

PREDATION MORTALITY NORWAY POUT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.8754	0.7249	0.5640	0.4539	0.4168	0.3660	0.3353	0.3341	0.3738	0.4450
1	1.8359	1.3475	1.1453	0.8133	0.8871	0.8747	0.7744	0.9646	0.9552	1.4749
2	0.2177	0.1549	0.1323	0.0891	0.0967	0.0942	0.0814	0.1038	0.0996	0.1713
3	2.1570	1.3443	1.1438	0.9085	1.2358	1.0559	0.9211	1.2569	1.2644	2.3548

BIOMASS OF OTHER FOOD ASSUMED TO REMAIN CONSTANT

/Continued

FISHING MORTALITY SPRAT Table 2.8.1. (Continued)

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.0905	0.0031	0.0204	0.0090	0.0044	0.0052	0.0103	0.0152	0.0020	0.1242
1	0.1030	0.1306	0.2724	0.1711	0.5767	0.5043	0.4972	0.5339	0.6681	0.4201
2	0.0272	0.5592	0.3502	0.6048	0.6411	1.0306	1.4581	1.7487	1.4143	0.8464
3	0.1168	1.0681	1.6845	0.1597	1.3430	1.2500	3.0099	1.8668	2.3095	1.8697
4	0.3777	0.3629	0.6046	3.5421	0.3121	0.3785	0.4264	1.2698	2.5332	3.4551
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 2)										
	0.0142	0.1290	0.1508	0.1532	0.1548	0.3272	0.4277	0.4507	0.6292	0.2316

STOCK NUMBERS SPRAT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	7383342308.	556014720.	242462448.	199574176.	291960000.	138671472.	83598296.	47660172.	38816432.	24703812.
1	622699712.	388311904.	285080320.	137323904.	122813440.	177535296.	82137240.	51272184.	32239780.	28090622.
2	57786748.	303586416.	116807352.	89198600.	50703048.	30508298.	47379524.	21362010.	14660516.	7840584.
3	6618425.	10646629.	14994168.	15174110.	10499755.	5561363.	2128781.	2146703.	895684.	949254.
4	2959183.	2489771.	1546034.	1185736.	6303181.	1209596.	703031.	47029.	141605.	43242.
TOTAL STOCK BIOMASS ON 1. JANUARY										
	4168011.	4208915.	3851134.	1849744.	1550205.	1349096.	912511.	501679.	325167.	237704.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 2)										
	587846.	1989348.	1304501.	1063337.	790157.	392084.	480026.	221488.	144560.	84899.

PREDATION MORTALITY SPRAT

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.4466	0.5651	0.4482	0.3765	0.3931	0.4185	0.3786	0.2757	0.2214	0.2137
1	0.9150	0.9706	0.7896	0.7253	0.7161	0.7169	0.7495	0.6191	0.6458	0.6521
2	1.5640	1.9491	1.5908	1.4347	1.4691	1.5319	1.5361	1.3230	1.2229	1.1435
3	0.7609	0.7614	0.7528	0.6188	0.7181	0.7182	0.7026	0.7518	0.6213	0.6714
4	1.1464	1.8881	1.3616	1.3856	1.2836	1.4336	1.4245	1.0973	1.0960	0.7436

/Continued

FISHING MORTALITY SANDEEL **Table 2.8.1.** (Continued)

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.0648	0.1535	0.1051	0.0678	0.2527	0.2566	0.1175	0.1973	0.3049	0.3285
1	0.5632	0.2531	0.5588	0.6458	0.7603	0.4035	0.8035	0.3615	0.6129	0.5765
2	0.3204	0.6294	0.7502	0.6641	0.9566	1.1486	0.9299	1.0437	0.3800	1.4572
3	0.4110	0.7560	0.4506	1.0525	0.5320	0.9432	1.1585	0.4870	1.1177	0.1374
4	0.7926	0.5712	0.8708	0.6729	0.6344	0.8584	0.6489	0.8696	0.7208	0.1944
5	0.4824	0.8608	0.3641	1.3174	0.2680	0.8111	0.3771	0.7782	0.2824	0.1087
6	3.9017	0.3352	0.5553	5.3174	1.9266	0.8096	0.3738	0.4899	0.1411	0.1480
MEAN F WEIGHTED BY STOCK NUMBERS FOR THE MATURE STOCK (AGE AT FIRST MAT. 2)										
	0.1369	0.2136	0.2296	0.2776	0.3069	0.3717	0.3241	0.2938	0.1641	0.3796

STOCK NUMBERS SANDEEL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	1421964928.	932929728.	848484224.	726962112.	520712512.	529062592.	290627584.	531611232.	72728520.	46497884.
1	162723296.	215579760.	128731688.	188127552.	241306064.	158925120.	177824608.	116406728.	227770256.	29868792.
2	34732156.	30205862.	57931412.	26664214.	45400904.	53107748.	50087040.	39101716.	38386728.	67093400.
3	6911620.	10095706.	6730407.	12301489.	7084221.	9367872.	9149574.	10601697.	7119861.	14117784.
4	7031709.	3336586.	3520299.	3190616.	3310548.	3215219.	2806744.	2210780.	4898780.	1785511.
5	1064968.	1763474.	1077880.	850939.	1010486.	1092476.	836618.	901272.	541857.	1442793.
6	144145.	421337.	506024.	504060.	166077.	561245.	349978.	424149.	291019.	299716.
TOTAL STOCK BIOMASS ON 1. JANUARY										
	2662063.	2476594.	2210073.	2145716.	2360490.	2091898.	1934105.	1713074.	1888113.	1260941.
SPAWNING STOCK BIOMASS ON 1. JANUARY (AGE AT FIRST MAT. 2)										
	710875.	652351.	887627.	633508.	737390.	874022.	812480.	705751.	691079.	1074399.

PREDATION MORTALITY SANDEEL

AGE	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	1.7217	1.7271	1.3014	0.9350	0.8340	0.7338	0.6974	0.5502	0.4850	0.4245
1	1.0208	0.9610	0.9157	0.6757	0.6534	0.6512	0.6112	0.6479	0.5094	0.4382
2	0.8148	0.7720	0.6994	0.5613	0.5217	0.5101	0.5229	0.5596	0.5202	0.3886
3	0.2172	0.1976	0.1958	0.1601	0.1580	0.1621	0.1619	0.1850	0.1655	0.1296
4	0.4905	0.4588	0.4492	0.3769	0.3743	0.3879	0.3871	0.4363	0.4016	0.3294
5	0.3448	0.2876	0.2960	0.2164	0.2200	0.2272	0.2022	0.2523	0.2098	0.1787
6	0.2470	0.2092	0.2193	0.1690	0.1814	0.1970	0.1733	0.2122	0.1885	0.1820

Table 2.9.1. Comparison of different runs of the multispecies VPA.
For each run on assumption changed compared to the "Key Run".
Run 2: Half feeding level **** Run 3: Total biomass constant
Run 4: "Other Food" disregarded **** Run 5 :Half M1
Run 6: Suitability adjustment factor.

(For a more detailed description of the runs see sect 2.8. and 2.9)

Species: COD

Age	Key Run	Run 2	Run 3	Run 4	Run 5	Run 6
Fishing Mortality (Mean 1979-83)						
0	0.00	0.00	0.00	0.00	0.00	0.01
1	0.19	0.20	0.19	0.19	0.21	0.20
2	0.91	0.92	0.91	0.91	0.99	0.92
3	1.08	1.08	1.07	1.08	1.16	1.08
4	0.72	0.72	0.72	0.72	0.79	0.72
5	0.74	0.74	0.74	0.74	0.81	0.74
6	0.72	0.72	0.72	0.72	0.78	0.72
7	0.77	0.77	0.77	0.77	0.84	0.77
8	0.77	0.77	0.77	0.70	0.84	0.77
9	0.87	0.87	0.87	0.87	0.95	0.87
10	0.80	0.80	0.80	0.80	0.87	0.80
- Predation Mortality (Mean 1979-83)						
0	0.46	0.26	1.02	0.46	0.49	0.10
1	0.21	0.10	0.29	0.20	0.21	0.059
2	0.027	0.013	0.036	0.028	0.027	0.012
3	0.011	0.0051	0.015	0.011	0.011	0.0037
4	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00
-- Stock in numbers (Mean 1979-83) (thousands)						
0	280570	249753	305809	280462	233849	257455
1	197700	194318	200131	197657	179299	194674
2	86312	85758	86727	86308	80893	85825
3	23651	23639	23660	23651	21634	23643
4	7950	7950	7950	7950	7348	7950
5	2898	2898	2898	2898	2661	2898
6	1104	1104	1104	1104	1021	1104
7	411	411	411	411	382	411
8	152	152	152	152	138	152
9	75	75	75	75	68	75
10	51	51	51	51	47	51

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Table 2.9.1. (Continued)

Comparison of different runs of the Multispecies VPA.
For each run, one assumption has been changed compared to the Key run.
Run 2: Half feeding level **** Run 3: Total biomass constant
Run 4:"Other food" disregarded **** Run 5 :Half M1
Run 6: Suitability adjustment factor.

(For a more detailed description of the runs see sect 2.8 and 2.9)

Species: WHITING

Age	Key Run	Run 2	Run 3	Run 4	Run 5	Run 6
Fishing Mortality (Mean 1979-83)						
0	0.15	0.20	0.15	0.13	0.17	0.18
1	0.28	0.32	0.28	0.24	0.31	0.29
2	0.48	0.51	0.48	0.46	0.53	0.48
3	0.75	0.78	0.75	0.73	0.82	0.75
4	0.87	0.89	0.87	0.86	0.94	0.88
5	1.00	1.01	1.00	1.00	1.08	1.01
6	1.17	1.17	1.17	1.16	1.25	1.17
7	0.98	0.98	0.98	0.98	1.05	0.98
8	1.13	1.13	1.13	1.13	1.22	1.13
9	0.55	0.55	0.55	0.55	0.60	0.55
10	1.11	1.11	1.11	1.11	1.19	1.11
- Predation Mortality (Mean 1979-83)						
0	0.63	0.52	0.64	1.71	0.86	0.23
1	0.58	0.33	0.58	0.87	0.61	0.39
2	0.19	0.10	0.19	0.27	0.20	0.16
3	0.11	0.06	0.11	0.15	0.11	0.10
4	0.09	0.04	0.09	0.13	0.09	0.09
5	0.05	0.02	0.05	0.06	0.04	0.04
6	0.03	0.02	0.03	0.05	0.03	0.03
7	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00
-- Stock in numbers (Mean 1979-83) (thousands)						
0	3201170	2560724	3199577	5998043	2699096	2695554
1	986529	872796	986026	1082085	862274	959606
2	538926	503828	538483	564076	483547	531865
3	231415	221462	231193	238812	212638	229252
4	86032	84508	86010	87131	80898	85634
5	21761	21597	21759	21872	20582	21690
6	4340	4320	4339	4356	4099	4339
7	1049	1049	1049	1049	986	1049
8	265	265	265	265	246	265
9	64	64	64	64	59	64
10	16	16	16	16	15	16

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Table 2.9.1. (Continued)

Comparison of different runs of the Multispecies VPA.
For each run, one assumption has been changed compared to the Key run.
Run 2: Half feeding level **** Run 3: Total biomass constant
Run 4: "Other food" disregarded **** Run 5 :Half M1
Run 6: Suitability adjustment factor.

(For a more detailed description of the runs see sect 2.8 and 2.9)

Species: HADDOCK

Age	Key Run	Run 2	Run 3	Run 4	Run 5	Run 6
Fishing Mortality (Mean 1979-83)						
0	0.17	0.25	0.17	0.11	0.19	0.20
1	0.33	0.39	0.33	0.28	0.37	0.34
2	0.70	0.72	0.70	0.68	0.76	0.70
3	1.06	1.07	1.06	1.05	1.14	1.05
4	1.07	1.08	1.07	1.06	1.15	1.06
5	0.87	0.87	0.87	0.87	0.95	0.87
6	0.83	0.83	0.83	0.83	0.91	0.83
7	0.89	0.89	0.89	0.88	0.97	0.89
8	0.72	0.72	0.72	0.72	0.79	0.72
9	0.67	0.67	0.67	0.67	0.73	0.67
10	0.87	0.87	0.87	0.87	0.94	0.87
- Predation Mortality (Mean 1979-83)						
0	1.45	1.08	1.45	2.43	1.50	0.99
1	1.04	0.61	1.03	1.06	1.03	0.91
2	0.16	0.08	0.16	0.23	0.16	0.13
3	0.05	0.02	0.05	0.06	0.05	0.05
4	0.04	0.02	0.04	0.05	0.05	0.06
5	0.02	0.01	0.02	0.02	0.02	0.03
6	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00
-- Stock in numbers (Mean 1979-83) (thousands)						
0	5070805	3525197	5079131	11761945	4504743	3854085
1	770313	693963	770031	855279	686336	749990
2	293541	286311	293352	296790	268340	293604
3	93170	91846	93096	93630	86714	93805
4	24366	24303	24361	24388	23265	24431
5	8076	8074	8076	8076	7530	8075
6	2154	2154	2154	2154	1972	2154
7	705	703	703	705	635	703
8	322	322	322	322	293	322
9	159	159	159	159	147	159
10	58	58	58	58	53	58

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Table 2.9.1. (Continued)

Comparison of different runs of the Multispecies VPA.
For each run, one assumption has been changed compared to the Key run.
Run 2: Half feeding level **** Run 3: Total biomass constant
Run 4: "Other food" disregarded **** Run 5 :Half M1
Run 6: Suitability adjustment factor.

(For a more detailed description of the runs see sect 2.8 and 2.9)

Species: HERRING

Age	Key Run	Run 2	Run 3	Run 4	Run 5	Run 6
Fishing Mortality (Mean 1979-83)						
0	0.50	0.57	1.51	0.42	0.53	0.54
1	0.20	0.21	0.20	0.17	0.21	0.19
2	0.13	0.15	0.13	0.11	0.14	0.13
3	0.19	0.21	0.19	0.18	0.21	0.19
4	0.23	0.22	0.22	0.20	0.24	0.22
5	0.28	0.28	0.28	0.28	0.30	0.28
6	0.29	0.29	0.29	0.29	0.31	0.29
7	0.87	0.87	0.87	0.87	0.95	0.87
8	0.77	0.77	0.77	0.77	0.95	0.77
- Predation Mortality (Mean 1979-83)						
0	0.94	0.52	0.94	1.52	0.94	1.02
1	0.34	0.18	0.34	0.53	0.33	0.20
2	0.03	0.01	0.03	0.04	0.03	23.03
3	0.53	0.18	0.53	0.48	0.53	0.38
4	0.02	0.01	0.02	0.05	0.02	0.02
5	0.07	0.03	0.07	0.18	0.06	0.06
6	0.0003	0.0001	0.0003	0.0006	0.0003	0.0003
7	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00
-- Stock in numbers (Mean 1979-83) (Millions)						
0	9195	7798	9103	11705	8617	8354
1	2699	2467	2683	3175	2501	2777
2	1857	1685	1845	2138	1769	1923
3	666	656	665	697	639	667
4	282	277	281	296	272	282
5	71	71	71	71	68	71
6	28	28	28	28	26	28
7	10	10	10	10	8	10
8	3	3	3	3	2	3

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Table 2.9.1. (Continued)

Comparison of different runs of the Multispecies VPA.
For each run, one assumption has been changed compared to the Key run.
Run 2: Half feeding level **** Run 3: Total biomass constant
Run 4: "Other food" disregarded **** Run 5 :Half M1
Run 6: Suitability adjustment factor.

(For a more detailed description of the runs see sect 2.8 and 2.9)

Species: SPRAT

Age	Key Run	Run 2	Run 3	Run 4	Run 5	Run 6
	Fishing Mortality (Mean 1979-83)					
0	0.03	0.02	0.03	0.11	0.04	0.13
1	0.52	0.69	0.53	0.38	0.56	0.49
2	1.30	1.63	1.30	1.03	1.36	1.28
3	2.06	2.35	2.06	1.77	2.13	2.10
4	1.61	1.67	1.62	1.49	1.65	1.70
	- Predation Mortality (Mean 1979-83)					
0	0.30	0.19	0.31	0.45	0.29	0.46
1	0.68	0.39	0.68	1.10	0.66	0.84
2	1.35	0.75	1.35	2.00	1.30	1.42
3	0.69	0.35	0.69	1.12	0.66	0.68
4	1.16	0.60	1.16	1.50	1.11	0.98
	-- Stock in numbers (Mean 1979-83) (Millions)					
0	44286	29766	44338	79440	40406	51282
1	27767	19349	27962	39913	25782	29700
2	5280	3578	5309	6522	5001	4969
3	328	237	329	384	307	297
4	248	171	292	347	274	252

Species: NORWAY POUT

Age	Key Run	Run 2	Run 3	Run 4	Run 5	Run 6
	Fishing Mortality (Mean 1979-83)					
0	0.09	0.10	0.09	0.21	0.10	0.09
1	0.43	0.51	0.43	0.33	0.56	0.42
2	0.90	1.09	0.91	0.72	1.17	0.90
3	0.70	0.78	0.70	0.68	0.91	0.70
	- Predation Mortality (Mean 1979-83)					
0	0.37	0.21	0.36	1.90	0.41	0.35
1	1.01	0.80	1.04	1.13	1.34	1.02
2	0.11	0.08	0.11	0.28	0.28	0.06
3	1.37	0.78	1.35	1.93	1.47	1.39
	-- Stock in numbers (Mean 1979-83) (Millions)					
0	365792	200969	371592	679382	158876	597462
1	54773	34949	54346	84274	24820	89036
2	11309	6672	11011	16635	4540	21241
3	1050	1050	1050	1050	536	2050

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Table 2.9.1. (Continued)

Comparison of different runs of the Multispecies VPA.
For each run, one assumption has been changed compared to the Key run.
Run 2: Half feeding level **** Run 3: Total biomass constant
Run 4: "Other food" disregarded **** Run 5 :Half M1
Run 6: Suitability adjustment factor.

(For a more detailed description of the runs see sect 2.8 and 2.9)

Species: SANDEEL

Age	Key Run	Run 2	Run 3	Run 4	Run 5	Run 6
Fishing Mortality (Mean 1979-83)						
0	0.36	0.58	0.36	0.33	0.37	0.33
1	0.55	0.65	0.55	0.49	0.59	0.47
2	0.99	1.12	0.99	0.81	1.04	0.83
3	0.77	0.88	0.77	0.64	0.82	0.62
4	0.66	0.79	0.66	0.53	0.72	0.56
5	0.47	0.56	0.47	0.36	0.55	0.55
6	0.39	0.47	0.39	0.33	0.47	0.51
- Predation Mortality (Mean 1979-83)						
0	0.58	0.55	0.59	1.98	0.56	0.54
1	0.57	0.34	0.57	0.99	0.56	0.62
2	0.50	0.25	0.50	0.95	0.48	0.24
3	0.16	0.08	0.16	0.30	0.15	0.04
4	0.39	0.22	0.39	0.49	0.40	0.65
5	0.21	0.12	0.21	0.36	-.22	0.21
6	0.19	0.10	0.19	0.32	0.20	0.21
-- Stock in numbers (Mean 1979-83) (Millions)						
0	125467	90890	125371	219661	115096	123779
1	42991	35207	42810	64707	40165	53798
2	11376	9920	11346	13958	10752	20997
3	4507	4032	4500	5255	4313	13775
4	1040	880	1037	1328	963	6129
5	488	426	486	624	440	2301
6	198	158	198	274	161	179

Table 2.9.2 Changes compared to Key run

SPECIES	RUN 2 Feeding level 0.5			RUN 3 Total biomass constant			RUN 4 "Other food" ignored			RUN 5 M1 halved			RUN 6 Suitability adjusted			COMMENTS
	F	N	M2	F	N	M2	F	N	M2	F	N	M2	F	N	M2	
COD	100	94	49	100	100	100	94	104	139	109	88	103	100	92	30	Age groups 1 - 3
WHITING	104	68	57	100	100	100	97	299*	159	113	85	102	100	62	54	Age groups 0 - 6
SAITHE	-	-	-	-	-	-	-	-	-	?	?	?	-	-	-	
MACKEREL	-	-	-	-	-	-	-	-	-	?	?	?	-	-	-	- - -
HADDOCK	104	56	65	100	100	100	97	279	158	109	85	101	100	66	79	Age groups 0 - 5
HERRING	105	67	54	100	99	100	91	186*	151	107	92	95	102	244**	96	Age groups 0 - 6
SPRAT	120	58	54	100	100	100	86	226	149	104	88	96	103	123	104	Age groups 0 - 4
N. POUT	116	55	65	100	102	100	90	269	174	129	37	111	100	155	100	Age groups 0 - 4
SANDEEL	116	64	58	100	101	100	82	485	200	85	88	81	68	99	78	Age groups 0 - 6

Run 1: Key run - No adjustment
Helgason-Gislason other food model M1 as in Fish Stock Assess. Working Group
Feeding level = 1
In each subsequent run only one assumption changed

*) 0-group 1983 extremely high

**) Abnormal Y.C. (not raised run)

Table 3.3.1 Extreme values of predation mortality for the 3 youngest ages of each species (excluding SAITHE and MACKEREL) together with upset = exp{(M2 (high) - M2 (low))/2}

Age / Species	0-Group			1-Group			2-Group		
	M2(Low)	M2(High)	UPSET	M2(Low)	M2(High)	UPSET	M2(Low)	M2(High)	UPSET
Cod	.37	.52	1.08	.16	.30	1.07	.02	.05	1.02
Whiting	.80	1.06	1.14	.40	.69	1.16	.16	.31	1.08
Haddock	1.24	1.77	1.30	.84	1.55	1.43	.15	.27	1.06
Herring	.84	1.21	1.20	.29	.49	1.11	.02	.04	1.01
Sprat	.21	.57	1.20	.62	.97	1.19	1.14	1.95	1.50
Norway Pout	.33	.88	1.32	.77	1.84	1.71	.08	.22	1.07
Sandeel	.43	1.73	1.92	.43	1.02	1.34	.40	.84	1.22

Table 4.3.1 Estimated state of fish stocks at steady-state under current levels of fishing mortality

	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway Pout	Sandeel
Biomass									
Recruitment									
Total Yield									

Table 4.3.2 Estimated steady-state yield in each fishery ('000 tonnes)in each fishery at current levels of fishing mortality.

Fishery	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway Pout	Sandeel
Roundfish (human consumption)									
Demersal (Industrial)									
Pelagic (Industrial)									
Herring (human consumption)									
Saithe									
Mackerel									

Table 4.3.3 Expected change of steady-state biomass* ('000 t) resulting from a 10% increase of F in each fishery.

Fishery in which F is increased	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway Pout	Sandeel
Roundfish (human consumption)									
Demersal (Industry)									
Pelagic (Industry)									
Herring (Human consumption									
Saithe									
Mackerel									

* Together with similar tables for total yield and recruitment

Table 4.3.4 Estimated change of steady-state yield ('000 t) in each fishery resulting from a 10% increase of F in each fishery.
Fishery = Roundfish (Human consumption)*

Fishery in which F is increased	Cod	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat	Norway Pout	Sandeel
Roundfish (Human consumption)									
Demersal (Industry)									
Pelagic (Industry)									
Herring (Human consumption)									
Saithe									
Mackerel									

* Together with similar tables for all other fisheries

Table 6.1.1. Comparison of estimated weights (in '000 tonnes) consumed by North Sea COD of various exploited fish species in the years 1967 to 1970 (Daan,1973) with values obtained using similar procedures for 1981

Species	Average 1967/1970	1981
Cod	56	38
Haddock	134	112
Whiting	47	98
Norway pout	not available	101
Herring	57	50
Sprat	not available	41
Sandeels	not available	131
Plaice	17	3
Sole	7	2
Mackerel	41	22

Table 6.1.2. Comparison of feeding coefficients for COD ($\emptyset = L^3/S$) where L represents the average length and S represents average stomach content weights obtained using various sampling programs (from Daan,1983).

Period	Area	$\emptyset$ - value
1966-1972	Total North Sea	.000158
1980	Roundfish area 6	.000147
1981	Total North Sea	.000151
	Average	.000152

Table 6.2.1 Comparison of Total consumption in tonnes by individual predators with estimated stock biomasses of prey in 1974 and 1981.

Predation Summary Table for the (Total) Year 1974

PREY	PREDATORS				TOTAL	STOCK BIOMASS	% CONSUMED
	COD	WHITING	SAITHE	MACKEREL			
Cod	14 143.5	695.1	718.2	220.2	15 777.8	395 922	3.6
Whiting	87 729.1	43 030.5	3 472.9	406.7	134 639.4	862 561	15.6
Saithe	0.0	0.0	0.0	0.0	0.0	1 028 415	-
Mackerel	0.0	0.0	0.0	0.0	0.0	1 147 761	-
Haddock	188 849.4	154 544.9	341 288.2	28 243.7	712 926.2	2 239 894	31.8
Herring	21 634.1	21 022.7	5 553.5	4 629.5	52 839.9	486 618	10.9
Sprat	112 124.0	425 022.9	5 726.4	209 858.7	752 732.1	4 168 011	18.1
Norway Pout	81 239.6	90 287.0	577 533.9	281 071.7	1 030 132.3	3 695 078	27.9
Sandeel	64 256.1	243 660.4	17 416.8	705 537.8	1 030 871.1	2 662 063	38.7
TOTAL	569 975.9	978 263.7	951 710.1	1 229 969.0	3 729 918.8	16 686 323	
Predation Summary Table for the (Total) Year 1981							
Cod	34 252.3	2 036.4	1 004.3	35.5	37 328.5	505 363	7.4
Whiting	87 042.6	34 884.0	1 780.8	11.8	123 719.1	571 206	21.7
Saithe	0.0	0.0	0.0	0.0	0.0	659 283	-
Mackerel	0.0	0.0	0.0	0.0	0.0	191 401	-
Haddock	90 048.1	85 931.9	45 734.7	450.0	222 164.7	613 925	36.0
Herring	41 264.5	114 472.0	6 570.5	1 650.2	163 957.2	651 375	25.2
Sprat	48 234.5	119 885.9	538.2	3 084.3	171 742.9	501 679	34.2
Norway Pout	81 463.9	145 031.2	287 377.0	46 487.5	560 359.6	4 179 634	11.7
Sandeel	121 856.1	273 832.4	9 779.4	84 945.6	490 413.6	1 713 074	27.2
TOTAL	504 162.0	776 073.9	352 784.9	136 664.9	1 769 685.8	9 586 940	

ZPURGE-I-NOFILPURG = No files purged for DUA1:(PER.MS) ** **:

Table 6.2.2 Environmental impact statement in respect of predation exercised by various predator species in the North Sea on HADDOCK.

PARTIAL PREDATION MORTALITIES

		COD						WHITING						SAITHE		
Haddock	M2	1	2	3	4	5	6+	1	2	3	4	5	6+	4	5	6
Age 0	1.4197	.0076	.1696	.0456	.0207	.0058	.0011	.016	.345	.293	.080	.02	.014	.0136	.167	.204
1	1.0376	.0052	.1881	.1902	.1180	.0480	.0168	.016	.019	.056	.026	.007	.006	.033	.144	.170
2	.1567		.0051	.0348	.0531	.0314	.0275		.00009	.0016	.0008	.0002	.0002	.0002	.0006	.001
3	.0424		.0005	.0022	.0080	.0057	.0260									
4	.0375		.0001	.0018	.0026	.0013	.0317									
5	.0146				.0005		.0141									
INDIVIDUAL PREDATION MORTALITIES x 10^9																
0		.037	.54	.97	1.3	.7	.3	.01	.2	.5	.4	.5	.7	.35	3.0	4.8
1		.025	.60	4.1	7.5	6.2	5.4	.0099	.013	.09	.16	.20	.3	.58	3.0	4.0
2			.016	.74	3.4	4.0	8.8		.00006	.0028	.0020	.0051	.013	.0038	.013	.024
3			.002	.048	.51	.73	8.3									
4			.000	.038	.17	.17	10.1									
5					.030		4.5									

Table 6.4.1. Andersen and Ursin Model versus the "Key Run"

Predation mortalities per year by species and age group in 1976

KR: Key Run AU: Andersen and Ursin

Age	Cod		Whiting		Saithe		Mackerel		Haddock		Herring		Sprat		Sandeel		Norway Pout	
	KR	AU	KR	AU	KR	AU	KR	AU	KR	AU	KR	AU	KR	AU	KR	AU	KR	AU
0	0.4	1.5	0.8	0.9	0	1.9	0	0.5	1.3	1.0	0.9	1.1	0.4	0.8	1.3	1.6	0.6	1.8
1	0.2	0.4	0.5	0.7	0	0.5	0	0.2	1.0	0.8	0.4	0.3	0.8	0.5	0.9	0.7	1.1	0.9
2	0.03	0.03	0.2	0.4	0	0.1	0	0.07	0.2	0.3	0.03	0.1	1.6	0.3	0.7	0.5	0.1	0.7
3	0.01	0.005	0.1	0.2	0	0.04	0	0.04	0.09	0.1	0.3		0.8	0.3	0.2	0.4	1.1	
4	0	0	0.1	0.1	0		0		0.1		0.03	0.1	1.4		0.09			
5	0	0	0.05	0.07	0	0.01	0	0.04	0.04	0.07	0.1				0.6	0.3		
6	0	0	0.04		0		0		0		0				0.9			

Notes: AU exercise was done in January 1980. (Unpubl.)

0-Group: A&U count from hatching .

KR counts from a later age (after metamorphosis) .

Saithe: KR excludes young saithe from the North Sea; AU admit them.

Mackerel: KR has zero: material not ready.

Decrease with age: AU is smoother because food preference functions were used.

Ration: KR uses digestion rates as estimated from experiments.
AU calculated requirements from the growth equation (cf. Section 2.1.4).

Table 6.6.1 Example of Uniqueness Table for f_1 and f_2

f_1	
$\bar{N}_1$	$\bar{N}_2$
800	-147.27
820	.107.73
540	-67.53
860	-26.70
880	14.75
900	56.81
920	99.46
940	142.69
960	186.49
f_2	
$\bar{N}_1$	$\bar{N}_2$
-95.97	22.00
483.57	27.00
409.38	32.00
1241.64	34.00
1512.42	42.00

Table 6.8.1 Estimated regression coefficients of ln (W (prey in stomach)/W(prey stock)) vs. ln (Weight (predator)/W (prey stock)) for COD and WHITING preying on seven prey species, by calendar quarter.

Parameter	PREDATOR									
	COD					WHITING				
	Q_1	Q_2	Q_3	Q_4	ΣQ	Q_1	Q_2	Q_3	Q_4	ΣQ
α	-1.34	-1.84	-0.70	-1.30	-1.33	-0.94	-2.74	-1.93	-2.03	-1.80
β	0.25	0.33	0.15	0.29	0.26	0.03	0.59	0.47	0.48	0.34
σ^2	0.41	0.27	0.13	0.36	0.27	0.002	0.28	0.28	0.35	0.16
$\hat{\eta}$	-5.36	-5.58	-4.67	-4.48	-5.12	-31.33	-4.64	-4.11	-4.23	-5.29
Ho: Slopes = 0			179.66 **					56.18 **		
Ho: Slopes are =			3.93 **					10.67 **		
Ho: Adjusted means =			6.55 **					3.02 *		

A) Prey species are: cod, haddock, whiting, Norway pout, herring, sprat, sandeel.

B) All age groups of all prey are included.

Table 6.8.2 Estimated regression coefficients of ln (W(prey in stomach) /W (prey in stock)) vs. ln (Weight (predator) W(prey in stock)) for COD and WHITING preying on seven prey species.

Predator	Prey Species	Regression Coeff. α	β	r^2	$\hat{\eta}$	Ho: Slopes = Ø	Ho: Slopes =	Ho: A.M.'S =
COD	Cod	-1.14	-0.24	0.07	-4.75			
	Haddock	-1.01	0.10	0.07	-10.10			
	Whiting	-0.50	0.05	0.01	-10.00			
	Norway Pout	-0.35	0.13	0.16	-2.69	19.52 **	8.57 **	21.73 **
	Herring	-1.84	0.45	0.28	-4.09			
	Sprat	-1.32	0.30	0.27	-4.40			
	Sandeel	-0.08	0.00	< 0.01	-			
	All	-1.33	0.26	0.27	-5.12			
WHITING	Cod	-3.48	-0.85	0.35	-4.09			
	Haddock	-2.13	0.37	0.20	-5.26			
	Whiting	-0.95	-0.43	0.23	2.21			
	Norway Pout	0.34	-0.31	0.26	-1.10	0.17 n.s.	14.14 **	39.35 *
	Herring	-4.00	1.04	0.27	-3.85			
	Sprat	-0.96	0.23	0.22	-4.17			
	Sandeel	0.34	-0.23	0.12	-1.48			
	All	-1.80	0.35	0.16	-5.14			

A) All age groups of prey included.

Figure 2.1.1. Flow chart for the program "MSVPA".

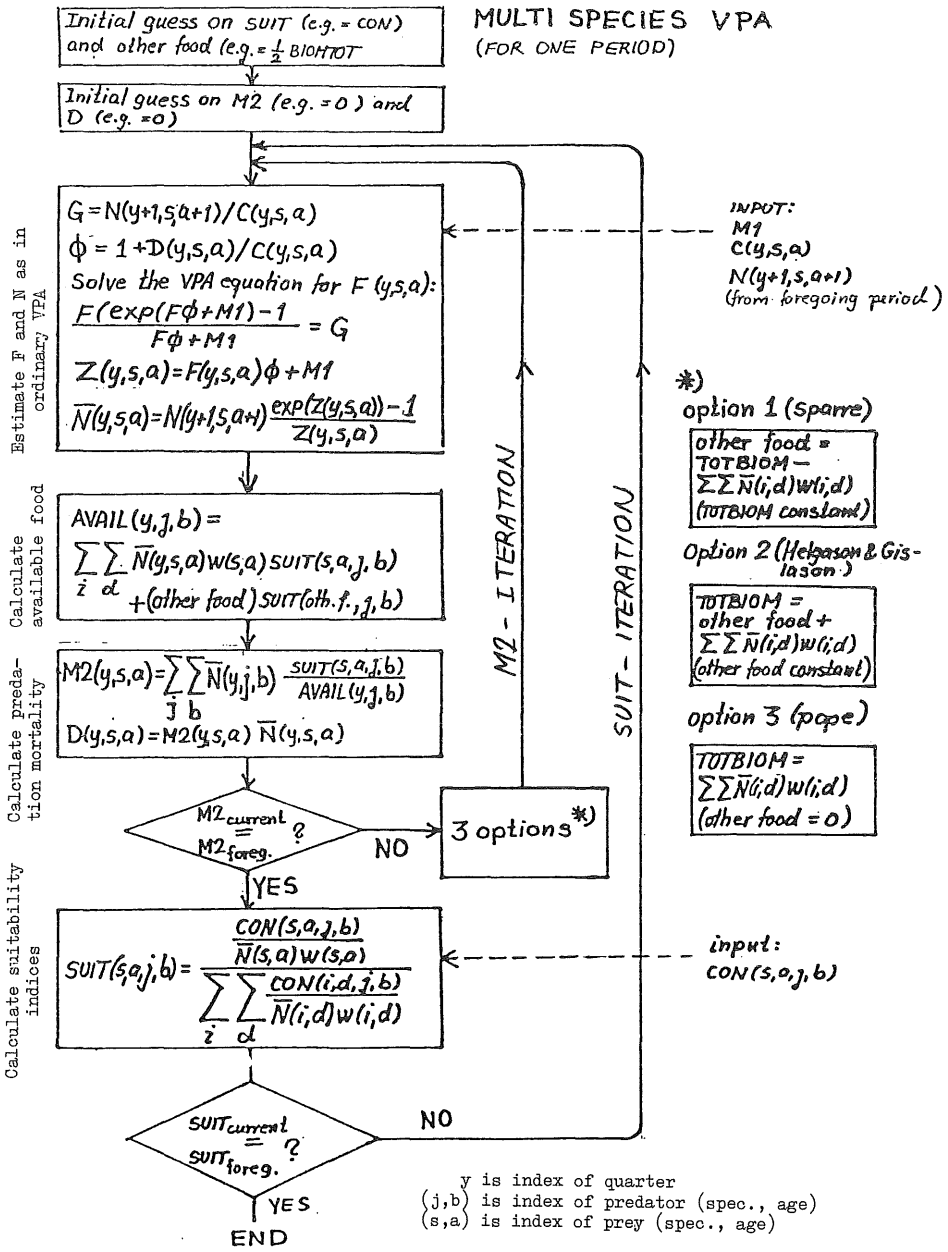


Figure 2.7.1. Plot of FF (ln W(prey in stomachs)/W(prey in stock)) vs. ratio (ln W(predator)/W(prey in stock)) for various prey species eaten by cod.

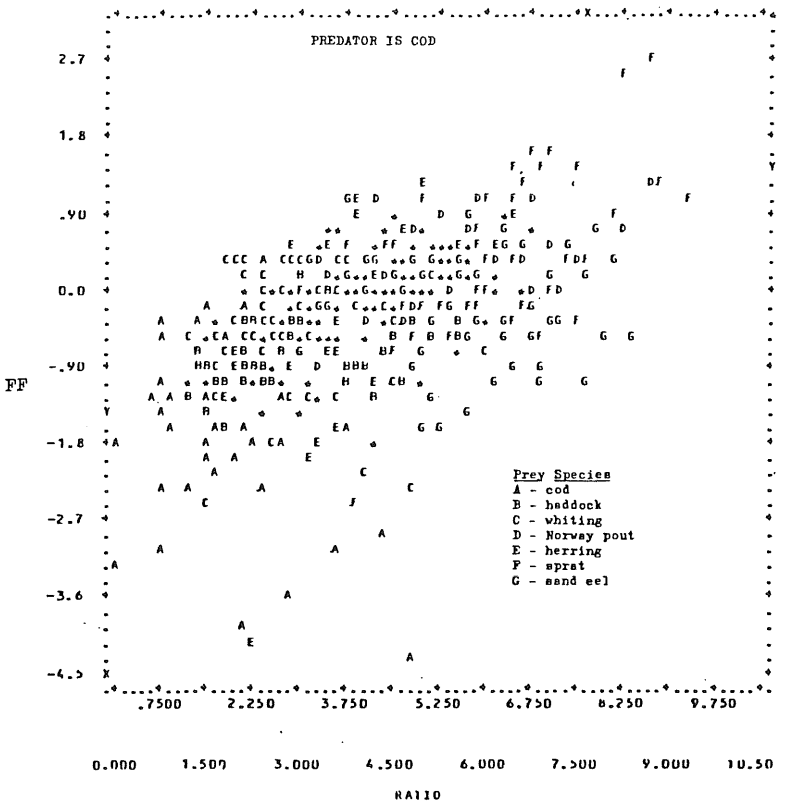


Figure 2.7.2. Plot of FF (ln W(prey in stomachs)/W(prey in stock) vs. ratio (ln W(predator)/W(prey in stock)) for various prey species eaten by whiting.

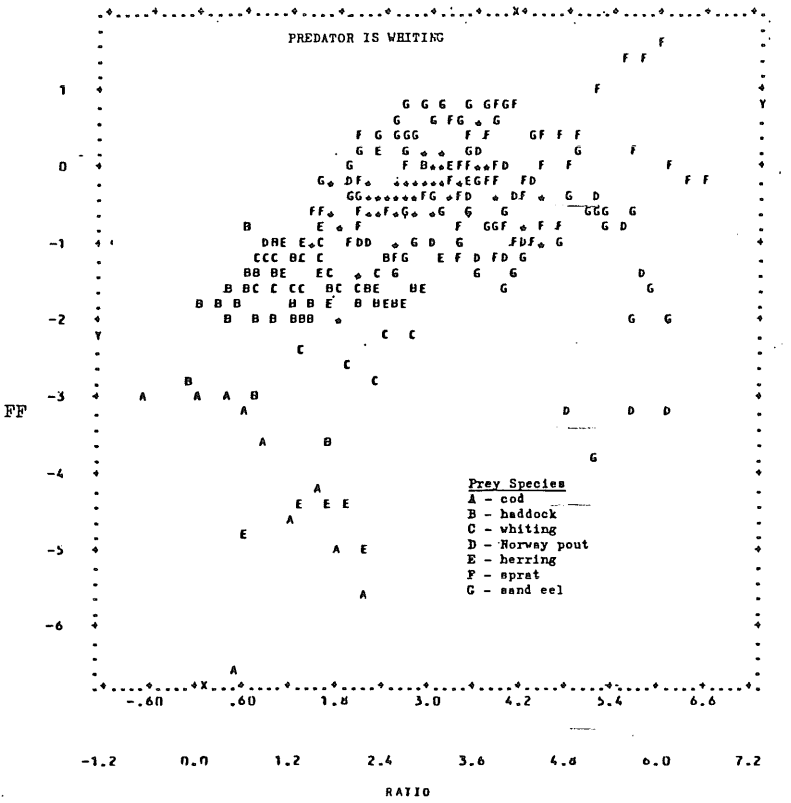
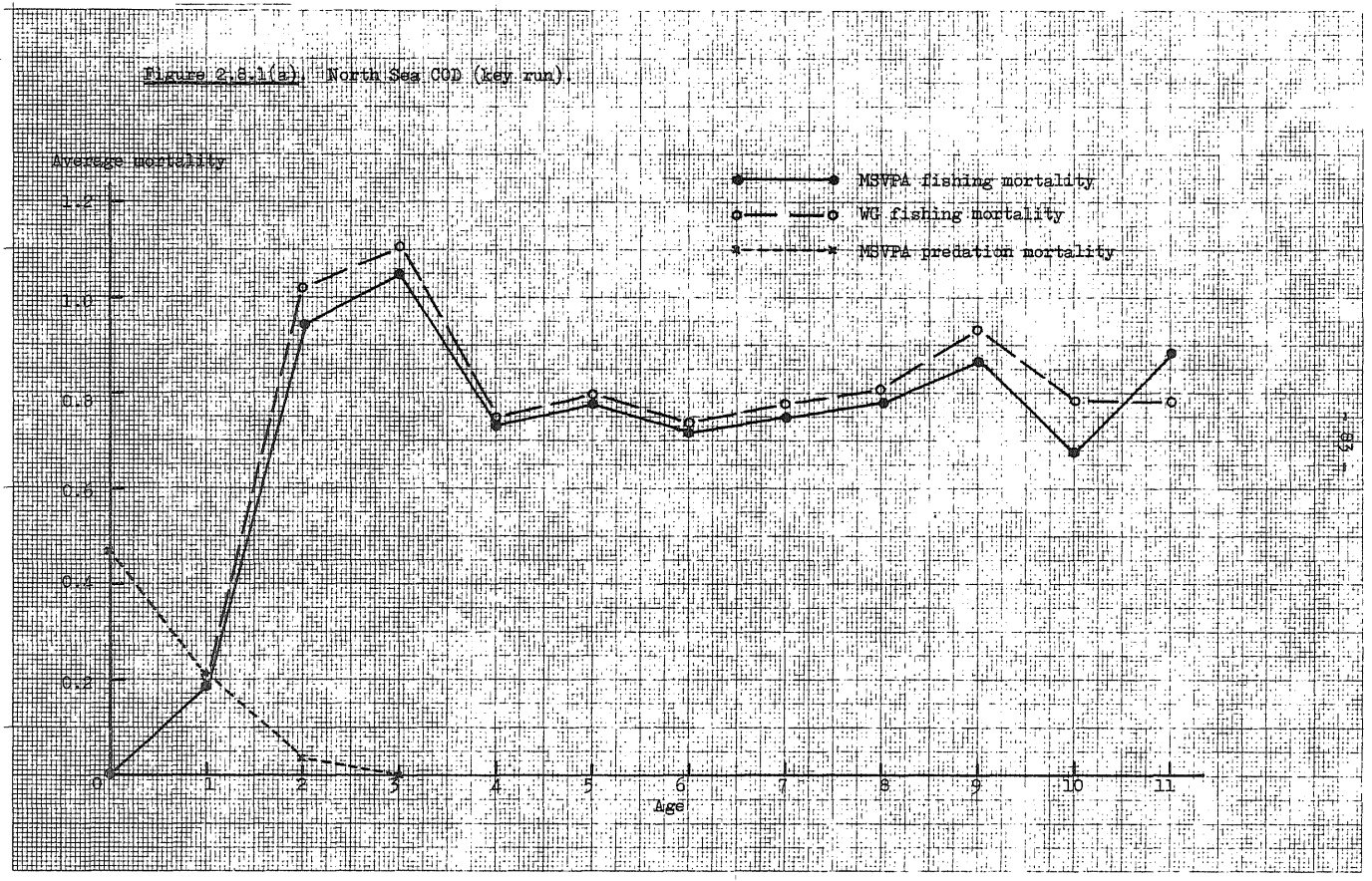


Figure 2.8.1(a). North Sea COD (key run).



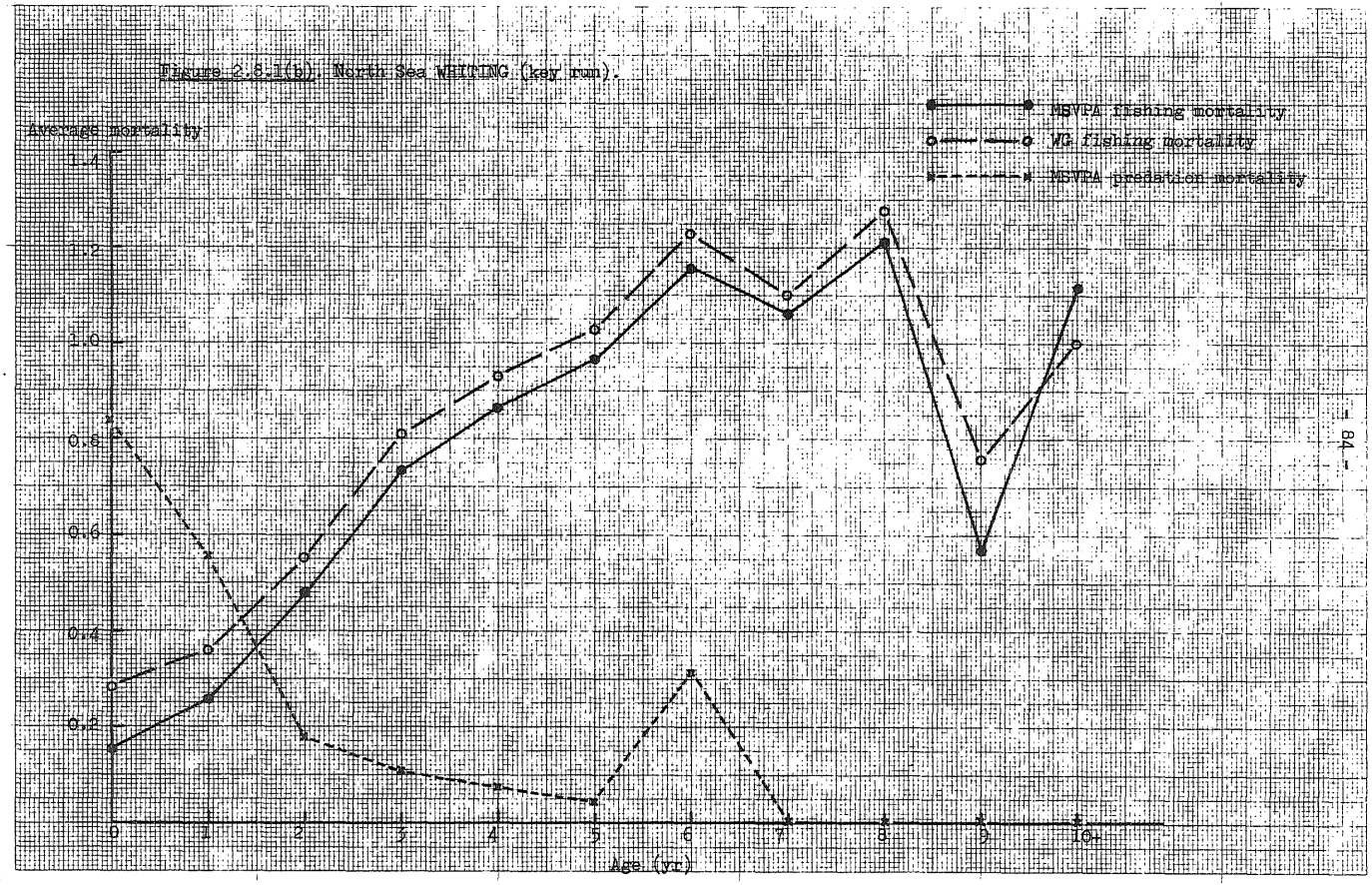
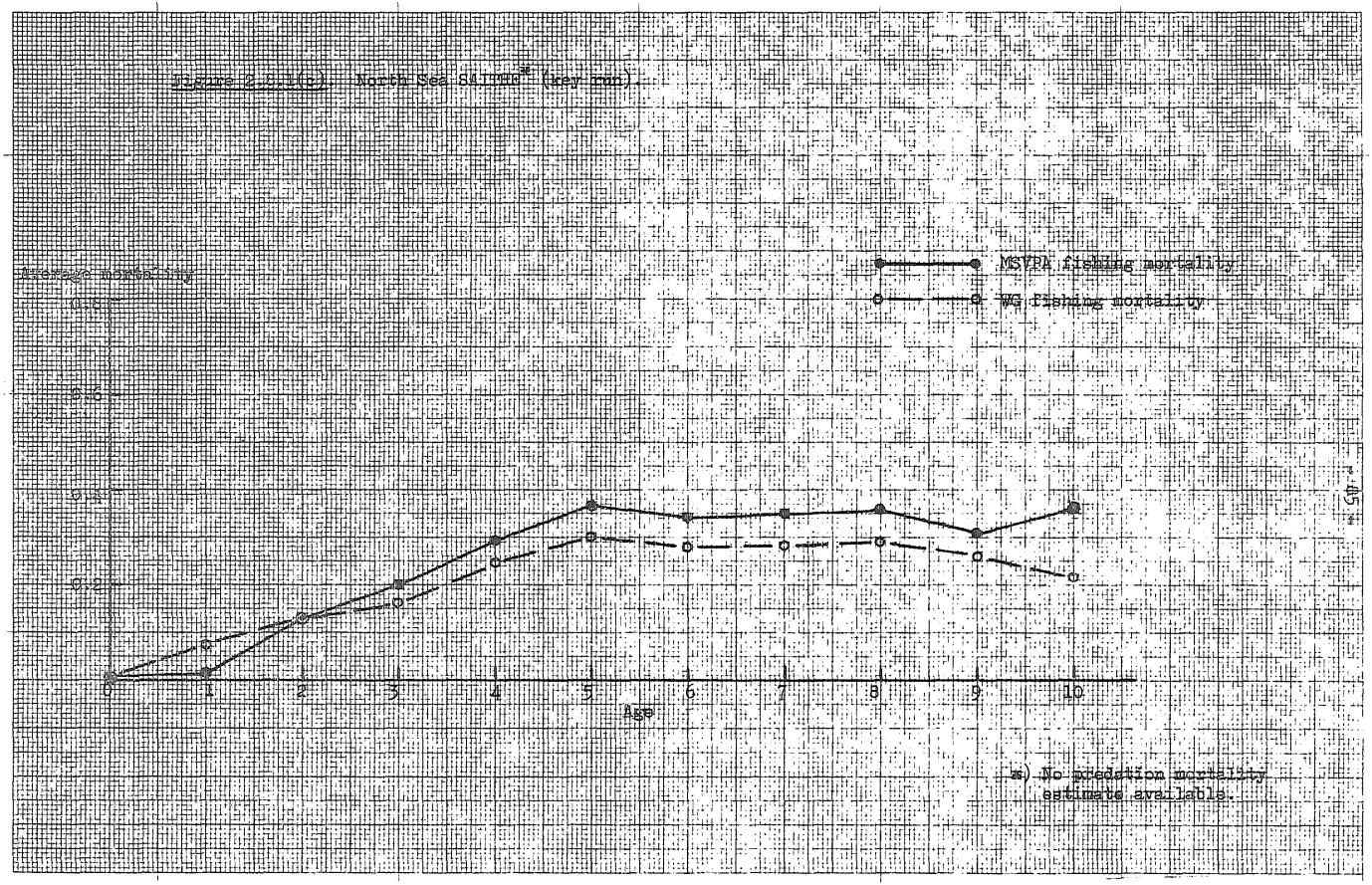


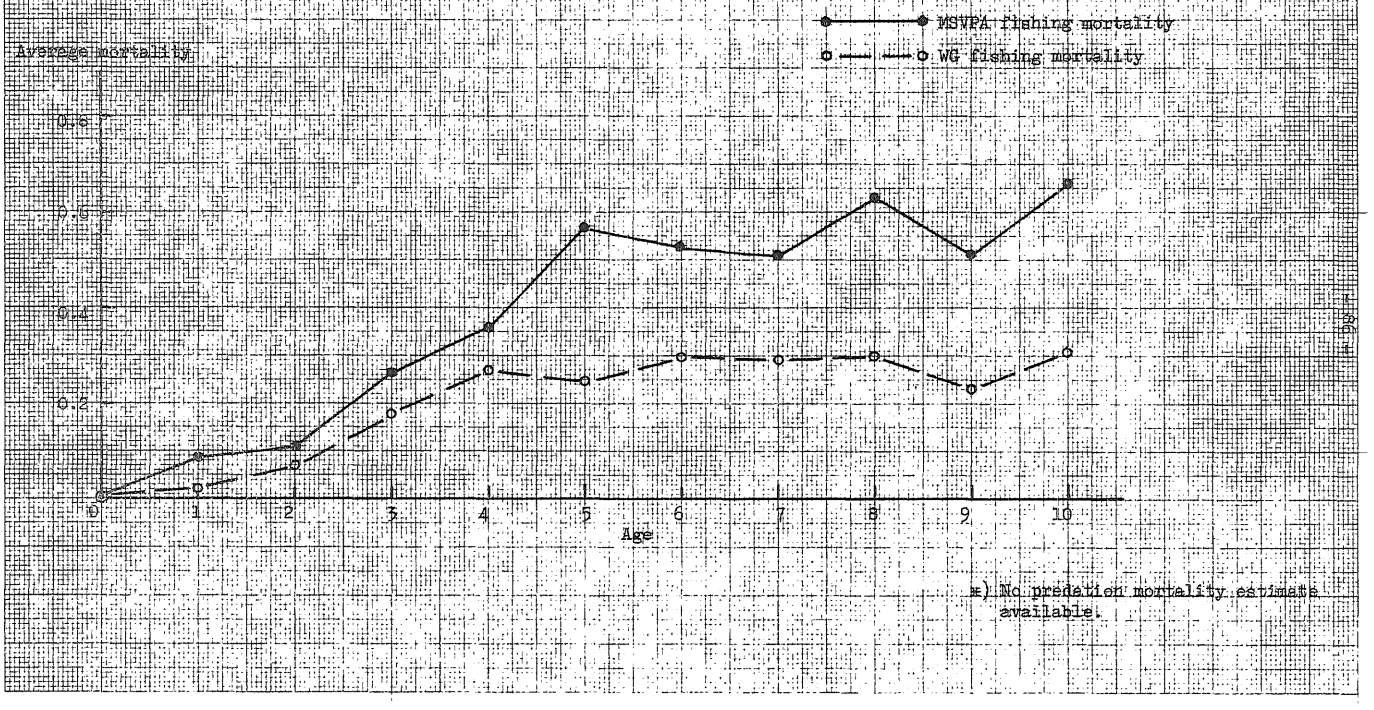
Figure 2.5.1(b). North Sea WHITING (key run).
MSVPA fishing mortality
VG fishing mortality
MSVPA predation mortality
Average mortality
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
10+
Age (yr)

Figure 2.5.1(xx) North Sea SAITHE* (key run)



*) No predation mortality estimate available.

Figure 2.8.1(a). North Sea* MACKEREL (key run).



*) No predation mortality estimate available.

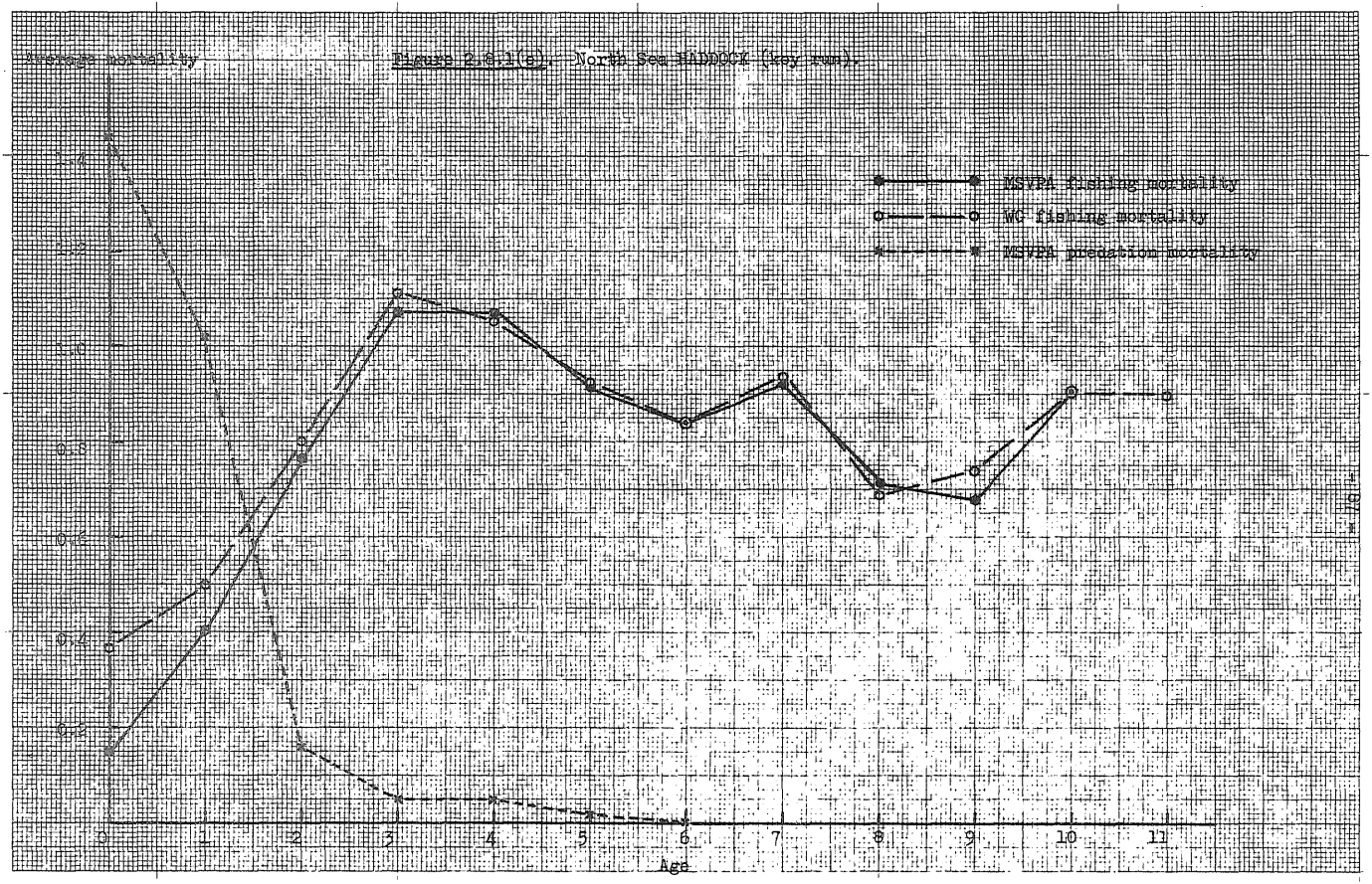
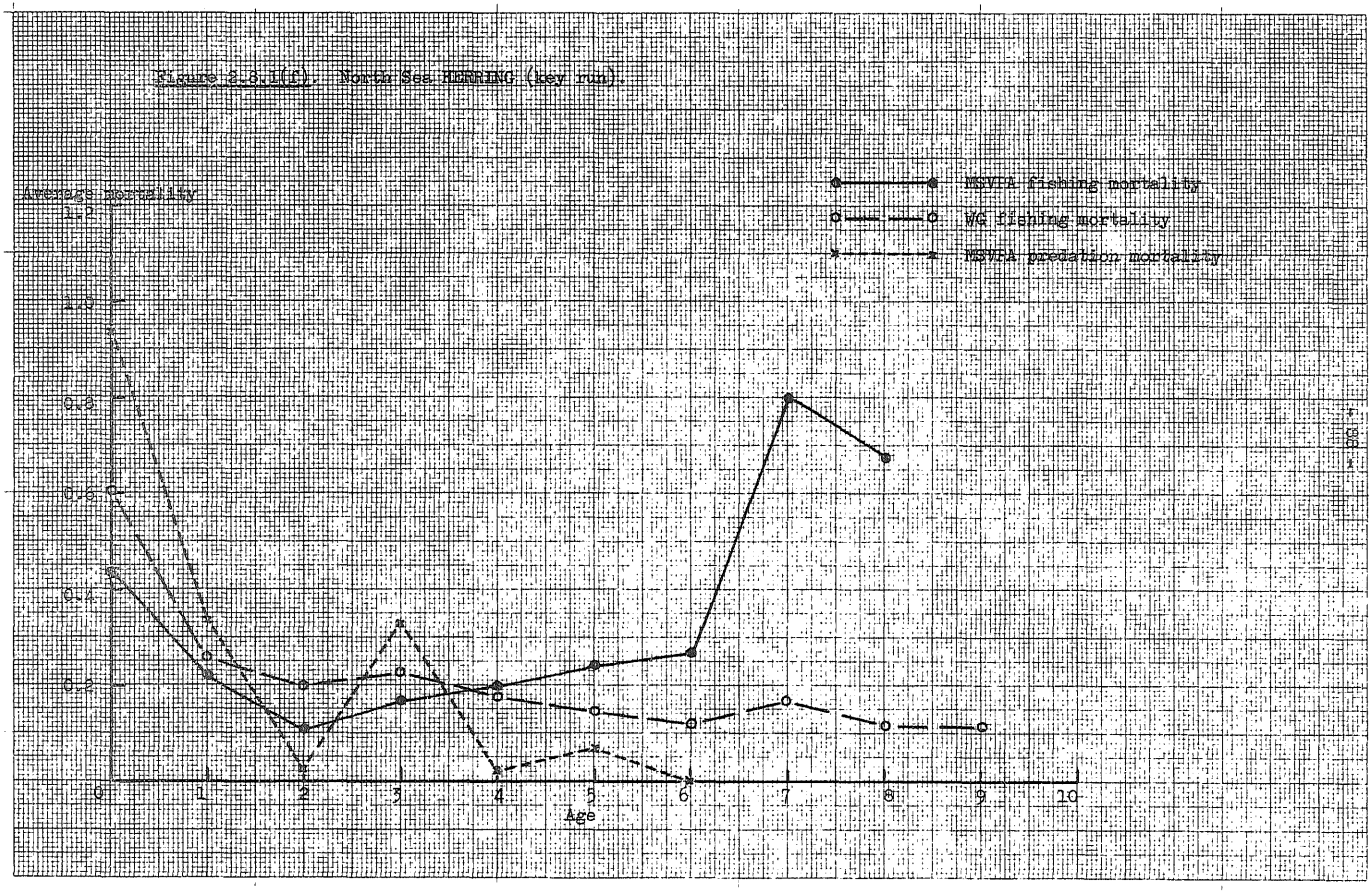


Figure 2.6.1(e). North Sea HADDOCK (key run).

Figure 2.8.1(f). North Sea HERRING (key run).



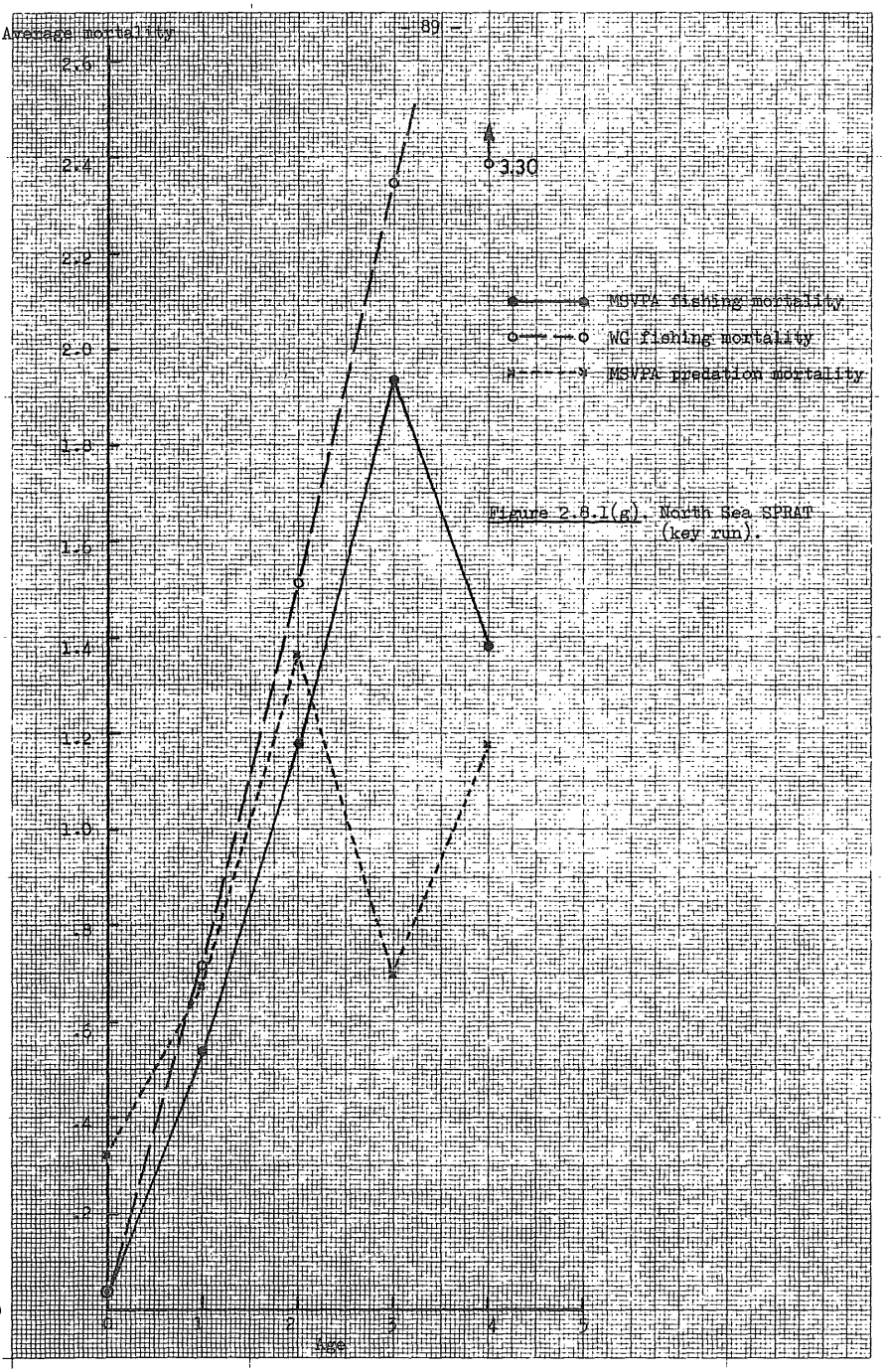


Figure 2.6.1(g). North Sea SPRAT (key run).

Figure 2.8.1(h). North Sea NORWAY POUT (key run).

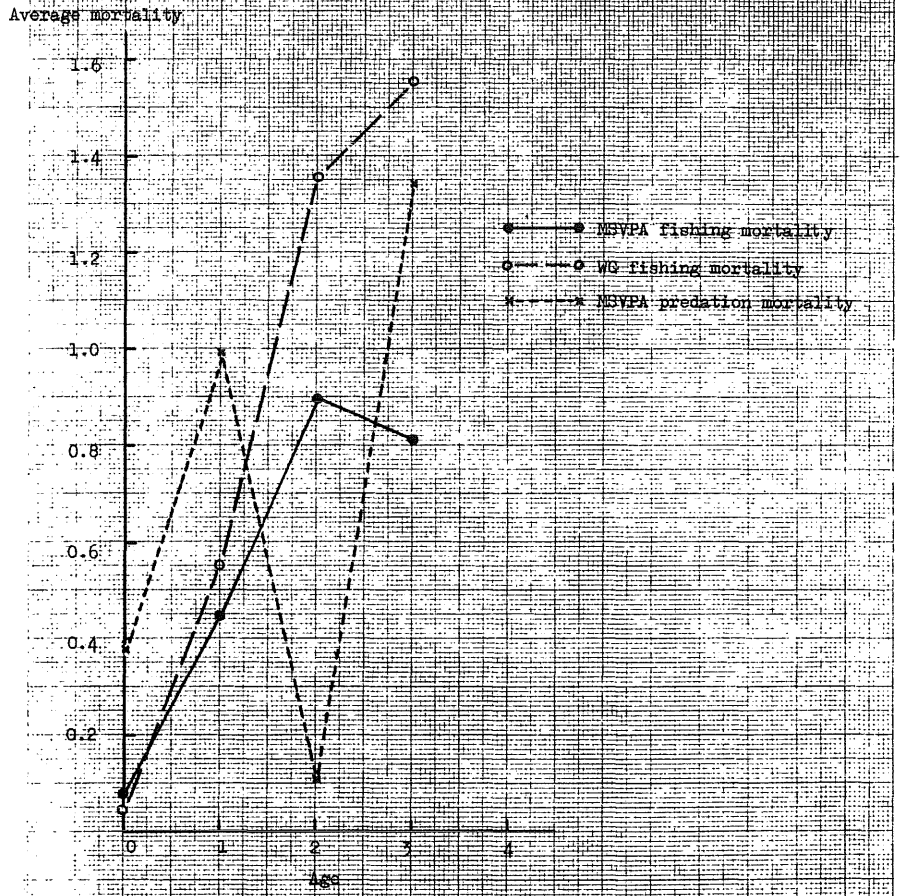


Figure 2.8.1(j). North Sea SANDEEL*) (key run).

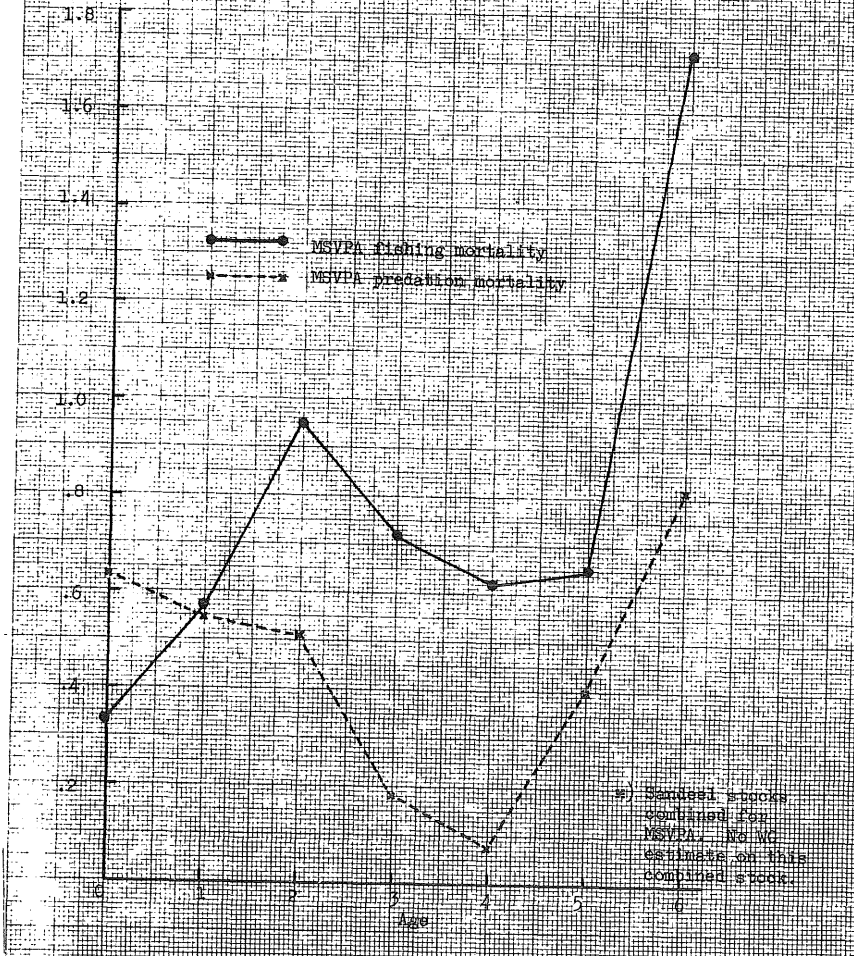
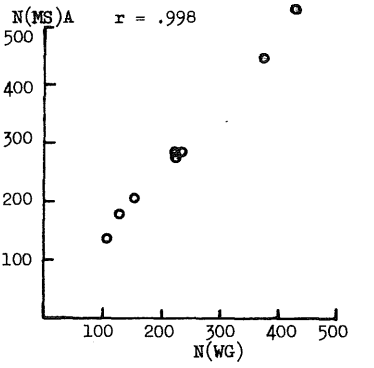
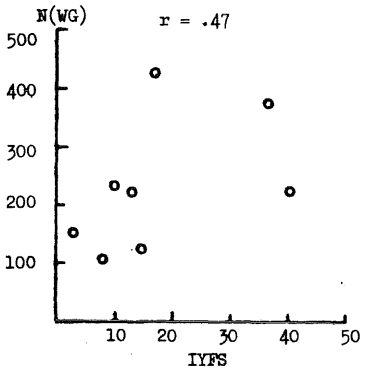


Figure 3.2.1. Relationship of multispecies VPA estimates of 1-year-old COD, Assessment Working Group VPA estimates of one-year-old cod and IYFS estimates.





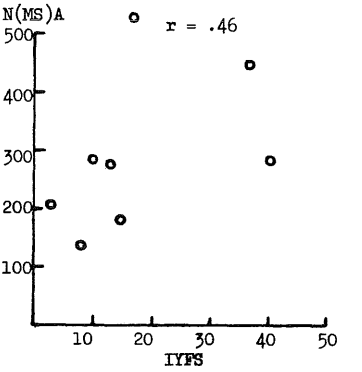
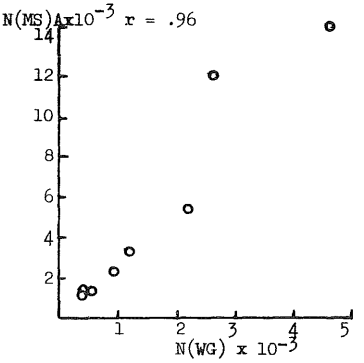
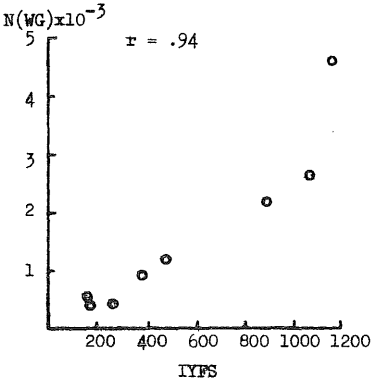


Figure 3.2.2. Relationship of multispecies VPA estimates of 1-year-old HADDOCK, Assessment Working Group VPA estimates of one-year-old haddock and IYFS estimates.





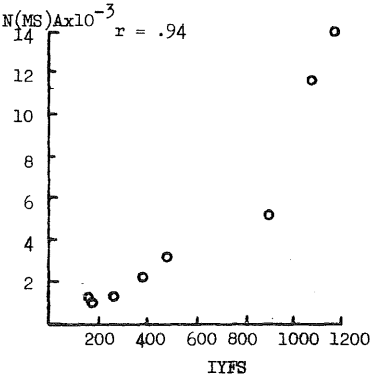
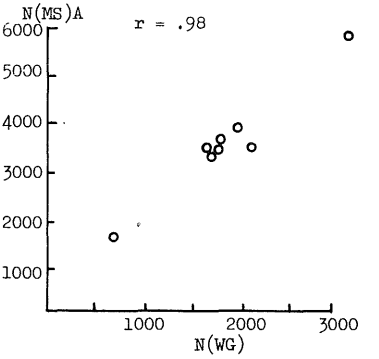
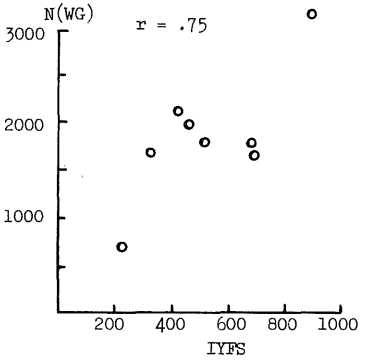


Figure 3.2.3. Relationship of multispecies VPA estimates of 1-year-old WHITING, Assessment Working Group VPA estimates of one-year-old whiting and IYFS estimates.





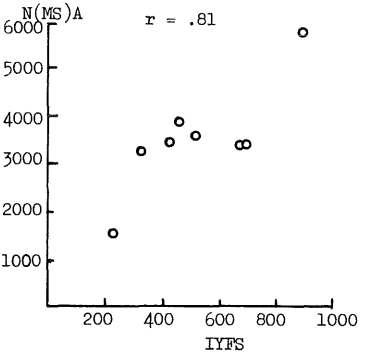
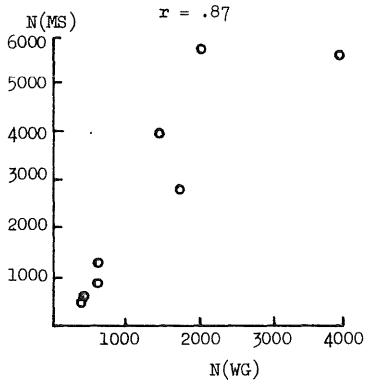
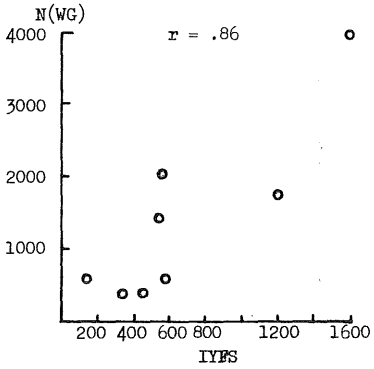


Figure 3.2.4. Relationship of multispecies VPA estimates of 1-year-old HERRING, Assessment Working Group VPA estimates of one-year-old herring and IYFS estimates.





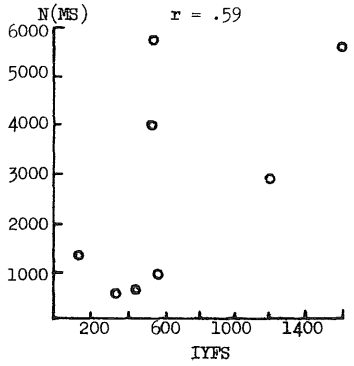
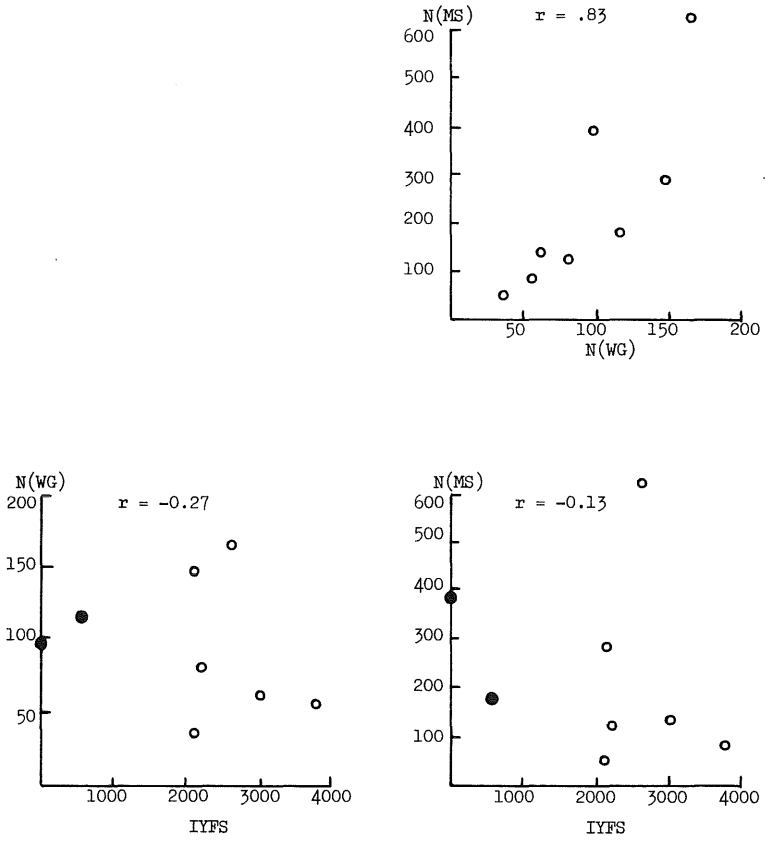


Figure 3.2.5. Relationship of multispecies VPA estimates of 1-year-old SPRAT, Assessment Working Group VPA estimates of one-year-old sprat and IYFS estimates.



● Abnormal years excluded from regression

Figure 3.2.6. Relationship of multispecies VPA estimates of 1-year-old SANDEEL and Assessment Working Group VPA estimates of one-year-old sandeel made by summing the northern and southern sandeel stocks.

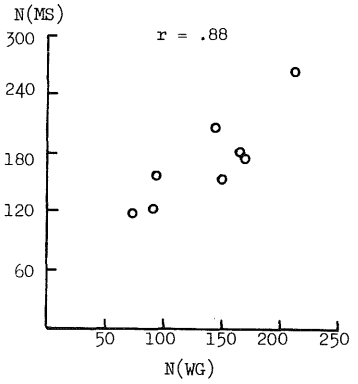


Figure 6.6.1. Graph of f_1 and f_2 example of uniqueness.

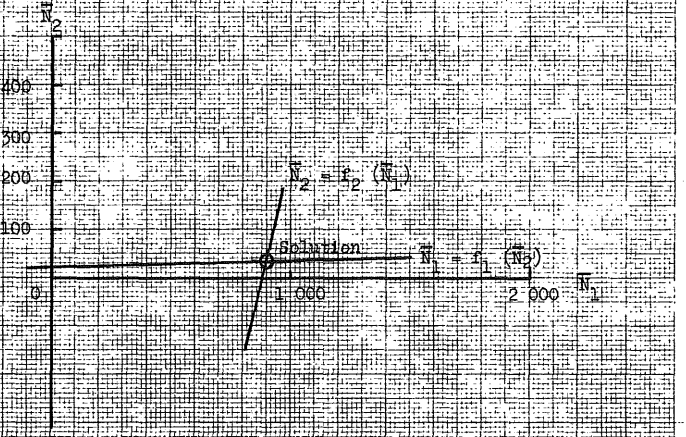


Figure 6.8.1. Illustration of Equation 6.8.4. (Note that length groups are converted into weight groups.)