

St. Hans' Østergade 14
1208 Copenhagen K
23 DEC 1995

**REPORT OF THE
MULTISPECIES ASSESSMENT WORKING GROUP**

Bergen, Norway
21-28 June 1995

This report is not to be quoted without prior consultation with the General Secretary. The document is a report of an expert group under the auspices of the International Council for the Exploration of the Sea and does not necessarily represent the views of the Council.

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Palægade 2-4 DK-1261 Copenhagen K Denmark

FRONTISPIECE

The Multispecies Assessment Working Group Songbook (Opus 1)

DRUNKEN SAILOR

What do you do with a drunken sailor?
(3x) - Earl-i in the morning?
(Chor. - Hoo-ray and up she rises (3x)
Earl-i in the morning.

Send him to ICES for a stock assessment. (3x)
Earl-i in the morning. (Chor.)

Send him to Bergen without a raincoat.
(3x) - Earl-i in the morning. (Chor.)

Put him in charge of the Grand Banks MULTSPEC
(3x)
Earl-i in the morning. (Chor.)

(J.P after traditional)

A WILD (ASSESSING) ROVER

I've been a wild rover for many a year
And I've spent all my money on whiskey and beer.
But now I'm returning with gold in great store.
And I promise to play the wild rover no more

(Chor>) -and it's no-nay-never
no-nay-never no more.
-and I'll play the wild rover
no never, no more.

Went right up to Bergen to meet with the crew.
Took forty-eight hours to decide what to do.
But now that we're sailing I'm held in a thrall.
Will Bormicon cod eat the capelin at all? (Chor.)

And MULTSPEC's a model that's bound to be best.
For no-one can think how to give it a test.
To estimate capelin when spawnings remote
So we use the old model instead of a boat. (Chor.)

And the Russians have come to offer their thoughts.
On digestion and growth and a model they've brought.
We'll all see it running in just a short while(r),
If Henrik can find us a FORTRAN compiler!

JOHN PEEL (Pope)

Do you ken John Pope with his VPA?
Do you ken John Pope's predators and prey?
Do you ken John Pope - it'll converge someday,
At F zero point one for the whole thing!

(Chor.)
For the Suits in the runs make the naughts grow bold.
But the M-twos make their futures cold.
Estimates of recruits are increased many fold.
But they ne'er see the light of the New Year.

Yes I ken John Pope and Henrik, too
Niels and the rest, the whole bloody crew,
From a stom' to a SUIT, from a SUIT to M2,
From M2 to cod growth in the model.

(Chor)

Section	Page
2.8.3.2 Concerns about the treatment of migration	24
2.8.3.3 Alternative approaches for modelling migration.....	25
2.8.4 Treatment of growth	25
3. DIRECTION TO ARCTIC FISHERIES WORKING GROUP AND THE ATLANTO-SCANDIAN HERRING, AND CAPELIN, WORKING GROUP	26
3.1 Background	26
3.2 Description of Multispecies Assessment problems	26
3.2.1 Arctic Fisheries Working Group	26
3.2.1.1 Growth of North-east Arctic cod.....	26
3.2.1.2 Cod cannibalism.....	26
3.2.1.3 Important issues not discussed by this Working Group	26
3.2.2 Atlanto-Scandian Herring, and Capelin Working Group	26
3.2.2.1 Norwegian spring spawning herring	26
3.2.2.1.1 Important issues not discussed by this Working Group.....	26
3.2.2.2 Barents Sea capelin	27
3.2.2.2.1 Input data used by the Working Group.....	27
3.2.2.2.2 Short-term prediction	27
3.2.2.2.3 Important issues not discussed by this Working Group.....	27
3.2.2.2.4 Multispecies processes highlighted.....	27
3.2.2.2.5 Past Management advice.....	27
3.2.2.3 Capelin in the Iceland, East-Greenland, Jan Mayen area.....	28
3.3 Advised methods for taking multispecies factors into consideration in the Arctic Fisheries Working Group and the Atlanto-Scandian Herring, Capelin and Blue Whiting Working Group.	28
3.3.1 Growth of cod for Arctic Fisheries Working Group.....	28
3.3.2 Advice on treatment of cannibalism of cod for the AFWorking Group	28
3.3.3 Advice on predation mortality levels on Herring	28
3.3.4 Barents Sea Capelin	28
3.3.5 Capelin in the Icelandic, Greenland, Jan Mayen Areas	29
3.3.6 Other multispecies interactions of relevance to these Working Groups	29
4. O-GROUP STUDIES AND SPATIAL EFFECTS IN THE NORTH SEA MSVPA.....	29
5. REVISION OF RATIONS IN NORTH SEA MSVPA	29
5.1 Problems with rations currently used in the model:	29
5.2 New experimental results to be used for the improvement of ration estimates.....	30
5.3 What improvement can be expected with regard to problems identified above?.....	30
5.4 What has to be prepared intersessionally?	30
6. NORTH SEA MSVPA.....	31
6.1 Revision of the 1991 North Sea stomach contents data	31
6.2 Comparison of results using old and revised stomach data for 1991	31
6.3 Remaining problems with the North Sea stomach contents data.	32
6.4 Summary and Recommendations.....	32
7. FUTURE OF MULTISPECIES ASSESS-MENT WORKING GROUP AND COMPREHENSIVE FISHERIES EVAL-UATION WORKING GROUP.....	33
7.1 Background	33
7.2 MSA Working Group Comments	33
8. SPATIAL DISAGGREGATION.....	34
9. THE FORM OF USEFUL MEDIUM TERM ADVICE.....	35
10. FOOD FOR THOUGHT.....	35
10.1 A method of estimating the natural mortality rates of fish at different ages (exemplified by North-East Arctic cod)	36
10.2 Smoothing Estimates of Yield from the Barents sea MSFOR	36

Section	Page
10.3 Notes on M2 as estimated in BORMICON.....	36
10.4 A Review of New Work and Ideas on Ration Size.....	37
11. CONCLUSIONS AND RECOMMENDATIONS.....	38
11.1 Conclusions.....	38
11.2 Recommendations.....	39
12. REFERENCES.....	40
Working Papers.....	42
Tables 2.2.1 - 10.2.1.....	43
Figures 2.2.1 - 10.3.4.....	103
Appendix 1.....	182

1. INTRODUCTION

The Multispecies Assessment Working Group met at the Institute of Marine Research, Bergen, Norway, from 21-28 June, 1995.

1.1 Participants

H. Björnsson	Iceland
B. Bogstad	Norway
T. Bulgakova	Russia
J. Collie	U.S.A.
A. Dolgov	Russia
H. Gislason	Denmark
S. Hall	UK - Scotland
K. Hauge (part-time)	Norway
J. Hislop	UK - Scotland
K. Korsbrekke	Norway
V. Korzhev	Russia
G. Lilly	Canada
E. Magnussen	The Faroes
K. Magnusson	Iceland
E. Nilssen (part-time)	Norway
O. Palsson	Iceland
J. Pope	UK - England and Wales
J. Rice (Chairman)	Canada
P. Shelton	Canada
D. Skagen	Norway
G. Steffansson	Iceland
H. Stefansson	Iceland
K. Sunnanå (part-time)	Norway
A. Temming	Germany
S. Tjelmeland	Norway
V. Tretyak	Russia
D. Vasilyev	Russia
N. Yaragina	Russia

1.2 Terms of Reference

The Terms of Reference (C.Res.1994/2:6:6) for the meeting were:

- a) continue the development of multispecies models of assessment, paying special attention to their application to boreal ecosystems and incorporating variable predator growth and spatial overlap of predators and prey;
- b) provide direction to the Arctic Fisheries Working Group and the Atlanto-Scandian Herring, Capelin, and Blue Whiting Working Group with regard to approaches and means of assessing impacts of predators on the stocks assessed by those groups, including, where possible, estimates of predation mortality and amounts eaten, and/or specific analytical approaches by which those Working Groups should produce such estimates;

- c) review and extend intersessional work on data analysis and modelling of predation processes on 0-group fish;
- d) review and extend intersessional work on comparisons of the northern and southern parts of the North Sea, with special reference to relating survey data to MSVPA results, and plan for a detailed treatment of this matter at the 1996 meeting;
- e) conduct the necessary planning for a thorough review of food rations in MSVPA, to be conducted at the 1996 meeting of the Working Group;
- f) evaluate the status of data required for the North Sea MSVPA and, if appropriate, carry out a key run.

In addition, the Working Group addressed several items raised in the reports of the ACFM meetings in September 1994 (Minutes - ACFM Consultations 21-24 September 1994) and May 1995 (Draft Minutes - ACFM Meeting 16-24 May 1995), and directed towards all Working Groups, or methodological Working Groups in particular. These topics included:

- g) Establishment of a Comprehensive Assessments Working Group, and the fate of the Multispecies Assessment Working Group;
- h) The nature and form of useful medium-term advice;
- i) The efficient use of time at Working Group meetings.

1.3 Overview

The main section of this Working Group report is Section 2, covering our testing of multispecies models of boreal systems. The first subsection waxes philosophical about the testing of models as an activity separate from the models themselves. It explains why the Working Group tried to perform both performance tests and sensitivity tests on each boreal model. It was impossible to apply identical, or even closely comparable, performance tests to all three models. Sensitivity tests were easier to apply, but only a small number of the many possible ones were investigated at the meeting. Where possible, sensitivity tests addressed how spatial structure was handled in the models.

The next three subsections present the three boreal models which were tested: MULTSPEC, BORMICON, and MSVPA. Each subsection is structured in the same way; a description of the model and the data used in parameterization, a descriptions of the exact tests preformed on each model, and the results of each test.

MULTSPEC is a forward simulation model, developed at IMR in Bergen, Norway. Modules of MULTSPEC can simulate many types of multispecies interactions in the Barents Sea, from primary production to marine

mammals. However, the Working Group only considered the components which model cod and capelin interactions. Features modeled include capelin maturation, predation processes, migration of both species, and cod growth.

The performance test was to simulate cod growth over the past 15 years. Sensitivity tests included investigating effects of scaling capelin biomass, basic meal size of cod, collapsing spatial resolution down to a single area, allowing cod to obtain a constant ration, use of a constant migration pattern through the entire simulation, and adding fixed age dependence to feeding suitabilities of cod as predator and maturation of capelin.

In the performance test to model cod growth, estimated cod growth increments tracked capelin abundance in the model reasonably well. However, in the model the pattern of capelin in cod diet is consistently 1-2 years ahead of the pattern of capelin in the acoustic surveys. In the sensitivity tests, rescaling capelin had a direct effect on capelin biomass, but few noticeable effects on cod. All the sensitivity tests involving simplifications of MULTSPEC led to much poorer fits to the parameterization data. In general simpler models had buffering effects on model dynamics. However, results were with the constant migration simplification particularly encouraging.

BORMICON is a forward simulation model of cod - capelin interactions, being developed at MRI in Reykjavik, Iceland. It does not simulate dynamics of other parts of the ecosystem, but contains substantial spatial structure and great flexibility in time steps. Model parameters are estimated by fitting a likelihood function to cod numbers at age and capelin numbers, for succeeding years after 1985. Processes simulated include migration, maturation, growth of mature cod, predation of cod on cod and capelin, and fishing (either as direct removals or as predation by a fleet).

Three evaluation runs were made; a base run with initial conditions set according to the Planning Group specifications, and two sensitivity tests. One was a run with 33 parameters estimated simultaneously; the other a run with the 16 base area subdivisions combined into three areas. As a performance test, the estimated size at age of cod was compared to survey size at age.

Results of the base run and both sensitivity tests were encouraging, with many similarities. Understocking of capelin seems a problem, and capelin is underrepresented in cod diets. Estimates of cod size at age showed the proper patterns over time, but with scaling problems at extreme values.

A version of MSVPA and MSFOR for the Barents Sea was developed in VNIRO, Moscow, Russia. The major modification from the ICES version of MSVPA is allowing year- and quarter-dependent weights at age and

natural mortality, which accommodates the large post-spawning mortality of capelin. The model was run including cod, capelin, herring, and shrimp. Terminal F's in the fourth quarter were tuned.

A retrospective base run was examined to assess the reasonableness of the model results. Estimates of prey populations were generally larger than from SSVPA's or surveys, reflecting the substantial predation mortality captured in MSVPA. Short-term forecasts were also reasonable. The base run and base forecast highlight the need for improvements in the tuning methods.

Sensitivity tests included: comparing runs with M1 constant or varying across quarters, and conducting various long-term forecasts from different starting conditions or assuming different events in the fisheries. Performance tests included: comparing MSVPA estimates of capelin consumption with direct estimates from cod biomass and ration estimates, comparing MSVPA estimates of cod recruits to survey estimates, and splitting the time series of cod stomach data and using each half to predict diet in the other half.

The sensitivity tests indicate that it is important to use M1 values which vary by quarter. Long-term forecasts with a 10% reduction in fishing mortality indicate a number of differences from long-term forecasts with baseline conditions. These generally can be traced directly to predation effects of cod on the species, including substantial cannibalism of older cod on pre-recruits. From the performance tests, the ability to predict stomach contents was good in most quarters, but poor in the fourth quarter, suggesting that important spatial effects are not captured in the present Barents Sea MSVPA. The tests predicting cod recruitment from MSVPA diets showed that MSVPA captured the temporal trends very well, but there are scaling problems which must be explored. Predictions using parts of the stomach contents data again captured temporal trends very well, but showed scaling differences between a period of high capelin abundance and a period of low capelin abundance. The patterns in the results suggest there may be prey switching by Barents Sea cod.

A following subsection contrasts the results. All three models performed very well at some tasks, and less well at others. The performance differences reflected the different purposes for which each model was developed, and differences in the model components for which good parameterization data were available. Because of these differences, the models were not, and should not be, ranked on any global scale. Each of the three models was considered to be in the developmental stage by its developers, and not ready for routine assessment applications. The Working Group concluded that all three models showed significant promise and warrant continued work. In fact, all three models performed better than the subjective expectations of the Working Group members, and refuted a number of preconceptions

developed during past Working Group meetings. The Working Group as a body also gained important experience testing large and complex assessment models; experience which may be of great value to ICES as it undertakes comprehensive assessments, and is called upon to provide advice on increasingly complex problems.

Several future directions for boreal models were identified. Parameterization and tuning of these models requires more systematic attention. Recruitment of cod may be more tractable within a multispecies predator-prey assessment framework than within a SSVPA - tuning survey framework. Prey switching may be a more tractable problem in boreal systems than in the North Sea.

Three other multispecies modelling approaches were applied to the Barents Sea system. One was a direct estimation of natural mortality rates from stomach survey data, to be used as input to a SSVPA. The others were extensions of the smoothing of suitabilities and partial M2's, as explored in previous Working Group meetings. The direct estimation method showed promising results, but application was hampered by sparse sampling data for some cod sizes and quarters. Smoothing MSVPA suitabilities by fitting the basic predator and prey species terms, and the curvilinear log weight ratio terms was improved by addition of interaction terms with quarter, prey species and prey age. Parameter estimates were consistent and reasonable. The results indicated that Barents Sea cod have a higher size preference ratio (i.e. for a given size of predator, prefer a smaller prey) than North Sea cod, and accept a wider size range of prey at each predator size. The smoothed UM2 analyses are consistent with the smoothed suitability analyses, both with regard to the importance of interactions in fitting the raw estimates (in this case, interactions of prey species with prey age), and with regard to the large size preference ratio and wide feeding spectrum at size for cod.

The Boreal multispecies modelling section concludes with a review of emergent concerns from the work completed at this meeting. Concerns include the need to design models which are testable, the need for focused attention to parameter estimation in multispecies models, alternative treatments of migration in these models, and the treatment of growth in the models.

The next section of the Working Group report contains advice to the Arctic Fisheries Working Group (AF) and the Atlanto-Scandian Herring, Capelin, and Blue Whiting Working Group, in response to a request from ACFM to advise "with regard to approaches and means of assessing impacts of predators on the stocks assessed by those groups".

The Working Group concluded that the current multispecies models have not been developed fully

enough to be used as a basis for provision of quantitative advice. Rather, the MSA Working Group had members of each area/species Working Group prepare a summary of the key multispecies problems faced by each Working Group. These problems were then addressed on a case by case basis. The MSA Working Group recommended specific analytical methods to be applied by each Working Group, as it addresses the specific problems during the Working Group meetings. Direction was provided on four specific problems: annual growth of cod assessed by the AF Working Group; estimates of cannibalism for cod assessed by the AF Working Group; predation mortality estimates of Barents Sea capelin; and improving estimates of Iceland - East-Greenland - Jan Mayan capelin. Because the Working Group did not review results of herring predation levels in the Barents Sea, it could not advise on methods to improve estimates of natural mortality in Barents Sea herring. The MSA Working Group also noted a number of multispecies problems which it understands are not currently addressed formally by the other Working Groups, but which may be important in the assessments conducted by those Working Groups.

The MSA Working Group reports very little intersessional progress on estimating of predation by 0-group predators, or investigating spatial effects in the North Sea multispecies assessments.

Section 5 of the report addresses the use of ration estimates in the North Sea MSVPA. These estimates have not been reviewed for 10 years. The Working Group Report lists a number of problems with the values currently used, generally arising from the very limited data available when the values were set. The report reviews the number of new experiments and analyses conducted during the past decade, covering almost all MSVPA predators. The Section summarizes the improvements in model performance which are to be expected if these new studies are incorporated in the ration estimates for the North Sea MSVPA, and specifies the intersessional work which needs to be done if ration estimates are to be revised at the next meeting to make a "definitive" MSVPA run for the North Sea.

Section 6 of the Report presents another set of North Sea MSVPA runs, using the 1991 stomach data. Since the last meeting of this Working Group, many improvements were made to the databases from the 1991 stomach sampling project, and in the process a number of errors in the databases were corrected. The Working Group could not redo all the tests of stomach data from the last meeting, but did want to determine the extent to which the conclusions drawn at the last meeting are altered by the improved databases.

Contrasting MSVPA results with the old and the new 1991 stomach data, the differences are small, leading to at most a few percent change in the estimates of prey eaten, and to even smaller changes in the biomass

estimates. There are some larger differences in the detailed diet composition of the individual predators. When suitability estimates from the two data sets are contrasted, only a few of the thousands of suitabilities change much. The last Working Group Report gave great attention to the differences in suitabilities using the 1981 and the 1991 stomach data sets. When the same differences are examined using the new 1991 stomach data, cod and haddock are in better agreement, although whiting are more different. The overall conclusion from these analyses is that the conclusions contained in the previous report are still valid.

This section concludes with a review of several remaining problems with the stomach database (both 1981 and 1991). The problems must be resolved before a "definitive" North Sea MSVPA key run can be made. One more meeting of the coordinators of the 1991 stomach sampling project should allow most of the problems to be settled, and is recommended strongly by the Working Group.

In Section 8, the MSA Working Group addresses several concerns raised by the North Sea Demersal Fish Working Group (DF), in response to its request for catch data disaggregated by statistical area and quarter. The MSA Working Group concurs with the DF Working Group, and highlights the point that there would be many users of such a database if it existed. The MSA Working Group also stresses the difficulties presented by the current situation, where collectors of diverse types of biological and physical data on the North Sea use many different spatial divisions. Merging of data sets for integrated analyses often entail complex and time-consuming conversions of spatial structures. The MSA Working Group draws two strong recommendations from this discussion. One is that ACFM support the workshop on spatial disaggregation proposed by the DFWSG. The other is that all Working Groups dealing with catch data from the North Sea (and other areas where multispecies assessments may be desired) report the catches by quarter, regardless of what level of spatial disaggregation is used. If not, MSVPA (and related assessment tools) cannot be applied for multispecies assessments.

In Section 9, the MSA Working Group reports its deliberations on the request from ACFM to assessment Working Groups to comment on the form of useful medium-term advice. Multispecies assessments are relevant in medium-term advice in several ways, mediated by variation in predation mortality and meeting ration requirements. The specific ways are presented and discussed in the report. It is premature to advise specific methods for including these effects in medium term advice, however. Further work on multispecies assessment methods, including further developments of MSVPA, needs to raise the statistical rigour of model operations and predictions. Only then will ICES be in a

position to include multispecies effects analytically in risk assessment and scientific advice.

The Food-for-Thought Section includes four subsections this year. The first describes an analytical method for estimating age-specific natural mortality rates from age-structured population data. The second subsection reports on efforts to fit an overall yield surface to the Barents Sea MSFOR results. This work is a continuation of the Working Group's past exploratory work on fitting similar surfaces to the North Sea. Preliminary multispecies yield curves are presented and interpreted. The third subsection explores further the M2 results from BORMICON. M2 of capelin turns out to be scenario-dependent and, depending on details of scenario parameterizations, M2 of capelin may or may not be related to cod biomass. Further direction for work on the issue is suggested.

The final subsection is an extensive review of the recent literature on estimation of predator ration. Developments addressed include methods for estimating gastric evacuation, initial meal size, sequential meals, species and temperature effects, and the handling of uncertainty in these calculations. Several equations are presented which begin a foundation for possible revision of the ration values used in the North Sea MSVPA.

The last section of the Report includes a listing of the 13 major conclusions and the 8 specific recommendations arising from the Working Group analyses and discussions.

1.4 Acknowledgements

The Working Group acknowledges the considerable support provided by the staff at the Institute of Marine Resources. The excellent provision of meeting and workspace, and of computer facilities and support, allowed the Working Group to work efficiently. The hospitality arrangements were also exceptional, enabling the meeting participants to have a memorable 10 days socially, as well as scientifically. Many of the staff at IMR deserve thanks, but special acknowledgement is given to the Research Director, Division of Marine Resources, for his interest, involvement, and support, and to Sigurd Tjelmeland and Jaime Alvarez for attending to countless details of local arrangements.

The Working Group gratefully acknowledges the work of the Planning Group on Boreal Multispecies Assessments (Anon. 1995). Without the excellent foundation laid through their efforts, the Working Group would have made far less progress on its evaluation of multispecies assessment models of boreal systems. Again, many individuals deserve credit for the work of the Planning Group, but special recognition should be given to its Chairman, Kjarten Magnusson, for his hard work and leadership in setting high scientific standards.

2. BOREAL MODELS

The core activity of the Working Group was to examine and test three different models of boreal fisheries systems. The three models were developed independently, and differed in structure and primary foci. The outputs of each model provided information of value in both the assessment and general fisheries ecology framework. None of the three models were in final state, but all three were developed fully enough for both sensitivity and performance testing. The preparatory work for this modelling had been carried out by the Planning Group on Multispecies Assessment of Boreal Systems at its meeting in February 1995 (Anon. 1995c).

2.1 Overview and Purpose of Tests

An evaluation of the performance of models depends of course on what the model is designed to do. A vague initial definition of satisfactory performance is that the model should be able to behave in a manner which is sufficiently similar to the behaviour of that part of the "real world" which the model is supposed to mimic. For BOREAL models a necessary requirement might be that modelled cod consumption and diet, cod growth and migration of capelin and cod are sufficiently similar to observations of those variables. "Sufficiently similar" remains to be defined. An adequate representation of a more limited set of variables, e.g. estimating predation mortalities of cod on capelin, is also a legitimate requirement.

It is important to realize that it must be possible to disprove a model, i.e. demonstrate that it can't adequately represent "reality". If the model can never fail, i.e. parameters values can be altered to accommodate any kind of observations, or the predicted output can't be compared to observations, then the value of the model is questionable. In this context some thought should be given to what would constitute model failure.

Two kinds of tests are considered useful for multispecies models, performance tests and sensitivity tests. In performance tests simulated output from the model is compared to observations of the real world. Goodness of fit provides one performance test but a more revealing test is to see how well the model explains data not used in the fitting of the model. This can either be data of a type not used at all in the likelihood function or a part of a time series of data where the other part has been used in the likelihood function. A rigorous performance test is to include all types of relevant data in the likelihood function and to fit the model to part of the time series and examine how well the model predicts the remainder (or the future). Such performance tests are an essential part of the development of models.

In large multispecies models most of the data are often used in fitting the model, leaving rather limited independent information, particularly sample data with

sufficiently low measurement error, for use in performance tests. In past meetings of the MSA Working Group (Anon. 1991, 1992) the empirical data on cod growth and on cod stomach contents from several Boreal systems have been subject to detailed analysis. It would be logical to use these databases with which the Working Group is already familiar in performance tests.

In MSVPA cod growth is not modelled so this comparison is not possible. In MULTSPEC the primary focus is on estimating capelin mortality, however cod growth rate in terms of both length and weight is calculated from the estimate of feeding level, the parameters of which are estimated from the cod stomach content data, and from the ambient temperature. In the case of BORMICON, cod growth is calculated from consumption, based on a standard bioenergetic model that takes into account the ambient temperature and the energy cost of swimming. Although empirical data on length and weight at age are not used at present in the likelihood function for BORMICON, the model is to some extent tuned to match observed cod growth.

With respect to cod stomach content data, the performance of MSVPA can be compared using the same approach as that adopted at the last MSA Working Group meeting (Anon 1994) in the application to the North Sea. Predicted proportions of prey in the diet based on estimated suitabilities can be compared directly with the observed diet for one or more years data that are not included in the model fit. A similar comparison can also be carried out for MULTSPEC and BORMICON. However, to compare model estimates of total consumption with stomach content data requires converting the stomach content data into consumption using a digestion model.

Stomach content data are not currently used in the likelihood function for BORMICON so that comparison of modelled diet with that derived from the empirical data constitutes a potentially powerful evaluation of model performance. In the case of MULTSPEC, stomach content data are included in the likelihood in order to estimate parameters in the feeding function and capelin migration rates. A comparison with the empirical stomach data will provide information on goodness of fit but won't constitute an independent test of model performance.

Some consideration was given to the value of a form of performance tests in which the output of the model is compared with empirical data with respect to whether or not relationships such as spawner stock-recruitment are rendered more coherent in the model estimates than in the raw data. For example, recruitment estimated in an MSVPA may be more coherent with respect to spawner biomass than recruitment estimated from a single species VPA. A problem in this regard with respect to capelin in Boreal systems is the expectation that the stock-recruit

relationship is likely to be quite variable as a consequence of process error.

A potentially useful performance test is to compare modelled 0-group abundance with observed 0-group abundance. This may be particularly useful with respect to cod cannibalism but would require 0-group surveys with reasonably small measurement error. 0-group survey indices may, however, also be used in the likelihood function (BORMICON).

In sensitivity tests the effect on the model output of varying functional relationships and their parameter values are examined by comparing the output with the output from a base run of the model. As a form of sensitivity test, the robustness of the model can be examined with respect to extreme conditions to determine at what stage the model fails to provide realistic output. A further robustness test would be to replace functional relationships with other, quite different, functional relationships and to compare the output with the base run.

A complete set of sensitivity trials is unfeasible. The large number of functional relationships and parameter values makes a full test of the sensitivity of the model very arduous, particularly if the relationships are non-linear and the parameters are correlated, as is the case in most multispecies models.

The sensitivity of the models to changes in suitabilities should be tested. However, the Working Group did not feature such tests at this meeting. In MULTSPEC and the base application of BORMICON, area structure and the migration parameters influence the realized suitability of the prey to the predator, so it would be inappropriate to adjust only the values of suitabilities. However, varying the area structure or the migration matrix, or alternatively applying a constant migration matrix throughout the whole time period, would constitute a further potentially useful test.

In discussion of sensitivity tests it was suggested that the potential use of the models by the assessment Working Groups should be borne in mind. In this respect, having found that a model is sensitive to a particular functional relationship or parameter value, it is important to ask the question "does it matter?" from the point of view of the model as a tool in the hands of an assessment Working Group.

A form of sensitivity analysis that was considered relevant in this context is to what extent simpler (more aggregated) forms of the model give results that depart substantially from the predictions of the base model. This could form a robustness test to see at what stage of aggregation the model falls apart.

An important use of complex and detailed simulation models is as test beds for simpler models. The

simulation models can be used to generate the data such that the performance of simpler models can be tested under a wide variety of hypothetical situations and their robustness investigated. In this way it becomes possible to locate the boundaries where the simpler estimation models break down and thus get some idea of the range where these models are valid and useful. It may eventually turn out that this is the most important use of highly elaborate simulation models like MULTSPEC and BORMICON.

Finally, it should be noted that the tests developed in the course of the meeting were restricted to those considered feasible within the time frame allowed. They certainly do not comprise a full evaluation of the model nor do they necessarily constitute the most important tests of the models. Further, some tests are not possible irrespective of the time frame allowed, because of the way the models have been constructed. For example, in BORMICON it is not possible to examine the effect of aggregating the 16 areas into a single area. A more complete summary of the types of tests which would be informative, and often more directly comparable among models, is tabulated in Appendix I.

2.2 MULTSPEC

2.2.1 Overview of MULTSPEC

MULTSPEC is a forward simulation model designed to address important management issues for the Barents Sea. Among the problems which can be investigated with MULTSPEC are determining the size of the spawning stock of capelin and variability in growth of cod related to food abundance and temperature. The present meeting focused on these two aspects by studying simulation runs and estimations over the historic period. Other aspects of the model were not dealt with. MULTSPEC was developed at IMR, Bergen. It is a multispecies model for the Barents Sea, where the stocks are divided on area, age, sex and - except for mammals - on length. The stocks modelled are minke whale, harp seal, cod, capelin and herring. Migration is modelled using transition matrices between 7 areas (shown in Figure 2.2.1). Used over an historical period, rather than in a forward simulation mode, the catch at age and length is subtracted from the simulated stocks each month.

The version of the model used at the meeting as well as the input data are stored at IMR and are available upon request. The input data and outputs from the reference run are stored in the archive from the meeting, available through anonymous ftp to kirkenes.imr.no on directory pub-incoming MSA Working Group 95 Multspec-Archive.

2.2.2 Input data

The input data for the capelin stock are acoustic estimates obtained in September-October each year, where 5-6 Russian and Norwegian vessels participate in a coordinated survey. For cod, starting numbers at age are taken from the single species VPA conducted by the Arctic Fisheries Working Group (Anon 1995a). The area distribution of cod is calculated from Norwegian survey data. For all capelin fisheries the total catch in age and length by area and month is used. The Russian catch is partitioned by length using age-length keys from Norwegian data. For cod the total catch by area, age and month is used.

2.2.3 Processes and simulation

In the MULTSPEC model predation of cod on capelin is modelled using a type II feeding relationship:

$$\text{feeding level} = \text{food abundance} / (\text{feeding level half value} + \text{food abundance})$$

and the maximum consumption for each individual as:

$$\text{maximum consumption parameter} * \text{Exp}(0.104 * T - 0.000112 * T^{**3} - 1.5) * W^{**0.802}.$$

Here, T is temperature and W individual weight. The geographical variation of temperature is taken from a climatological model that is scaled according to the annual variation in the temperature at the Kola section.

The functional relationship and the temperature and weight dependent parameters follow Jobling (1988).

The growth is modelled as a function of the feeding level and the temperature:

$$\text{growth in weight} = C_8 - W^C_9 \cdot (f - C_{10}) \cdot (C_{11} \cdot T + C_{12})$$

$$\text{growth in length} = C_4 \cdot W^C_5 \cdot f \cdot (C_6 \cdot T + C_7)$$

where the Cs are parameters, f is the feeding level and T temperature. The time step is one month.

The modelling of minke whale and harp seal was not considered by the meeting.

The MULTSPEC model has been used to study the subsystem mature capelin - cod, in which the processes of maturation of capelin, migration of mature capelin, growth of immature capelin during the winter, catch of capelin and predation by cod on mature capelin are modelled. The maturation parameters (length at 50% maturity, steepness of maturation function) have been estimated using acoustic abundance data from the September survey and catch data, where it is assumed that all fish die after spawning. The growth of mature capelin is estimated using data on weight at age in the catches in January-April. The predation parameters (half value and maximum consumption) and a reduced set of

migration matrix elements are estimated by comparing the consumption calculated from the stomach data with the consumption calculated by the model, for each data cell (area/year/month combination) using maximum likelihood. The migration parameters vary by year. Figure 2.2.2 shows the modeled consumption vs. the consumption calculated from the stomach data for the data cells (year-month-area) used for estimating parameters.

The values obtained for half value and maximum consumption can be used to predict the consumption of capelin by cod. The parameter estimation is described in more detail in WP 2. The spawning stock calculated for each of the years in the estimation can be used together with the observed recruitment to investigate which level of capelin spawning stock size one should aim at. Capelin management is described more fully in Tjelmeland and Bogstad (1993), where the estimation of maturation parameters for capelin is also described, and in Section 2.2.5. Bogstad *et al.* (1995) performed long-term (20 years) simulations using MULTSPEC with all the 5 model species included, and confirmed that the model behaves reasonably and is able to produce the type of stock size fluctuations which have been observed.

2.2.4 Evaluation runs - description

At the Planning Group meeting, a number of performance and sensitivity tests were suggested. Some of these had been performed prior to the meeting (WP 1), while some other tests were suggested at this Working Group meeting.

Growth of cod

Cod growth in the Barents Sea is highly variable, and the variability is important in the management of cod (see Section 3.2.1.1). Therefore it was decided to evaluate how well MULTSPEC could simulate the observed variability in growth. This is a performance test, in that the model was asked to simulate data which were not used in parameterization of the model.

Scaling of the capelin stock

In order for the model to account for both fishing and predation in each area and in each month during the estimation period January-March, it was necessary to use a penalty function on outfishing (simulated harvest plus predation losses exceeding simulated stock size) to force capelin into certain areas. This model approach can be contrasted to an alternate approach, where the number of capelin from the acoustic survey is multiplied by a constant factor before the simulation starts, and if the parameter values change. This can be viewed as a sensitivity test of the model to the scaling of capelin abundance relative to other species in the model.

Change of the initial meal size to mean meal size ratio

The reference run uses a ratio of 1.0, i.e. continuous feeding is assumed. In view of the considerable amount of empty stomachs regularly found, the model was tested also for a ratio of 1.5, to examine the sensitivity of outputs to assumptions about feeding rate or ration size. See Section 10.4 for a discussion of the initial meal size to mean stomach content ratio problem.

No area division

The area division adds to the model's complexity, and makes it difficult and cumbersome to estimate the predation parameters. An estimation of predation parameters where only one area is used for the mature capelin during January-March reveals how much is lost in terms of accuracy of the estimated spawning stock when the area division is not used. It is a sensitivity test of spatial structure, posing the extreme case of no spatial dynamics.

Constant ration

Setting the feeding level half value to zero will show how much accuracy is lost by reducing the number of predation parameters. This is also a sensitivity test of the model to feeding parameters. Again, it is a test of the model at an extreme parameter value.

Constant migration pattern

The estimation in the reference run is carried out by estimating migration parameters in each year and for each value of the predation parameters. This adds to complexity and it was decided to investigate the effect of using one set of migration parameters throughout the whole period. This is another sensitivity test, with regard to the model's behaviour under different spatial distributions of fish. In contrast to the "No Area Division" however, in this case the number of areas stays at its base value, but movement among areas is altered.

Suitability by age

The suitabilities in MULTSPEC are functions of length of the predator and the length of the prey. It was decided to test the sensitivity of the spawning stock biomass of capelin to different formulations of suitability. In the case examined cod aged 2 years and younger did not eat capelin and cod aged 3 year and older had a constant suitability of 1.

Age-dependent (not length-dependent) maturation of capelin

In the MSVPA model for the Barents Sea a constant maturation by age was used (WP 5). To test for the sensitivity of MULTSPEC outputs to this formulation of maturation, runs were made with length-dependent

maturation. The parameters of the maturity ogive for each year in the simulation were estimated within MULTSPEC.

2.2.5 Evaluation runs - results

2.2.5.1 Cod growth

Figure 2.2.3 shows the cod growth (weight increment through the year for age 2-6), capelin abundance as measured by the acoustic survey in the autumn, and amount of capelin consumed during the year (calculated as in Bogstad and Mehl (1992) but using the evacuation rate model given by dos Santos and Jobling (in press)) divided by cod biomass at the start of the year. The figure shows that the variability in cod growth is closely related to the variability in capelin consumed per cod biomass, for all the cod age groups 2-6. However, the increase in capelin abundance as measured by the survey does not occur until 1-2 years after the increase in cod growth and capelin consumed. A possible explanation of this is that the first good year classes of capelin are grazed down before they show up in the surveys. This implies that if cod growth variability is modelled only by capelin abundance, there will be a time lag between the variability in the data and in the model results.

Using the parameter values for maximum consumption, half value and other food from the baseline run described in WP no. 1, we ran MULTSPEC from 1983 to 1994, with cod as the only predator and capelin as the only prey. The number, length and weight of each stock by age and area was reset annually, using a value taken from the surveys. We then compared the calculated length of a cod cohort at the end of each year simulated (Figure 2.2.4:text Modeled 1) using MULTSPEC, with the length and weight of the same cohort at January 1 the next year as used by MULTSPEC as input data. We also attempted to test the effect of not updating the cod length and weight at age annually for cod age 3 and older in the simulation (Figure 2.2.4:text: Modeled 2). The results of these comparisons are given in Figure 2.2.4. In general, the model produces growth variation which is in reasonably good agreement with the observed data, when considering the time lag between capelin survey abundance changes and cod growth changes which was commented on above.

2.2.5.2 Scaling of the capelin stock and change of initial meal size to mean stomach content ratio

Either increasing the capelin stock by a constant factor or increasing the initial stomach content to mean stomach content ratio yielded greater spawning stock biomass for capelin. In turn, the larger capelin spawning biomass meant there were fewer problems with the model not being able to account for both consumption on capelin and the capelin fishery in some areas. Table 2.2.1 shows the results obtained when both the capelin stock and the

initial meal size to mean stomach content ratio are increased by 50% with respect to the reference run.

The fit is better in both cases, but the model is much more sensitive to directly rescaling capelin biomass by 50% than it is to scaling just the stomach contents. For the scaling of capelin there is a large increase in spawning stock; for the increase in the initial meal size to stomach content ratio the increase in spawning stock is slight.

2.2.5.3 The effect on the capelin spawning stock from model simplifications

Table 2.2.2 shows the capelin spawning biomass estimated by the simplifications described in Section 2.2.4. In some cases the estimation process was not finished during the meeting, in which case the best fits obtained to that point are given. With respect to the reference run, it may be seen that:

Using only one area has a buffering effect on variation in spawning stocks. For medium capelin abundance, spawning biomass estimates are similar to estimates using the 7 areas in the reference runs. For high capelin abundance we get substantially lower spawning stock biomasses and for extreme low capelin abundance we get a somewhat higher spawning stock. It seems that the one area simplification is not able to capture the full range of variability with respect to the reference run. This is probably caused by the nonlinearity in the feeding relationship.

Constant migration, constant ration, and constant suitability by age yield similar spawning stock biomasses as the reference run. However, in the constant ration case there is more predation for low abundance, as may be expected. The small change from the reference run in the constant migration case is promising with respect to the usefulness of the model in short-term forecasts of the capelin spawning stock.

Using constant maturity at age yields different spawning stock biomasses with respect to the base run. Time did not allow investigation of details of these results.

For all the model simplifications, we got much higher values of the likelihood function, i.e. a worse fit. Time did not allow the Working Group to discuss the reasons for this, but clearly each simplification led to a poorer ability to fit the observations in the parameterization data sets.

2.3 BORMICON

2.3.1 Overview of BORMICON

BORMICON is a multispecies forward simulation model that is being developed at the Marine Research Institute

(MRI) in Reykjavík. It is designed for simulation of interactions between stocks that can be divided into sub-stocks with a uniform pattern of behaviour. The abundance numbers and mean weights are tracked by age and length for each stock unit.

The model is designed to allow for flexibility in the division of the calendar year into smaller time intervals, the division into areas and the division of stocks into sub-stocks. The calendar year may be divided into any number of time steps that need not be of equal length, and the number of areas, their sizes and environmental parameters are also all read from an external file.

The BORMICON simulations (WD 9), presented to the Multispecies Assessment Working Group, deal with cod as predator and capelin as prey. The area structure covers 16 areas (Figure 2.3.1) of which at most 13 were used in the presented simulations. The model has been run using a time step of one month.

2.3.2 Input Data

The input for the start of the simulation is the number of fish by length, age, maturity and area for predator and prey species. The cod input data are the results of the Icelandic Groundfish Survey in March 1985, scaled by VPA values. The capelin input data are the results of the capelin acoustic survey in January 1985.

The term "initial values" denotes values of parameters to be used as a base for further estimation or evaluation, e.g. through maximisation of a likelihood function. The initial values were used without modification in a base run.

The term "renewal data" is used to denote numbers on annual immigration or recruitment. These are read from files and are disaggregated by length and area and scaled to absolute stock numbers either by using VPA numbers for cod or acoustic numbers for capelin.

For the cod, the renewal data are based on the results of the groundfish survey for age 3. The renewal data for capelin, as the number of age 1 fish by length, and area, are the final acoustic survey results (autumn or January) backcalculated, accounting for fixed natural mortality and catches, to August.

Catches can be entered in a variety of different ways, one of which is to use the absolute numbers caught by age and length group and subtract them directly from the stock abundance in each month and area. This is termed "direct catch". A different approach has been taken in the runs presented by including the fleets as predators. A predator fleet "consumes" according to a suitability function much like a selection pattern in fisheries. The input of catches for both species is therefore given in tonnes per area and month and the model attempts to catch the appropriate amount through the modelled

consumption mechanism. It should be noted that this may result in a catch composition different from the one observed in the data. This problem can be alleviated by estimating suitabilities for fleet/area combinations based on a likelihood function which includes catches in numbers at age and length.

The input for the likelihood function is the number of cod by age and year in the groundfish survey and the number of capelin by year in the acoustic survey in January. The indices can potentially be disaggregated by areas or any combination of areas. In the future, mean length and weights at age, length distribution and age composition from catch data and survey data and observations of diet from stomach content data will be added to the likelihood function.

All input data, parameter values, program settings and outputs are archived on the MRI computers.

2.3.3 Model Structure and Formulations

To achieve flexibility in the division of stocks into sub-stocks, the sub-stocks are modelled as separate entities and the population of one sub-stock can move to another sub-stock. This can happen in two ways:

- Due to age. The oldest age group of a sub-stock can move to another sub-stock.
- Due to maturation. A calculated proportion of each age-length group of a sub-stock moves to another sub-stock.

The division into sub-stocks is as follows:

- Immature cod 3-8 years; mature cod 5-11+ years.
- Immature capelin 1-3 years; mature capelin 2-4 years.
- Length groups are by 1 cm for cod and by 1/2 cm for capelin.

In addition to sub-stocks other entities in the model are fleets and "other food". The fleets consume in the same way as the predator sub-stocks, and have suitabilities for the prey. "Other food" is another group of prey, in addition to the sub-stocks. This approach allows the predators to have a certain suitability for this prey and more than one kind of "other food" can be included.

The simulation flow chart is:

- Migration
- Consumption
- Direct catch
- Growth
- Natural mortality

Spawning

Maturity

Age update

Immigration

As described above, in the runs presented, the "direct catch" was not implemented.

Migration is described by matrices, the entries of which give the proportions of the sub-stock moving from one area to another. The model allows entries in the migration matrices to be parameterized and these parameters can be estimated within the model. Examples of this are given in Section 2.3.5.

The same migration matrices have been used for all years in the simulations, with the exception of a single year where an unusual capelin distribution required a special parameterization.

For initial values of cod migration parameters, locations of monthly commercial catches were considered along with survey information. Thus, although parameters were set in a somewhat *ad hoc* way to obtain the initial values in a base run, they are subject to the restrictions that the base simulation must be roughly able to sustain the observed catches and the observed survey distribution. An exact formulation of these criteria requires modifications of the likelihood function and estimation of a fairly large number of parameters, and this is not complete at the present time.

Consumption is assumed to be dependent on the length of the predator and the prey and is defined by the feeding level and maximum consumption. Feeding level is a function of the sum of the biomasses of individual prey weighted by their respective suitabilities. This results in a type 2 functional feeding relationship. In the baserun suitabilities are read from an external file and are not normalized (scaled) at present. The suitabilities are parameterized and can therefore be estimated (cf. parameter estimation run).

The growth of immature and mature cod is determined by standard relationships using consumption and temperature. The basic equation covering average growth in weight of fish in an age-length cell is of the form

$$G = aC / (w^{**r}) - b(w^{**q}) \exp(cT)$$

where a, b, c, q and r are parameters, C denotes the total consumption, T the temperature and w the weight of the fish at the start of the month. The average growth in length is then determined from this equation with

modifications in cases of starvation and subsequent increase in weight but not length. The growth in length and weight is then obtained by distributing the fish into upper length groups in an appropriate fashion.

The growth of immature and mature capelin is read from a file.

Spawning takes place on specified areas and in specified months and results in spawning mortality and weight loss. However, these features are not implemented in the runs presented in this report. Capelin spawning is followed by total mortality.

A major component not included in the simulation is a spawning stock-recruitment relationship. At present the recruits are introduced as immigrants and information on them is read from an external file.

The fraction of a sub-stock of cod maturing is obtained by probabilities calculated with a maturity ogive which depends on length and age.

2.3.4 Evaluation runs - descriptions

Three different runs were considered, 1) the baserun, 2) a run based on parameter estimation and 3) a 3-area run. The baserun was basically in accordance with recommendations of the Planning Group. As far as the other simulations are concerned their general objective was to explore some of the main properties of the model, such as the importance of area structure in the case of the 3-area run and possibilities for parameter estimation in the estimation run. Three areas were considered as a minimum for a representation of migrations and species overlap.

- 1) The **baserun** is based on 16 defined areas. Parameters are fixed at initial values and no optimization of the likelihood function is performed. These values have been adjusted to yield "reasonable" model performance, as explained in the working paper (cf. Table 2.3.1).
- 2) The **parameter estimation run** is based on parameters obtained by optimizing the likelihood function with respect to several (33) parameters. Other parameters, assumptions and input values are as in the baserun. This run is designed to test the performance of the model when estimating somewhat more parameters than intended. Thus, the likelihood function only includes distributional and abundance information from the groundfish survey which takes place in March and the acoustic survey in January, but it is used to estimate migration parameters for other months along with some consumption parameters.

The results from the estimation procedure are given in Table 2.3.1 and the simulation is described in Section

2.3.5. Somewhat surprisingly, it is seen that most of the parameters are estimated at fairly reasonable levels, with the notable exception of the single negative recruitment value. This can be obtained since there is no implemented bound within the minimization algorithm, but in effect the recruitment is simply set to zero within the program.

- 3) The **3-area run** is similar to the baserun except that the number of areas has been reduced to, a) an oceanic feeding area north of Iceland (areas 11, 12 and 14), b) a northern area incorporating nursery grounds of cod and migration routes of maturing capelin (2-8) and c) a southern area incorporating spawning areas of cod and capelin (1, 9 and 10). Clearly, initial values of parameters had to be adjusted in accordance with the revised areas. In particular, the suitability parameters and migration parameters have changed completely.

2.3.5 Evaluation runs - Results

It should be noted that the model is not in its final form nor have all parameters been estimated from data. The results presented in this report should therefore be regarded as preliminary and should not be taken literally. In particular, problems were found in the input data and these will need to be cleared up before any firm conclusions can be drawn.

2.3.5.1 The Baserun (Figs. 2.3.2-2.3.8)

In this run the biomass of cod (4+) follows the results of VPA analysis very closely, whereas groundfish survey estimates are somewhat lower. The capelin biomass is around one million tonnes until 1991 when an increase up to approximately 1.6 million tonnes is observed. Simulated values are in most years considerably lower than acoustic survey values.

Capelin consumption by cod decreases somewhat during 1988-89 following the decrease in the stocks and increases in 1990-91 with increasing capelin stock. However, the consumption of other food decreases more markedly following the decline in the cod stock. The consumption by cod is of the order of 10 g/kg cod/day on an annual basis, or approximately 1% of the bodyweight per day which is reasonable, whereas monthly values indicate a peak in consumption during autumn. However, the fraction of capelin in the diet is low compared with results based on stomach content data (Magnússon and Pálsson, 1989).

Understocking of capelin, i.e. insufficient modelled capelin abundance to yield observed historical catches, is around 400 thous. tonnes per year in 1985-89 (40-63% of catches) but none in 1991-92. Understocking is primarily a result of total capelin deficit rather than spatial distribution of predator and prey.

2.3.5.2 Parameter Estimation Run (Figures. 2.3.9 - 2.3.15)

In this run the cod stock decreases more rapidly during the last years and follows the survey data more closely than in the baserun. This is perhaps not entirely unexpected since the model is fitted to the survey data in this run.

The size of the capelin stock is considerably increased compared to the baserun and follows the acoustic values somewhat more closely. This is mainly explained by the fact that a parameter multiplying capelin recruitment is one of those estimated and is given a value considerably higher than in the baserun. It should be noted that the decline in the capelin stock in 1990-91 is more pronounced and a stock crash occurs in 1991 since recruitment is estimated for every year and is set to almost zero in 1990 and 1991.

The total consumption is similar to that observed in the baserun, whereas the share of capelin in the diet has increased due to the increase in capelin stock size and fluctuates more than in the baserun. The share of capelin is quite low, however, compared to earlier estimates (Magnússon and Pálsson, 1989).

The length at age is considerably lower for year class 1987 than for year classes 1983 and 1984.

As noted in the previous section most of the parameter estimates are quite reasonable and in fact the model seems to provide an adequate description of overall biomass trends when presented with only very limited information within the likelihood function. The notable exception is the mean length at age and proportional composition of the diet, which deviates considerably and it thus seems that there is potential gain in incorporating such information in the likelihood.

2.3.5.3 3-area run (Figs. 2.3.16-2.3.21)

In this run the cod stock is slightly larger than in the baserun, but the trend is virtually identical. The simulated stock tracks the VPA stock size values quite closely. The capelin stock is somewhat larger than the baserun in most years and shows a similar overall trend in stock size. The simulated capelin stock size is markedly below the acoustic values. However, the capelin spawning stock is driven to a crash towards the end of the simulation period. This is probably explained by the large areas which lead to increased accessibility of the capelin to the cod and hence increased predation on the spawning stock. Understocking is slightly less pronounced in this run than in the baserun.

Capelin consumption by cod is very similar to that observed in the baserun.

Lengths at age are similar to observations in the baserun.

Apparently, there is not much to distinguish between this run and the baserun, except possibly the crash in the capelin spawning stock. It should be stressed that although the area structure is the only formal change in model settings, a number of parameters (and their interpretations) have inevitably changed as a result of altered area structure; notably the suitability parameters may have different meaning.

Finally, it should be further stressed that all these runs are preliminary and should in fact rather be considered as "experiments", and initial steps in sensitivity testing. Results should not be taken as adequate representations of "reality". At this stage the only thing which can be deduced from comparison between the baserun and the 3-area run is that similar output can be produced in terms of total biomass trends.

2.4 MSVPA

2.4.1 Description of MSVPA for the Barents Sea

2.4.1.1 The Program

New versions of the MSVPA and MSFOR for the Barents Sea fishery community (cod, capelin, shrimp and herring) are presented. This new version of MSVPA allows year- and quarter-dependent weights at age (in both the catch and the sea) and an option for quarter-dependent values for residual natural mortality M1 (a feature that is especially useful for modelling the high post-spawning mortality of capelin). This version of MSVPA seems to be more appropriate for modelling boreal communities than the traditional MSVPA version used for the North Sea. The basis for the modifications was the Baltic Sea version of the MSVPA program.

Using the VNIRO software, retrospective estimates have been obtained for the period 1980 - 1993 and a short-to-medium term forecast has been made for 1994 - 1997. A long-term forecast has been made using MSFOR as implemented at ICES, and is described in Section 2.4.4.5.

Populations in the model have the following age structure:

Cod: age groups 0-15 (1-15 - as predator and 0-3 - as prey)

Capelin: age groups 0-6;

Shrimp: age groups 0-5;

Herring: age groups 0-12 (0-4 as prey).

The stock of Atlanto-Scandian herring is considered as a whole, although only young herring enters the Barents Sea.

For the calculation of suitabilities the "old" version of MSVPA was used in which suitabilities were calculated separately for each year and then averaged. The average suitability was then used in forecast and hindcast runs.

2.4.1.2 The input data

This section describes how data were used in the model. The Working Group acknowledges that uses of data were arbitrary in some cases, and opportunities exist to explore alternate uses of some data. Most of the alternative uses could not be explored during the time available at the meeting.

The source of stomach content data was the joint IMR-PINRO database for the period 1984-1992. The data processing procedure has a number of peculiarities intended to increase the sample sizes and is described in Bulgakova *et al.* (WD6). Briefly, these procedures involved the ageing of cod with known length (but not - age) using age- and quarter-specific age-length keys and ageing of prey of unknown length by means of weight reconstruction coefficients, estimated statistically as a function of digestion degree. Cod rations were estimated after Bogstad & Mehl (1992) using the dos Santos model of digestion (dos Santos & Jobling, 1992). The rations were calculated quarterly for 1984-1992 and were averaged by the whole time interval for every quarter (for results see WD6)

Catch-at-age data by quarters

Cod. The data on catch-at-age by quarters for 1980-1989 were presented by PINRO. The data for 1990-1993 were calculated by splitting the yearly catch-at-age data for all countries (Anon., 1995a) in proportion to historic levels. The proportions calculated as the average for 1985-1989 were 0.318, 0.231, 0.233 and 0.218 for quarters I-IV respectively.

Capelin. The quarterly distribution of the Barents Sea catches for 1980-1992 were obtained from PINRO. In 1993 capelin was fished only in quarters I and II. Russian catch data were available for each of these quarters but Norwegian data were for the two quarters combined. The Norwegian catch was distributed between the two quarters in equal parts. In the IV-th quarter of the terminal year (1993) there was no fishing, but the catches in the terminal quarter cannot be zero, hence the minimal catch values by age groups were used, which allowed the MSVPA program to be run.

Shrimp. Catch-at-age data by quarters for all years were presented by PINRO. Since ageing of shrimp is known to be a very complicated problem, a conditional age - length relationship was used.

Herring. Yearly catch-at-age data for 1980-1992 are taken from Table 3.3 in Anon., (1995b). Table 3.2 (Anon., 1995b) presents Russian and Norwegian catches separately. We calculated quarterly catches by age groups assuming that: 1) 90% of Norwegian catches were in quarter IV and 10% - in quarter I; 2) Russian catches were entirely taken in quarter I and 3) the age structure of catches was the same for both quarters.

Maturity at age

The proportions of mature fishes by age group in the model were taken to be constant and equal to the mean for the whole time interval.

Cod. The data from Table 3.19 in Anon.. (1993a) were averaged over the period 1982-1991.

Capelin. The estimates obtained in PINRO are used:

Age group	1	2	3	4	5	>=6
Proportion of maturity	0	0.13	0.85	0.99	1.0	1.0

Shrimp. Shrimp of age groups 4 and older were considered to be mature (as recommended by B.I.Berenboim (PINRO)). For age group 3 the proportion mature is taken as 0.5.

Herring. The average estimates for 1980-1993 calculated from Table 3.12 (Anon., 1995b) were used:

Age group	<3	3	4	5	>=6
Proportion of maturity	0	0.13	0.85	0.99	1.0

Weights at age by years and quarters

Weights at age for a given quarter of the given year in catches and "in the sea" were taken equal to each other for all species except herring. Where data for an age group were not available, year-average data were used.

Cod. For 1980-1992 weights at age by quarters were taken from age-length keys obtained from PINRO; the data for 1993 were not available and year - mean values were used (Table 3.5 from Anon., 1995a). Because the growth of cod has slowed in recent years the values of weight at age for 1996 were taken to be different from the data for the last year of fishing (1993) and the same for all quarters.

Capelin. Weight at age data by quarters for 1980-1992 were provided by PINRO. In 1993 capelin were fished from January - April; for quarter I the average of January - March data was used; for quarter II - the April data; for quarter III - the data from Russian-Norwegian acoustic surveys for age groups 1-4; for age groups 5 and 6 of quarter III and for all ages of quarter IV the data were averaged by years.

Shrimp. For 1980-1992 the year-mean quarter-independent data were used. For 1993 and for the forecast years the lower values of weight at age were taken: age 2 - 2.0g; age 3 - 3.8g; age 4 - 5.6g; age 5 - 7.3g.

Herring. The data from PINRO for age groups 0, 1, 2 and the data from the Working Group (Anon., 1993b) for

older ages were used, the latter being the same for all quarters of a given year. For 1993 the joint June survey data for age groups 1 and 2 in quarter II were used; for other age groups and quarters the data were as in 1992. The weight at age data in the catch and in the stock were taken to be different (Table 3.6-3.7, Anon., 1993b).

Stomach Contents data:

The stomach data used were from the multi-year Norwegian and Russian surveys of the Barents Sea. The sampling strategy and identification methods are described in WD6 and WD8. During the meeting inconsistencies were discovered in some of the stomach-content data files. In a few cases the amount of capelin consumed was inconsistent with the total stomach-content weight. These inconsistencies were fixed to allow the MSVPA to run correctly. The Working Group **recommends** that a thorough review of the stomach-content data files should be made to permit a definitive key run for the Barents Sea.

The biomass of "other food" for cod.

The value of "other food" was taken equal to 30 million t, that is 3 times higher than the total amount of the "main" food for cod (capelin, shrimp and herring).

2.4.1.3 Estimation of the residual natural mortality M1

As a first approximation we assume that M1 is equal to half of the total natural mortality for age group subject to predation. For other ages M1 is assumed to be equal to total natural mortality. After that the values of M1 were changed while tuning.

Cod. The estimates of total natural mortality were taken to be equal to those obtained by V.L.Tretyak (Tretyak, 1984).

Capelin. The main spawning period for capelin is from February to May (quarters I and II). Post-spawning mortality, which is very high for capelin, must be attributed to these quarters only. Hamre (1985) used acoustic survey data for yearly natural mortality estimation for capelin age groups 2-3 ($M=0.733$ 1/year on average). Referring to Russian data on cod feeding, Hamre asserted that 75% of yearly mortality occurred between 1 October and 1 May (7 months) and 25% from 1 May to 1 October (5 months), i.e. mortality was equal to 0.0785 and 0.0367 per month, respectively. These values were used to calculate quarterly natural mortality rates for ages 2 and 3 (see the first line in the table below). To these values for quarters I and II we added post-spawning mortality. Many authors have argued about the proportion of spawning capelin that die and this question appears not to have been resolved.

Let $f(\text{age})$ = proportion mature at age, and m = the proportion of fish that die after spawning, e.g. $m=0.9$ corresponds to a post-spawning mortality of 90%. Thus, the post-spawning mortality per quarter, being the same for quarters I and II, is calculated by the formula: $V = -0.5 \cdot \ln(1-m \cdot f(\text{age}))$.

For the first approximation $M1=M/2$ was assumed. Later the values of M1 were adjusted by tuning the parameter m , which gave the best fit to survey results for $m=0.5$.

Shrimp. The estimates of natural mortality for shrimp were taken as follows (1/quarter):

Age group	0	1	2	3	4	5
M1	0.2	0.2	0.08	0.8	0.12	0.16

Herring. In the Report of the Working Group on Herring and Capelin (Anon., 1995b) the value of M for herring was stated to be equal to 0.23 for recent years (beginning from 1991) and 0.13 for previous years. Because in MSVPA the parameter M1 is not year-dependent and because we are interested in more precise estimates of stock size for recent years, we assume $M=M1=0.23$ 1/year (or 0.06 1/quarter) for older ages and $M1=0.1$ 1/quarter for age groups 0 - 3.

2.4.1.4 Tuning

Terminal F for quarter IV by years

Cod. The yearly terminal values of F for the last age were taken from Anon. (1995a) and were recalculated into values for quarter IV by multiplying the yearly F by the proportion of catch (in numbers) in quarter IV in the total catch of the given year. The values of terminal F for 1993 were taken from the same source and were multiplied by 0.218 (the proportion of catches in quarter IV with respect to total yearly catches for the last 4 years).

Capelin. Terminal F for the last age was assumed to be small (0.001) for the years when the catches in quarter IV for the last age (6) were ~10 times less than the catches in previous age groups. For the years of no fishing $F=0.001$ is assumed since zero values of F are not permitted.

Shrimp. Values of terminal F for the last age group for quarter IV were taken as follows: 0.12 for 1980-1985 and 1990-1991, 0.2 for 1987-1988 (the catches in quarter IV in these years were somewhat higher) and 0.02 for 1992.

Herring. Terminal F values for the last age group were taken from Anon. (1995b) and were multiplied by the proportion of catches in quarter IV with respect to total yearly catches.

F for terminal year

Cod. The model tuning was started with cod for two reasons. Cod dynamics are less influenced by changes in the stock sizes of other species included in the model. Also the Working Group on Arctic Fisheries uses advanced methodology for detailed cod stock assessment. At first M1 was tuned bearing in mind the increase in M2 in the last years. Then the estimates of recruitment (Anon., 1995a) at age 3 for the last 4 years were tuned. The results of tuning show that the prognostic estimates of recruitment for age 3 $R(3)$ obtained by the Working Group seemingly did not take into consideration the mortality from cannibalism, which increased for the years of high cod stock size and low capelin stock. Hence the $R(3)$ estimates from the Working Group (Anon., 1995a) were considered only as indexes and the $R(0)$ estimates for 1990 were considered as basic ones.

For the forecast calculations a multiplier for F was chosen which resulted in a catch of 770,000 t in 1994 (TAC) and the multiplier for R - to obtain $R(0)$ = 1.4 billion in 1994.

Herring. Higher values of M2 were used for herring. These values were to characterize the mortality from disease. The values produced stock estimates for 1980-1990 which were considered to be somewhat high. The tuning was performed using stock at age data from June surveys of 1994 (the first prognostic year) by choosing the appropriate value of F for quarter IV, 1993 in MSVPA and comparing the survey results with the estimates of stock size in the beginning of quarter III of 1994 from MSFOR. Thus the two packages (MSVPA and MSFOR) were alternately run. Variations of F slightly influenced the stock estimates.

The multiplier for F equals the value which resulted in a catch in 1994 of 485,000 t; the multiplier for R was chosen to produce the recruitment in 1994-1996 equal to the level of 1993.

The tuning of any species produces a strong influence on the others, thus the tuning on the recruits is rather approximate.

Shrimp. The estimates of shrimp stock size obtained by means of MSVPA were higher than survey estimates for almost all years except the most recent period. The tuning was carried out simultaneously both on the stock number in 1993 from the spring survey and on estimates of recruitment at age 2. The recruitment estimates were regarded as an index of generation abundance in quarter II, i.e. the ratio $R(2, \text{year})/R(2, 1990)$ was calculated and assumed to be constant during the tuning procedure. The denominator of this ratio was changed on every iteration, and hence was changed each time the values of $R(2, \text{year})$ were recalculated.

The multiplier for F for the forecast was taken to produce the catch value in 1994 equal to 40,000 t; the multiplier for $R(0)$ - to obtain $R(2)$ = $25 \cdot 10$ in 1995.

Capelin. The yearly October survey data were used and at first the values of M1 were tuned (see 2.1.3.2 above and WP7*). This year capelin tuning was difficult because of the absence of fishing in quarter IV in 1993.

The multiplier for F is taken equal to zero (there will be no fishing in most current years); the recruitment at age 0 - on the level of 1992 ($\sim 7 \cdot 10^{-3}$, i.e. of low value).

The results of tuning are presented in Figure. 2.4.1.

2.4.2 Results

Several results of the MSVPA runs for the Barents Sea are reported, to give some insight into the basic performance of the model, and the types of outputs which are produced. These results do not comprise tests of model sensitivity, but the reasonableness of the results provides a simple, if relatively easy, performance test.

2.4.2.1 The results of retrospective estimation using the MSVPA version with quarter-dependent values of M1

Although the new version of MSVPA makes it possible to input quarterly values of M1 for all species included in the model, the quarter-specific values were used only for capelin. The main results are presented in Tables 2.4.1-2.4.3. and in Figures 2.4.1-2.4.6.

The retrospective estimates of both total (beginning from age 3) and spawning stock of cod were tuned to be close to results of single-species VPA (Anon., 1995a) (see Figure 2.4.1). In these reconstructions, cod stock size reached its maximum in 1993.

The historical values of capelin biomass estimated in the autumn surveys were fit more closely using quarter-specific values of M1 than using a constant M1 for all quarters (Figure 2.4.2). The better fit is especially apparent for spawning stocks. Both the collapse in 1986-1987 and the new decrease in 1992-1993 were reflected. Retrospective biomass estimates for shrimp also show a satisfactory correspondence to the results of surveys (Figure. 2.4.3). Very high values of predation mortality (M2) for shrimp of age 5, especially in the last years ($M2 = 5.9$ in 1993) are problematic. The estimates of suitability of shrimp age 5 as prey for most cod age groups are much higher than suitability estimates for other shrimp age groups. This could be evidence for the selectivity of cod feeding. The values of SUIT were especially high for shrimp of age 5 in quarters III and IV, up to 0.7-0.8.

The estimates of herring stock appeared to be higher than single-species estimates, probably because substantial

predation by cod is taken into consideration. Although the absolute values differ, the overall trends are similar (Figure 2.4.6).

The very high estimates of the herring stock in the beginning of the period could be caused by overestimated values of M1. These estimates were based on the Atlanto-Scandian Herring and Capelin Working Group statement about the recent increase in young herring mortality due to disease (Anon., 1995b).

Figure 2.4.5 shows the historical changes in prey biomass eaten by cod, disaggregated by prey species. The biomass of capelin eaten was higher in comparison to other species for all years. The biomass of herring consumed rose substantially in recent years, practically reaching the level of the capelin biomass consumed in 1993.

The amount of young cod consumed might be considered insubstantial in comparison with the amount of other prey that is eaten (Figure 2.4.5). Considering the cannibalism of cod in terms of numbers eaten, however, cannibalism can have a great impact on estimates of recruits. Cannibalism appears to have been especially high after sharp decreases in capelin stocks. The amount of age 1 cod consumed is as high as 40% of the total numbers in 1985 and 1993, and 27% for age group 0 in 1988 (Figure 2.4.6). The predation mortality of age group 1 takes place in all quarters (mainly in quarters III and IV), whereas age group 0 are being cannibalized only in quarter IV. The mortality from cannibalism for age groups 2 and 3 is lower.

2.4.2.2 Short-term forecast

The forecasts of stock sizes and catches for 4 species are calculated using MSFOR. The version used permits consideration of quarterly differences in M1. The results are presented in Tables 2.4.4 - 2.4.10.

The total cod stock (including all age groups) reaches a maximum in 1993, then decreases. The decrease in biomass is due both to reduction in growth rate (for all forecast years the lower values of weight at age, expected in PINRO for 1996, are used) and to increased cannibalism.

The capelin stock size was forecast assuming zero catches. Nevertheless, its biomass still decreases.

Shrimp biomass will decrease due to increased predation in the absence of capelin.

Herring stock size and catch will remain largely unchanged over the period of the forecast. The spawning stock biomass will continue to rise, which could reduce the effective fishing mortality level, and support higher catches.

2.4.2.3 Conclusion

1. It is important to use enhanced versions of MSVPA for modelling boreal systems, and to include quarter- and year- specific parameters wherever it is possible: rations, weight at age (in catches, in the sea and in stomachs) and residual natural mortality.
2. The tuning procedure applied has a number of shortcomings. The first is an ideological one: the tuning on the results of single species VPA could entirely negate the advantages of the multispecies model. Furthermore, the tuning on survey data (usually of rather low precision) cannot yield consistent results. A second disadvantage is that the tuning procedure is very time-consuming because changes in any parameters lead to changes in all blocks of the model. Thus, the development of an automated procedure for multispecies tuning seems to be very important.
3. In order to make Barents Sea multispecies modelling with MSVPA more reliable, the MSWorking Group **recommends** the use of joint Russian and Norwegian data on a quarterly basis: catch at age and weight at age (in catches and in the sea).

2.4.3 Tests of MSVPA applied to the Barents Sea

2.4.3.1 Comparison of results for two versions of M1: M1(a) and M1(a,Q)

The introduction of dependency of M1 on quarters for Barents Sea capelin influences mainly the seasonal variation of capelin numbers. The influence of this factor on other species is negligible. Computer experiments to test the sensitivity of capelin numbers to this modification of the basic MSVPA approach were carried out in the following way. The first MSVPA run was made with weight at age variable by years and age-specific M1 for capelin nonvariable by quarters. The second run used an updated version of MSVPA which used M1(age,Q) with high M1 for quarters I and II because of postspawning mortality and low M1 for quarters III and IV (estimates of M1 are discussed in Working Paper 7). The relative discrepancy of capelin stock numbers as a function of age (Figure 2.4.7) varies synchronously for the two year classes 1983 and 1987.

Run 1 produced underestimated values of adult capelin stock numbers in all quarters. The most significant underestimates were in quarter III (up to +30%).

The same modification of MSFOR (M1 as a function of quarter) results in analogous seasonal variation of capelin stock number estimates (Figure 2.4.8)

We conclude that within an MSVPA approach, the post-spawning mortality must be included explicitly, or else the quarterly estimates of capelin numbers are likely to

be seriously in error, even if the mean estimate for the year is reasonable.

2.4.3.2 Comparison of capelin consumption by cod from MSVPA and calculated using rations and cod stock estimates

The following analysis was undertaken as a performance test of the MSVPA for boreal ecosystems. So-called "observed" consumption of capelin by cod was calculated as the sum of products of year, quarter and age-dependent rations of cod, and cod numbers at age estimated by MSVPA. These values were calculated for the age groups best represented in the cod stomach data base: age groups 1-8. These values were compared with "estimated" values of capelin consumed by cod, which were taken from the output of the MSVPA version with quarter dependent M1. This comparison was made on a yearly and quarterly basis.

The discrepancy between the percent deviations from the mean of "observed" and "estimated" consumptions appeared to be significant for some years and quarters, especially for quarter IV of 1991 (Figures 2.4.9-11). In an attempt to explain these discrepancies they were compared with changes in spatial overlaps of cod and capelin distributions. Spatial overlaps were calculated on the basis of the MULTSPEC output as follows: for every subdivision (i) of the Barents Sea for every month, the ratio of capelin stock in this region to total capelin stock was multiplied by the same ratio for cod. These values were summed by subdivisions to produce a single estimate for every month. The estimates obtained were then averaged over 3 months to produce quarterly estimates of spatial overlap for every year from 1984 - 1992. The percent deviations from the mean for overlaps by quarters and by years are also presented in Figures. 2.4.10 and 2.4.11. The mean values for every quarter were calculated independently.

Figure 2.4.12 represents the difference between the "observed" and "estimated" capelin consumptions as absolute deviations of each consumption value from their respective mean values. The differences are displayed as a function of quarterly spatial overlap. No relationship between the size of the discrepancies and the degree of overlap is apparent. Thus, discrepancies between "calculated" and "observed" values of consumption cannot be explained by means of differences in spatial overlap, at least from these data. Other measures of spatial distribution and overlap might be worth further examination, however.

2.4.3.3 Comparing model output with data: predicting the abundance of young cod.

As another performance test, we compared the estimated abundance of young cod from a key run of MSVPA with the available survey data reported in the Report of the Arctic Fisheries Working Group (Anon, 1995a). Data

from Russian and Norwegian surveys are treated separately and data for different areas are averaged to give a mean abundance index. Figure. 2.4.13 shows the abundance predictions from each source for cod aged 1 - 3, along with the predictions from single species VPA for 3 year old fish. In examining these figures it is important to recognise that each data set has been arbitrarily scaled by a constant coefficient to place all data on a convenient scale, with approximately the same abundance value for 1980. Figure 2.4.13 shows that, for all ages, both models capture the temporal trends in the survey data until the late 1980's, but that for age 1 and to a lesser extent age 2 MSVPA appears to overestimate cod abundance to a greater degree than VPA. This result implies that for these later years M2 is over-estimated by MSVPA. Although this conclusion appears to be robust, it is difficult to arrive at a convincing explanation, particularly in view of the good performance of the model in earlier years.

2.4.3.4 Test of consumption estimates with different portions of stomach contents data

The MSVPA was re-run to test whether the estimates of prey biomass consumed were sensitive to which years of stomach-content data were included. MSVPA assumes that suitability remains constant over years; in the Barents Sea apparent suitability may have changed due to dramatic changes in prey abundance and changes in overlap between cod and the prey species. This test is similar to tests of the stability of suitabilities for applications of MSVPA to the North Sea (Anon 1991, 1994, Rice *et al.* 1991). It can be considered both a sensitivity test of the model (sensitivity to different stomach data sets, or different consequent suitability estimates) and a performance test (ability to predict stomach contents in some years, using stomach data from other years).

The base run included all years of stomach-content data from 1984 to 1992. Two additional runs were made which included only the stomach-content data from 1984-88 or from 1989-92. The rationale was to contrast a period of low capelin abundance (1984-88) to a period of high capelin abundance (1989-92). In the run with only 1984-88 stomach data, the MSVPA should fit the observed stomach contents quite closely for these years, such that the MSVPA estimates of prey consumption for these years can be treated as the "observed" consumption in 1984-88. The estimates of prey consumption in other years (1980-83, 1989-92) are considered "predicted" values. Likewise for the run with 1989-92 stomach-content data, prey consumption in 1989-92 is considered "observed" and prey consumption in 1980-88 is considered "predicted". In this fashion the two runs were tested for their ability to predict stomach-content data not used in the MSVPA.

The estimates of prey consumed varied between the runs (Fig. 2.4.14). As expected, estimates from the base run

were intermediate between the 1984-88 and 1989-92 runs. The 1989-92 run predicted higher consumption of capelin in all years, which suggests that cod switched to feeding on capelin as the capelin became more abundant. All three runs predicted an increase in herring consumption starting in 1990, but the 1989-92 run was much higher than the 1984-88 run. A possible explanation is that prior to 1990 many fewer herring migrated into the Barents Sea and the stock was less vulnerable to cod predation. Cod apparently increased its preference for herring as the herring stock increased and expanded its migration range. There was a large difference between the runs in the predicted amount of cod consumed. Based on the 1989-92 run, the suitability of cod diminished as the suitability of capelin and herring increased. The estimates of cod consumed should be considered provisional because of inconsistencies in the age-1 cod weight in 1993. These sensitivity runs suggest that the suitabilities of capelin and herring, as prey of cod, changed between the two periods. The shifts are consistent with the known changes in abundance and distribution of these prey species.

The two runs with partial stomach-content data were used to test whether the MSVPA model can predict diet composition better than a simple assumption of constant diet composition (Figure 2.4.15). For the forecasted proportion of capelin in the cod diet from 1989-92, the open bars are considered "observations", the solid bars are the MSVPA "predictions" and the horizontal line is the mean proportion of capelin from 1984-88. The hindcast is for the years 1984-88. In this case the "observations" are the solid bars, the MSVPA "predictions" are the open bars and the horizontal line is the mean proportion of capelin from 1989-92. In both cases, the MSVPA predictions are closer to the "observed" values than the simple mean. This test indicates that the assumption of constant suitability is preferable to the assumption of constant diet composition. Ideally the MSVPA predictions should be compared against the observed diet composition, but there was not time to do that at this meeting.

The total food consumed by Barents Sea cod increased in relation to cod abundance (Figure 2.4.16). The MSVPA results suggest that other food was substituted in the diet during the period of low capelin abundance (See Section 2.4.4.2).

2.4.3.5 Long-term MSFOR predictions

Long-term predictions could be viewed as sensitivity tests, to the extent that forecasts differ as initial conditions or scenarios are changed. However, the usual view of long-term forecasts is that the model is being used in an exploratory mode, shedding light on potential consequences of alternative human interventions or natural events. It is premature to view these runs as performance tests, although they predict the future status

of stocks, and the predictions can be compared to trajectories that the stocks follow. Forecasts are dependent on assumptions about future environmental and fishery conditions, which are unlikely to be realized exactly. These complexities can be dealt with in probabilistic ways, but application of MSVPA and MSFOR to the Barents Sea had not reached the stage where such probabilistic runs were possible at this meeting.

The VNIRO version of the MSVPA and MSFOR models are run on PC's and the dimensions of the arrays in the models are limited by the amount of computer memory available. In practice this means that predictions cannot be carried more than 4 years ahead.

It was therefore decided to transfer the Barents Sea database to the format used by the latest version of the ICES MSVPA and MSFOR programmes. Because these programs assume that M1 does not change over quarters a constant M1 was estimated by averaging the quarterly M1's used in the VNIRO version. No other changes in input parameters were necessary.

Runs with the ICES version of the MSVPA and the VNIRO version produced very similar results, except for consumption of cod by cod in the most recent years where the VNIRO version produced much higher estimates than the ICES version. In this case the difference could be explained by the use of a varying prey weight at age in the stomachs in the VNIRO version versus a constant averaged prey weight at age in the stomachs in the ICES version.

The ICES MSFOR model was subsequently used to predict the percentage change in yield and biomass following a 10% reduction in fishing effort in the fisheries for cod, capelin, shrimp and herring. Recruitment for all species was kept constant at the average level estimated by the MSVPA in the period from 1980 to 1990. In the baseline run all fishing mortalities were kept constant at the average over the years 1980-1992. In the 10% runs the input fishing mortalities of each of the species were reduced by 10% compared to the baseline. Predictions were carried forward to an equilibrium situation in which the estimated numbers at age changed less than 0.01% over a 9 year period. Both single species and multispecies predictions were performed. The input to the single species predictions were generated by running the MSVPA in the single species mode with the values of natural mortality shown in Table 2.4.11 .

The results from the long-term multispecies baseline run are shown in Table 2.4.12. Compared to the average total biomass estimated by the MSVPA over the period from 1980 to 1993 the biomass of capelin was predicted to decrease by 32%. Herring, cod and shrimp biomass increased by 16, 11 and 9%, respectively. Even larger changes were seen in the predicted catches. Long-term

herring catches were predicted to increase by 168%; cod and shrimp catches by 37 and 25%, respectively. Compared to the MSVPA average capelin catches decreased by 47%. Considering the major changes which have taken place in the Barents Sea ecosystem in the period from 1980 to 1993 it is not surprising that long-term equilibrium predictions diverge from the MSVPA average.

Table 2.4.13 shows the results from the 10% change in fishing mortality runs expressed as percentage changes from the baseline prediction in total biomass, SSB and catch. Reducing the fishing mortality on cod by 10% results in a 4% decrease in the total biomass of cod, a 17% increase in cod SSB and a 1% decrease in the catch.

The increase in the cod biomass increases the predation mortality of its prey and the biomass and catch of capelin and herring consequently decline somewhat. Surprisingly enough the biomass of shrimps remains unaffected by the increase in cod biomass. Presumably this is due to a change in the age composition of the cod stock. Reducing fishing mortality on cod leads to an increase in the biomass of older large cod, while at the same time reducing the abundance of younger cod due to the predicted increase in cod cannibalism. An increase in the biomass of larger cod with a relatively low proportion of shrimps in the diet seems thus to be balanced by a reduction in the abundance of smaller cod with a high proportion of shrimps in their diet. For capelin, shrimp and herring a 10% reduction in the fishing mortality is predicted to increase the total biomass of the target species by 2 to 3% and to reduce the species catch by 5 to 7% with no significant indirect effects on other species.

Due to cannibalism multispecies predictions for cod result in a smaller increase in cod biomass than the single species predictions. In the single species predictions the increase in cod biomass is in fact large enough to counteract the reduction in effort in the fishery. In the single species predictions the catch of cod therefore increases by 4%. For the prey species the decrease in catch becomes larger in the single species prediction because the increase in biomass resulting from the decrease in fishing mortality does not become counteracted by a compensating decrease in predation mortality.

Overall the results from multispecies predictions in the Barents Sea show many similarities with the results from the North Sea. As in the North Sea the major result seems to be that species interactions will result in a general shift in MSY of the predators towards higher fishing mortalities. The importance of growth overfishing at current levels of effort is thus reduced. Reducing fishing effort will generally lead to reductions in the predicted long-term equilibrium catch. However, it is important to remember that MSFOR predictions assume recruitment to be unaffected by changes in SSB.

Increasing effort may reduce the SSB to a level where this assumption is violated.

2.5 Contrasts and Conclusions Regarding Multispecies Models of Boreal Systems

All three boreal models seemed to perform well at some things, but each also performed less well at some other things. Generally, however, where a model performed poorly at present (say, an inability to reconstruct proper lengths at age for cod as predators), the problem was not due to some structural error in the model. Rather, performance could be improved through simply obtaining better estimates for some model parameters.

It was unsettling in several contexts that we lacked a systematic approach to the interrelations among model testing, selecting which parameters to estimate, and model tuning. It left the Working Group questioning its ability to give these (or other) models really rigorous tests, where a model could actually fail. On the other hand, the role of tuning in application of single species assessment models has always been challenging. It should not be surprising that tuning and parameter estimation requires more systematic exploration in multispecies models as well.

The mixed performance by each model brought into focus the degree to which the models were being designed to address different multispecies management problems. The most immediate needs for advice from the model (for example, estimating spawning biomass of capelin in MULTSPEC) had determined where the efforts in model development and parameterization have been focused. Contrasts of the performance of the three models should keep in mind the most direct intended applications of the models, and not unfairly rank the models globally on the basis of a specific performance test. There is a strong conviction within the Working Group that all three models performed well enough to continue development of each. Moreover, the availability of several multispecies models for boreal systems is not just an incidental consequence of different management needs. Rather, it should be considered a desirable objective, rather than a redundant luxury.

The results of the runs and model tests indicate that none of the models is ready for routine application. However, all are still considered to be in a developmental state, and have not been proposed as routine assessment tools yet. It is worth special note that MSVPA performed much better than many Working Group members had expected, based on the absence of migration and spatial structure in MSVPA.

More generally, even though the models are in developmental states, the models have progressed far enough to show that some preconceptions of the modellers and the Working Group were incorrect. Based on previous meetings and experience, the Working

Group expected it to be necessary to model spatial structure and migration in detail. All three models suggest that for many purposes it is not necessary to include great detail in migration and spatial structure, although there needs to be some way to reduce the capelin vulnerability to predation for at least parts of the year. There are many ways to achieve this in models other than through complex migration patterns, and some alternatives might prove simpler to model, to parameterize, or to test.

As a final general point, the Working Group learned a lot about how to test these large complex models. Attendance at the Working Group meeting included many individuals very experienced in stock assessment, model development, and model testing. Nonetheless, members generally mis-judged how hard it would be to test these multispecies models at all, let alone test them all in similar ways, with comparable levels of rigour. Because of the demands for provision of increasingly complex advice, requiring increasingly complex models (Stefansson *et al.* 1995), the experience gained in testing such models will be very valuable to ICES.

2.6 Future directions for Boreal Models

The first point to make is that all three models, BORMICON, MSVPA, and MULTSPEC, showed substantial promise. Further work on each is justified. Beyond that general endorsement, a number of specific lines of inquiry appeared particularly worthy of pursuit.

- a) It will be valuable to get young cod (age groups 0, 1, and 2) into all models. The role of cannibalism and predation by other species may be an important component of recruitment dynamics. At least some aspects of those processes may be tractable within these multispecies boreal models.
- b) The Working Group has devoted much effort to seeking evidence of prey switching in the North Sea. The MSVPA results suggest the process might prove much more tractable within the Barents Sea, and possibly boreal systems in general, because of the greater contrast in the time series.
- c) It seems worthwhile to pursue putting more attributes into the likelihood functions being minimized in the parameter estimation steps. This step would use available data in statistically more rigorous ways.
- d) Preliminary results with MSVPA at this meeting suggest that within a yield per recruit framework, $F_{0,1}$ for Barents Sea cod might be somewhat higher than predicted by single species models. It is worth determining if BORMICON and MULTSPEC also make this prediction. In general it would be useful to explore how BORMICON and MULTSPEC perform in long-term simulations.

- e) The role of "other prey" is clearly important in boreal models (and systems). Studies to learn more about its role would be valuable.
- f) MSVPA currently has no spatial structure nor migration. A serious look at how spatial overlap could be brought into the Barents Sea MSVPA is warranted. Runs with BORMICON and MULTSPEC also suggest there should be more work on alternative ways to capture variability in catchability of prey to predators, whether through migration, spatial structure, time-varying suitabilities, or some other method.
- g) Testing of these multispecies models is not a one-time pass / fail thing. Development and testing are on-going activities, which should complement each other.

2.7 Other Models and Methods Applied to Boreal Systems

2.7.1 Direct Estimation of Natural Mortality Rates

A Working Paper WD7 was presented by Korzhev *et al.*, and an additional paper by Tretyak (1993) was tabled. The related methods use annual stomach survey observations to provide estimates of predation on each age of 1-3 year old cod by older ages of cod. Estimates of *per capita* numbers eaten by each predator age are prorated by the numbers of the predator population and summed to give estimates of the numbers removed by predation. These predation removals are then used together with fishing removals as inputs to a VPA.

Table 2.7.1 shows overall natural mortalities. It should be noted that the results for the years prior to 1984 were based on average values. The relatively high predation mortalities on 3 year old fish in these earlier years probably arises from the use of average values as data. Some later years also show possibly high M2 values for age 3 fish. To investigate these problems further, M2's were broken down into partial M2's by predator age. Table 2.7.2 shows how the partial predation mortalities were generated by each predator age group. These results suggest that the stomach database may have relatively small numbers of cod eating cod and that the results might therefore be quite variable from year to year. It might be worthwhile to apply some smoothing method to these results.

Stomach content data are available in the form of length of prey by each length and age of predator. To use the method required that prey are divided into age group. An age-length key approach to ageing prey may help to give better estimates of the prey age distribution than can be obtained by the cohort slicing technique used currently. Ageing material obtained from stomach contents will also help clarify this problem.

The approach is an interesting one, because, given suitable smoothing of results or extensive stomach sampling, it enables predation mortality to be estimated directly with a minimum of model assumptions. Having established population sizes for cod, an analogous method could be used to estimate predation removals of alternative prey species which could then be entered into VPA's.

Because the results clearly are affected by sparse data for cod feeding on cod, an attempt was made to smooth the results. The Partial M2's generated on the three prey ages were divided by estimates of predator biomass (from 1984-1990) and the resulting UM2 values were averaged over this period. These averaged results were plotted against the logarithms of the ratios of the average prey weight to average predator weight. Plots of these results are shown in Figures 2.7.1 - 2.7.3. The plots also show estimated UM2 curves fitted by eye. The formula for these curves was:

$$UM2 = a * \exp \{-.5 [(\ln (Prey \text{ Wt.} / \text{Pred. Wt.}) - m) / s]**2\}$$

Common values were chosen for $a = 1.2E-6$, and $s = 0.5$. Values of m increased on the older ages of prey. These plots indicate that the results are reasonably coherent. However, it should be noted that the tendency of the preferred prey ratio tending to increase on older prey is different from the cod feeding plots shown in the Working Paper. Those plots suggest larger ratios between predators and prey weights for smaller prey.

2.7.2 Smoothing Estimates of SUITABILITIES from the Barents Sea MSVPA

The MSVPA method constructs suitability estimates SUI for each quarter, predator age and prey age combination. Following previous Working Group practice SUI estimates were fitted to a restrictive statistical model. As for the UM2 estimates reported in the previous section, the resulting statistical model forms both a succinct description of the suitability terms and also some measure of the importance of the various components factors which influence SUI (e.g. quarter, size and species).

Average quarterly suitability terms estimated from the key run of the Barents Sea MSVPA were made available in the standard format which contains details of quarter of the year, predator species and age, prey species and age, SUI, predator and prey weights in the sea and predator and prey average biomass. Statistical fitting of the SUI estimates was made using a GLM with a Poisson error structure and a log link function. The basic model fitted therefore was

$$SUITABILITY = a(\text{Prey}) * \text{EXP} \{-.5[\ln(\text{Prey Wt.} / \text{Pred. Wt.}) - m] / s]**2\} + e$$

where as for the fitting of UM2, $a(\text{Prey})$ is a prey specific term and m and s are the mean and standard deviation terms that describe the log normal feeding relationship. The error term e results from SUITABILITY being taken to have a scaled variance Poisson distribution. This model was further extended by including a prey age and or quarter factors in a or a prey species specific m .

Table 2.7.3 shows the goodness of fit measures of these various statistical models. In the table the following notation is used in the specification of the linear predictor of the GLM (PS=prey species, LWR= $\ln(\text{Prey Wt.} / \text{Pred. Wt.})$, PA= prey age, Q= quarter, nested interactions are indicated as PS.PA etc). The basic model explains 23% of the deviance obtained with a simple mean term. It does this using an additional 5 degrees of freedom. As in the case of UM2, fitting an interaction to the LWR term (i.e. either fitting a species specific mean term to the mean of the log normal size relationship or a quarterly specific term) produced little improvement in fit and was not pursued further. However, fitting a nested quarter. prey species interaction to the model (allowing the factor a to differ by both prey species and quarter) explained 33% of the basic deviance while fitting a nested prey species.prey age interaction to the model explained 55% of the basic deviance. Fitting a nested prey species. prey age. quarter. interaction to the model (allowing the factor a to differ by both prey species, prey age and quarter) explained 71% of the basic deviance.

Model parameter estimates from the fit of the basic model are shown in Table 2.7.4 and these are interpreted as α , μ and σ terms in Table 2.7.5. This indicates that the mean (most preferred) prey ratio for Barents Sea cod is about 1:86. The spread of preference as indicated by the σ term is however quite wide.

Model parameters for the fit with a nested prey species. prey age interaction are shown in Table 2.7.6 and their interpretation as α , μ and σ terms in Table 2.7.7. This analysis indicates that the mean (most preferred) prey ratio for Barents Sea cod is rather larger at about 1:120 again with a wide spread as indicated by the σ term.

The individual suitability multipliers, the $a(\text{prey age})$ terms indicate that in general the various prey have rather similar suitabilities (i.e. are eaten in proportion to their biomass) but that shrimp have (probably) anomalously high suitabilities on the youngest and oldest ages while the suitability of the two youngest ages (ages 0 and 1) of herring are lower. The suitability of capelin is approximately double on the mature age groups 4-6.

The results of these two runs are broadly consistent with the results of the fits to the UM2 terms (Section 2.7.3). Both sets of analyses indicate that cod in the Barents Sea appear to have a rather larger mean prey ratio than the cod in the North Sea.

2.7.3 Smoothing Estimates of UM2's from the Barents Sea MSVPA

The MSVPA method constructs partial M2 estimates for each year predator age and prey age combination. Following previous Working Group practice, the average annual partial predation mortality (M2) estimates were fitted to a restrictive statistical model. The resulting statistical model forms both a succinct description of the partial M2 and some measure of the importance of the various components factors which influence partial M2 (e.g. size and species).

Average annual partial M2's estimated from the key run of the Barents sea MSVPA were made available in the standard (Pope file) format which contains details of predator species and age, prey species and age, M2, predator and prey weights in the sea and predator and prey average biomass. From these data estimates were constructed the partial M2 per unit predator biomass (UM2) for each predator age, prey age combination and the corresponding Logarithm of the prey weight to predator weight, (Ln Ratio). Log scale scatter plots of UM2 on Ln Ratio indicated that the relationship of UM2 results to Ln Ratio was in the form of regular curves of the domed form that would be expected from a log normal size ratio feeding model. The curves for the various ages of the various prey species are shown in Figures 2.7.4 (cod as prey), 2.7.5 (capelin as prey), 2.7.6 (shrimp as prey), and 2.7.7 (herring as prey). Compared to curves produced for the North Sea these seem rather flat topped and appear to have peaks at larger ratios of predator to prey weight (more negative Ln Ratio).

Statistical fitting of the UM2 data was made using a GLM with a Poisson error structure and a log link function. The basic model fitted therefore was

$$UM2 = a(\text{Prey}) * \text{EXP}\{-.5[\text{Ln}(\text{Prey Wt.} / \text{Pred. Wt.}) - \mu]^2 / s\} * 2 + e$$

where $a(\text{prey})$ is a prey specific term and m and s are the mean and standard deviation terms that describe the log normal feeding relationship. The error term e results from UM2 being taken to have a scaled variance, Poisson distribution. This model was further extended by including a prey age factor in a or a prey species specific μ .

Table 2.7.8 shows the goodness of fit measures of these various statistical models. In the table the following notation is used in the specification of the linear predictor of the GLM (PS=prey species, LWR= Ln(Prey Wt. / Pred. Wt.), PA= prey age, nested interactions are indicated as PS.PA etc). The basic model explains 42% of the deviance obtained with a simple mean term. It does this using an additional 5 degrees of freedom. Fitting an interaction to the LWR term (i.e. fitting a species specific mean term to the mean of the log normal size relationship) produced little improvement in fit and

was not pursued further. However, fitting a nested prey species, prey age interaction to the model (allowing the factor (to differ by both prey species and prey age) explained 83% of the basic deviance.

Model parameter estimates from the fit of the basic model are shown in Table 2.7.9 and these are interpreted as alpha, mu and sigma terms in Table 2.7.10. This indicates that the mean (most preferred) prey ratio for Barents Sea cod is about 1:109. The spread of preference as indicated by the sigma term is however quite wide.

Model parameters for the fit with a nested prey species, prey age interaction are shown in Table 2.7.11 and their interpretation as alpha, mu and sigma terms in Table 2.7.12. This analysis indicates that the mean (most preferred) prey ratio for Barents Sea cod is rather larger at about 1:129 again with a wide spread as indicated by the sigma term.

The results of these two runs indicate that cod in the Barents Sea appear to have a rather larger mean prey ratio than the cod in the North Sea where the results of Anon. 1994 indicate cod to have a mean ratio of between 1:74 (1981 feeding data) or 1: 63 (1991 feeding data). The sigma term which indicates the spread of feeding also appears to be larger in the Barents Sea. These differences (if significant) may result from the main prey species (capelin, krill etc. being comparatively small and may also result from the more size specific spatial distribution of the Barents Sea cod which may thus require it to adopt more catholic size preferences than the North Sea cod does.

2.8 Emergent Concerns

Although the Working Group was not able to conduct identical (or even parallel) tests of each of the three boreal models, several themes emerged as common to all models. Some concerns were also common to the tests of all models. Review of the emergent concerns allows some synthesis of the diverse efforts of the Working Group.

2.8.1 Designing models to be tested

Although the Working Group included many experienced modellers, the Working Group generally was surprised how difficult it was to identify rigorous but feasible tests of these multispecies models. The difficulties had several causes. Some of the problems were simply technical; the models are large, complex, and contain nuances not easily seen by those not working with them routinely. In addition, the models are developed to predict or simulate things which are often not easy to measure directly and precisely. Therefore many of the most practical tests were also most indirect. Another factor which contributed to the difficulties in testing the models was that the models generally used most of the readily available data in their

parameterization steps. Model developers need to use available data, so the models perform reasonably. However, the more data used to estimate parameters, the fewer data are available for independent tests of model performance. These concerns about testing models did not arise uniquely with this meeting. However, the experiences at this meeting led to several generalizations which might help guide development of future multispecies models.

Whatever the model, it is important that it be designed with a view to the kind of tests that can be carried out to evaluate it. This is particularly important with respect to complex models which are technically hard to evaluate. As a minimum requirement, models should be designed to be able to formally examine goodness of fit with respect to the available data. Fit sums of squares decreases with increasing number of parameters. To be rigorous, the significance of the reduction in the fit sums of squares obtained by introducing an additional parameter should be examined. In order to say something useful about multispecies problems in Boreal systems despite the limitations of the data, it is inevitable that a number of assumptions have to be introduced, not only regarding functional relationships, but also the parameters for these relationships. Given this flexibility it is almost inevitable that such models will fit the data at least reasonably well so that goodness of fit may not be particularly revealing.

Irrespective of how well the model can explain the observations, it is necessary to design further more stringent tests that models may fail, as described in Section 2.1. We often learn a great deal from the way a model fails a good test. Moreover, models that always pass the tests we put them to are suspect. If a model can accommodate nearly everything, it is likely to predict nearly anything. With this in mind, it may be useful to purposefully design multispecies models so that they leave at least part of the observations (e.g. half of the time series or an important variable that can be predicted by the model) out of the fitting procedure. As an extension of this it is useful if a model developed for one boreal system can readily be applied to another similar boreal system (e.g. applying BORMICON to the Barents Sea).

Model evaluation becomes increasingly more difficult with increasing model complexity. It is important that the input data and the output data are available in flat files amenable to a variety of alternative analyses including comparison with empirical data. Further, the source code needs to be available for experimentation. Such experimentation is facilitated if the code is of modular design so that, for example, one growth function can be unplugged and another plugged in to replace it. "Pseudo-functions" (i.e. code which appears to perform some function, but in practice a set value is used, so the code is inactive) complicate independent evaluation. It would be useful to have stripped down

models for the base run (i.e. to have all inactive code and parameters removed).

2.8.2 Estimation in these models

Formal parameter estimation of Boreal multispecies models is at an early stage. The inclusion of 33 parameters into the likelihood function for BORMICON and the results of the subsequent optimization is probably a unique exercise in multispecies modelling and much can be learnt from it. Unfortunately, time constraints dictated that the exercise could only be given very superficial evaluation by the Working Group. For example, a variety of slices through the likelihood may be particularly revealing regarding the problems of parameterizing complex models from limited data.

In contrast to the BORMICON experiment described in Section 2.3.5, it is common practice, and often a necessity, to fix the values of many of the parameters. The assignment of values may be either arbitrary or based on independent analyses. Either way, the number of free parameters to be estimated in the likelihood function is restricted. This has a desirable consequence, in that artificially high degrees of freedom are reduced, so tests are more stringent. However, the practice also entrenches preconceptions and assumptions within the model framework, requiring the free portions of the model to accommodate to the preconceptions.

There is a long history of discussion among modellers about the relative values of data driven and assumption (hypothesis) driven approaches to modelling, and about which approach gives more insight into the real world. The Working Group did not resolve that debate. The meeting did highlight that the issue has many practical consequences, and is not just a philosophical matter of taste among different modellers.

2.8.3 Treatment of Migration

Explicit incorporation of migration is one of the features distinguishing multispecies models developed for boreal fisheries systems from ones developed for temperate multispecies systems. The fish species in boreal ecosystems undertake extensive seasonal migrations between feeding and spawning areas. A consequence of these migrations, described at some length in WD 3 and in Stefansson and Palsson (1995), is that the vulnerability of capelin to cod predation varies throughout the year. Interannual variation in migration patterns, driven by temperature and ocean currents, further modifies the overlap between predator and prey. The goal of the boreal models is to describe the average migration patterns and deviations from the average as indexed by environmental correlates. Eventually the models could be animated to provide a graphical representation of movement.

2.8.3.1 How migration is actually handled in the boreal models

The treatment of migration is very similar in BORMICON and MULTSPEC. For purposes of migration, the cod and capelin stocks are divided into immature and mature substocks. For each substock there is a transition matrix which contains the proportions of the stock migrating from one area to another in the time step of one month. Some months may share the same matrix. The number of matrix elements that it is necessary to specify is reduced substantially by eliminating impossible pathways and making some simplifying assumptions about migration pathways. Even so, a large number of transition probabilities must be specified.

A preliminary effort was made to estimate the migration parameters of Icelandic cod from tagging data (Stefansson and Pálsson 1995). The resultant migration matrices were not able to satisfactorily reconstruct catches over the parameterization period, and the matrices were not used.

Without the ability to estimate migration parameters directly from tagging data, the matrices must be specified in a somewhat *ad hoc* fashion. Proportions migrating are assigned to all the permissible pathways. These proportions are scaled by a smaller number of multipliers which are then tuned to reproduce seasonal distribution patterns. Migration of the immature substocks is more dispersive than the mature components, and can therefore be described with fewer parameters with less seasonal variation. Migration of the mature substocks must reproduce the spawning migration, which requires more seasonal variation and more parameters (e.g. 53 proportions must be specified for the mature Icelandic cod stock). With tuning, these migration matrices do move the fish around to the desired locations.

A subset of the migration parameters was included in the sum of squares that measured the model fit to observed data. In BORMICON the immature migration parameters were included in the sum of squares (3 for cod, 8 for capelin). Two of the cod parameters were included in the minimization performed for the base run, and all were allowed to vary in one of the performance evaluation runs. In MULTSPEC, interannual variation in mature capelin migration was described with 3 parameters, which were estimated for each year in the base run.

Migration is not explicitly included in the Barents Sea MSVPA. However, variations in the seasonal overlap of predator and prey species may be reflected in the quarterly suitability estimates. These suitabilities should be examined to see whether they are consistent with the seasonal migrations of cod and capelin.

2.8.3.2 Concerns about the treatment of migration

The general migration structure is well established but the values of the migration parameters are largely unknown (Stefansson and Pálsson 1995)

The tuned migration matrices appear to move the fish to the right places at the right time, and the simulated distributions can, and should, be compared with survey distributions whenever they are available. However, because of the numerous alternative pathways, different matrix parameterizations could result in similar apparent distributions.

Inclusion of some of the migration parameters in the sum of squares helps improve the model fit to survey distributions. However some of the estimated parameters were extreme values and it is not clear whether they describe realistic migration patterns.

A side-effect of migration that was encountered in both boreal models was insufficient fish in an area and month to sustain fishing and/or predation ("outfishing" and "understocking"). Even if the stock would not be reduced below zero, the fishing mortality estimated for that period could be unrealistically high. These discrepancies may result from migration being misspecified in a given year, and for the prey may result from excessive predation "upstream" of the given area.

Given the inability to empirically estimate migration matrices, the value of explicitly including migration in multispecies models is open to question. The seasonal changes in overlap between predator and prey may be adequately captured by seasonally varying suitabilities without an explicit spatial representation. A spatial model is necessary if the total mortality is high and the spatial distribution of mortality varies in a fashion unrelated to stock abundance, as is most likely the case in the Barents Sea.

Some of the model evaluations suggest that the predator-prey interactions may be adequately represented with a less spatial structure in the model. The BORMICON run with three areas produced biomasses of cod and capelin quite close to the base run. Adjustment of the suitabilities might reduce the excessive mortality of mature capelin. The MULTSPEC run with constant migration resulted in estimates of capelin SSB quite close to the base run, even though the sum of squares was substantially increased. This result holds promise that MULTSPEC can be used to predict capelin SSB with the mean migration pattern, without needing to predict deviations from the mean pattern. The runs of MSVPA with different years of stomach-content data indicated that model estimates of food consumption depended upon the data set selected. To the extent that these differences are due to changes in distribution, and not to predator-prey switching, MSVPA needs to

incorporate spatial structure when applied to boreal fish communities.

2.8.3.3 Alternative approaches for modelling migration

Markovian transition matrices work best for describing movement that is dispersive or unidirectional and time invariant. For species such as yellowfin tuna in the western Pacific, the migration proportions can be estimated from tagging studies (Hilborn 1990). The concept of Markovian transition breaks down for seasonal migration patterns because the fish must have some sense of "memory" about where they are going and where they have been. The need to specify a migration matrix for each month of the year, combined with the interannual variations in migration patterns, virtually eliminates the possibility of estimating the transition probabilities from tagging data.

An alternative to Markovian transition matrices is to assume that platoons of fish spend fixed amounts of time in each area. A platoon is defined as a group of fish recruiting to the population in a time interval. Each platoon is then tracked through the areas. The fish vulnerable to fishing or predation consist of all the platoons in that area at that time. This approach has been used to model the spawning migrations of Pacific salmon through gauntlet fisheries (Starr and Hilborn 1988). Assuming that fish spend a fixed amount of time in each area, reduces the number of migration parameters to estimate. However, increased book-keeping is required to track the distribution of each platoon.

A diagnostic for tuning the migration matrices was that they should reproduce seasonal distributions. A simpler approach may be to assume fixed proportions of the stock in each area in each month. The proportions could potentially vary from year to year depending on environmental conditions. With high mortalities, this approach could still be prone to having insufficient fish in an area, and unrealistic downstream effects. With a "backward" model, such as MSVPA, the problems of insufficient fish in an area are avoided because fish are added in as needed.

A further simplification is to ignore the spatial representation of migration and to incorporate the seasonal overlap in the suitability coefficients. On a monthly time step, the suitabilities could be modelled with a sine wave or other functional form. In this case, it would only be necessary to specify the amplitude and phase of the sine curve.

2.8.4 Treatment of growth

Numerous studies have documented the high variability in growth of cod in boreal ecosystems. Attempts to explain this variability have focused on the influence of stock size, the physical environment (especially water

temperature), and the abundance of prey, notably capelin (Anon. 1991; Mehl and Sunnanå 1991; Steinarsson and Stefansson 1991; Jørgensen 1992). Regression equations may be formulated to predict changes in cod growth based on any combination of these factors. A regression equation incorporating capelin abundance has been used by the Northwest Working Group to predict the growth of Icelandic cod, but such a model has not yet been used by the Arctic Fisheries Working Group to predict growth of Barents Sea cod.

A major purpose of BORMICON and MULTSPEC is to predict the growth of cod more accurately than is possible with regression models by incorporating predictions of annual variability in overlap of cod and its prey. The only prey considered at this time is capelin.

The first step is calculation of the feeding rate of the cod. Both models calculate feeding rate as a proportion of the maximum feeding rate. This proportion, or feeding level, is a function of the sum of the biomasses of individual prey weighted by their respective suitabilities. The maximum feeding rate of a cod of specified size at a specified temperature is taken from Jobling (1988).

In the present version of MULTSPEC, growth of cod of a specified length or weight is calculated from the feeding level and temperature. The parameters of this relationship have not yet been estimated using a statistical approach. However, they have been set so that the growth pattern and fluctuations modelled by MULTSPEC are in reasonably good agreement with observed growth.

In BORMICON, growth is calculated from feeding rate using bioenergetic considerations. Growth in weight is calculated from a relationship between growth, feeding, swimming speed and temperature (Jones 1974). Growth in length is calculated from growth in weight and condition. The bioenergetic model could be refined to take into account advances in understanding of activity metabolism, seasonal variability in partitioning of growth between body mass and gonads, and energetic value of the prey. It is seen in Figure 2.8.1 that refinements of BORMICON parameters are needed to better track the observed mean length-at-age.

The short time steps and relatively high number of areas possible in both models open possibilities for exploration of seasonal and spatial variability in growth. These would be fruitful to pursue intersessionally, or at a future meeting of this Working Group or of a special group assembled to conduct such analyses.

3. DIRECTION TO ARCTIC FISHERIES WORKING GROUP AND THE ATLANTO-SCANDIAN HERRING, AND CAPELIN, WORKING GROUP

3.1 Background

ACFM requested the Multispecies Assessment Working Group to provide direction to these two Working Groups "with regard to approaches and means of assessing impacts of predators on the stocks assessed by those groups, including, where possible, estimates of predation mortality and amounts eaten, and/or specific analytical approaches by which those Working Groups should produce such estimates." During discussion, consensus was reached quickly that none of the three multispecies models had reached a point where the quantitative estimates required by the Working Groups would be extracted from model results in a routine manner. Moreover, the issues of concern to the other Working Groups would not be addressed fully, even if estimates of predation mortality were provided by this Working Group. Therefore the MSA Working Group adopted the following approach.

Members of both the Arctic Fisheries Working Group and the Atlanto-Scandian Herring, Capelin, and Blue Whiting Working Group reviewed the core assessment problems facing each Working Group, with regard to multispecies interactions. The MSA Working Group framed each problem in the light of the multispecies databases which were available, and the multispecies analytical tools which the Working Group felt were most likely to provide useful and reliable uses of the data. In each case the recommended analyses require some population values which are expected to be updated by the area and species-based assessment Working Groups. Therefore, rather than doing the analyses with old population data, the MSA Working Group presents advice on how the two assessment Working Groups should obtain the necessary estimates for each core problem. The methods should be feasible to implement during the respective Working Group meetings.

3.2 Description of Multispecies Assessment problems

3.2.1 Arctic Fisheries Working Group

3.2.1.1 Growth of North-east Arctic cod

Individual growth of North-east Arctic cod is highly variable and related to the abundance of capelin and also to temperature. Problems in predicting the growth of cod caused severe problems in the management of cod in the last half of the 1980s (Mehl and Sunnanå, 1991). Since 1992, the growth of cod has been predicted by the Working Group in qualitative ways, choosing between high, medium or low growth options according to expected development of the prey stocks and the

temperature. Regressions relating the growth to the food abundance and temperature have been published, and should be relevant for the medium-term forecasting done by the Arctic Fisheries Working Group. In a next step multispecies models should underly the quantification of growth of cod with respect to food abundance and environmental variables.

It is worth emphasising that in this boreal group multispecies effects are supposed to be no less important in the short-term forecasts than in long-term forecasts.

3.2.1.2 Cod cannibalism

The stomach content data show that cod cannibalism is high and variable. Cod cannibalism can be quantified by including cannibalism in the VPA using stomach content data, as indicated by the work done on the MSVPA for the Barents Sea at this Working Group meeting (Section 2.3.3). It can also be included as 'catch' of ages 1-3 to improve the tuning of these age groups. In order to include cannibalism in the cod assessment, one will have to agree upon the methods for calculating the number consumed by age. When comparing the data on cod cannibalism used as input to the MSVPA, as given in Section 2.3.3 of this report, to the data presented by Bogstad et al. (1994), some discrepancies are apparent. These may be associated with the aggregation of the stomach content data, the age-length keys and weight at age data of prey, as well as the model used for gastric evacuation rate. Methods for predicting the cannibalism should be developed using multispecies models since the choice between young cod and other food organisms (including plankton) is important for forecasts of cannibalism.

3.2.1.3 Important issues not discussed by this Working Group

Predation by cod was thought to be a potentially significant source of mortality on haddock and redfish, at least when cod stocks are abundant. At this meeting only the results of cod predation on capelin were reviewed thoroughly. Therefore it is premature to advise on the magnitude of these interactions, and on estimates of the mortality levels. However, the interactions warrant investigation.

3.2.2 Atlanto-Scandian Herring, and Capelin Working Group

3.2.2.1 Norwegian spring spawning herring

3.2.2.1.1 Important issues not discussed by this Working Group

The Atlanto-Scandian Herring, and Capelin Working Group regularly discussed multispecies problems relating to Norwegian spring-spawning herring. It was not possible to review the cod-herring interactions within

either MULTSPEC or MSVPA during the time available for this meeting. Such a review is required, however, to address issues including:

- Natural mortality on juveniles.
- Preferable level of the stock in order to fully utilize the plankton production in the Norwegian Sea.
- Effect of cannibalism on recruitment in herring.

3.2.2.2 Barents Sea capelin

3.2.2.2.1 Input data used by the Working Group

The input used by the Atlanto-Scandian Herring, Blue Whiting and Capelin Working Group to assess the Barents Sea capelin stock include the following:

- The joint Russian-Norwegian trawl-acoustic survey. The abundance of capelin is given in number and mean weight by age and 0.5 cm length groups.
- The joint PINRO-IMR stomach content data base.
- Catch statistics as number and mean weight of capelin by age, length and season.
- Temperatures (Kola section, but also other sections might be included).

3.2.2.2.2 Short-term prediction

Prior to the collapse of the stock in the period 1983-1988 the catch was evenly divided on the autumn season (August-December) and the spring season (January-April). The assessment was done shortly after the September cruise. A constant escapement strategy was used for the management. An optimal spawning stock of about 0.4 million tonnes was calculated using the single-species model CAPELIN (Hamre and Tjelmeland, 1982).

The spawning stock - catch relation for the winter fishery in January-April involves a 6 month forecast of the maturing stock. Inputs for this forecast are:

- The trawl-acoustic estimate of the total stock.
- A maturation model.
- Natural mortality.
- Growth in weight.

The maturation rate, natural mortality, and growth in weight all may be influenced by multispecies interactions.

3.2.2.2.3 Important issues not discussed by this Working Group

Time did not permit this Working Group to discuss the problems relating to the 18-month forecast needed for advice on an autumn TAC. The impact of herring on capelin, both by direct predation and as a shield against predation from cod, was also not discussed. Finally, this Working Group did not review any results which would shed light on the effects of harp seals as predators on capelin.

3.2.2.2.4 Multispecies processes highlighted

The A.-S. Working Group divides the forecast into two periods: October to December and January to March, primarily because the coverage of stomach samples used to assess consumption from cod is much poorer in the former than in the latter period.

The natural mortality in October-December is based on estimates of the yearly natural mortality of immature capelin. These estimates are from assessments based on acoustic surveys. In recent years the increase of the cod stock has led to an expansion of its area of distribution. As a result, now there is some overlap between cod and capelin in the late autumn period, as well as during the winter. In order to make a better assessment of the natural mortality in this period there should be more stomach samples and cruises to assess the changing geographical distribution of cod during this period. The cruises that may be used are 1) a new demersal cruise in August conducted by IMR, 2) the joint PINRO-IMR pelagic cruise in September and 3) the demersal cruise carried out by PINRO in October-December.

For the January-March period the approach of the A.-S. Working Group assumes that all the natural mortality stems from consumption by cod. It is unclear to what extent harp seal migration from Spitsbergen - Franz Josef Land to the breeding areas in the entrance to the White Sea contributes to the natural mortality on capelin.

In the assessment a forecast of the mean capelin stomach content of cod is made and the consumption is worked out using the stomach evacuation rate model by dos Santos and Jobling (1992) and the recent assessment of the cod stock made by the Arctic Fisheries Working Group prior to the meeting of the Atlanto-scandian herring and capelin Working Group. The method is described by Bogstad and Gjørseter (1994). The following assumptions and input data are used:

- Capelin survey.
- Cod stock assessment.
- Only immature cod prey on capelin during January-March; the cod maturity ogive applied is taken from the cod assessment.
- Initial stomach content to mean stomach content ratio.
- Temperature.
- Overlap in time and space.

3.2.2.2.5 Past Management advice

Until 1983 the Working Group advised on specific quotas. When the first signs of the capelin collapse were apparent in 1984 the Group recommended caution and when the collapse was manifest in 1985 it recommended no catch.

In 1987 the Terms of Reference changed from "advice on any necessary management measures" to "provide catch options within safe biological limits".

Thereafter the Working Group provided a table with catch options and estimates of spawning stock. All normative judgement was left to the Mixed Russian-Norwegian Fishery Commission to take actions which kept the stock within "safe biological limits". However, in the present situation the stock is not considered "within safe biological limits" and no such table is provided.

Before the capelin stock recovers, the A.-S. Working Group would like to have a method for determining a target spawning stock developed and reviewed by ACFM, even though the application of the method is outside of the ACFM responsibility as long as the stock is "within safe biological limits".

3.2.2.3 Capelin in the Iceland, East-Greenland, Jan Mayen area

The Atlanto-Scandian herring and capelin Working Group is currently using fixed natural mortalities (0.035 per month) to account for predation and other sources of mortality of this capelin stock. The necessity to test the effects of spatial overlap of Iceland cod and capelin in relation to trophic interaction has been emphasized (Anon. 1992).

3.3 Advised methods for taking multispecies factors into consideration in the Arctic Fisheries Working Group and the Atlanto-Scandian Herring, Capelin and Blue Whiting Working Group.

3.3.1 Growth of cod for Arctic Fisheries Working Group

None of the three models reviewed at this meeting have reached a state of development and testing which allows this Working Group to recommend their use for predicting growth (or size) of cod. The Working Group explored the ability of both MULTSPEC and BORMICON to model growth or size of cod. In both cases results were promising, and warrant further development. The implementation of MSVPA which was reviewed did not model growth.

The Multispecies Assessment Working Group advises the Arctic Fisheries Working Group that the Report of its 1990 meeting (Anon. 1991) contains the results of tests of a number of empirical models for predicting cod growth from environmental variables including prey abundance and hydrographic attributes. The MSA Working Group still considers the conclusions and recommendations of that meeting to be valid, although some of the approaches have been developed further since that meeting. Results of these developments are

available in the literature. At least until the multispecies models have been developed and tested further, the AF Working Group is encouraged to apply the empirical models endorsed in Anon. (1991), or their successors.

The MSA Working Group also advises that stomach content data are a perfectly acceptable source of independent variables for predicting growth (and other things), as long as they are handled in statistically appropriate ways. The results of both the 1990 and the 1992 (Anon 1992) meetings suggest stomach contents data may be a good predictor of variation in growth, although the MSA Working Group has not had the opportunity to explore the appropriate analyses at its own meetings.

3.3.2 Advice on treatment of cannibalism of cod for the AF Working Group

The results reviewed at this meeting indicate that most cannibalism in North-East Arctic cod is inflicted on the age groups 0 - 3. This means the cannibalism is important for interpreting recruitment surveys and calculating or using recruitment indices. However, mortality on those age groups is unlikely to affect the older ages represented in the VPA. Although most of the cannibalism is inflicted by ages 4-8 or so, the young cod consumed comprise a small part of the diet of the older cod. Therefore growth in these ages is unlikely to be strongly dependent on availability of younger cod.

If estimates of cod predation mortality on prerecruit cod are required, at present they should be derived using the direct method of Tretyak (1993) or MSVPA. However, this would require a special run of MSVPA made for that purpose. We do not advise simply taking values from the Tables in Section 2. The cannibalism levels imply that routine yield per recruit methods are likely to provide pessimistic estimates of the F which maximizes yield per recruit. It appears that the highest yield could be obtained with somewhat higher exploitation rates than would be estimated from a single-species YPR.

3.3.3 Advice on predation mortality levels on Herring

The MSA Working Group did not review the role of herring in the models with sufficient detail to provide on advice on patterns of predation mortality in herring, or on factors affecting it.

3.3.4 Barents Sea Capelin

Based on the results reviewed at this meeting, the MSA Working Group advises that the Atlanto-Scandian Herring, and Capelin Working Group should consider predation mortality on capelin in its assessment of the stock dynamics. However, MULTSPEC is a much more complex tool than the ASHCBW Working Group requires to address this task. Rather, the Working Group

should use a simple empirical feeding relationship of cod on capelin. The best simple model for forecasting capelin predation mortality can be identified by testing the performance of each alternative model against the performance of MULTSPEC on the historic data set.

3.3.5 Capelin in the Icelandic, Greenland, Jan Mayen Areas

The recently developed BORMICON model should, in theory, possess the structure required to address questions of this type. However, at present the model is in an exploratory phase and final conclusions cannot be drawn. The preliminary findings discussed at the MSA Working Group meeting indicate a deficit in the capelin biomass and, hence, insufficient biomass to meet predation by cod and catches. Possible explanations for this discrepancy may be related to underestimation of the stock by acoustic measurements or underestimation of capelin recruitment by underestimation of pre-recruit mortality. Alternatively, the present "tuning" of the model, e.g. in relation to suitabilities, migrations and consumption, might also contribute to this discrepancy in one way or another.

Further work on the performance of the model is planned for the next months, in particular in view of cod-capelin interactions.

3.3.6 Other multispecies interactions of relevance to these Working Groups

Even the species interactions which were the subject of analyses at this meeting have not received definitive treatment. More work is required on several fronts. One area of special importance is the need for more sampling across the year, to describe better the seasonal changes in overlap of predators and prey, and other associated factors.

The roles of herring, marine mammals, seabirds, etc. are also relevant to advice on predation mortality on the species assessed by these Working Groups. However, even more work is required before quantitative estimates are available for the impacts these species have on their prey. The MSA Working Group chose to review the models' performances relative to cod and capelin, because the data were most extensive for these species. Also the signals from cod - capelin interactions were believed to be stronger than the signals for interactions with other species. It is reasonable to have the first tests of the models focus there. It is also reasonable to have the MSA Working Group review future analyses and models of the influences of other predators and prey on the species assessed by these other Working Groups.

4. O-GROUP STUDIES AND SPATIAL EFFECTS IN THE NORTH SEA MSVPA

Studies of the feeding of "0" group fish (see section 3.6.3 of Anon. 1994) clearly indicate that considerable within age group predation occurs. The Working Group noted that several papers on 0-group feeding and behaviour were being presented to the ICES Annual Science Conference and were grateful that they were made available to the Working Group. They underlined the type of within age group interactions that occur in the 0-group.

Such studies and the results of the 1991 stomach survey indicate that there maybe important effects of within 0-group predation on the dynamics of the species involved. The appropriate ways of modelling these effects are however, far from clear. Section 9.1 of Anon. (1994) (previous Multispecies Working Group) indicated possible modelling approaches but there has been little or no progress to report in this direction since the previous meeting. Clearly this is a difficult area that may need encouragement of individual modelling efforts.

No interessional progress was reported on investigating differences between the northern and southern North Sea with regard to stomach data or other matters associated with MSVPA runs. It was speculated that some relevant work might be presented at the Aarhus Symposium in July 1995. Again, without directed encouragement of individual efforts, the Working Group does not expect to see significant progress reported on this topic.

5. REVISION OF RATIONS IN NORTH SEA MSVPA

5.1 Problems with rations currently used in the model:

Ration estimates used at present have not been revised in 10 years. Those estimates were based on a few experiments performed between the mid 1970s and early 1980s. The major deficiencies of the rations presently used can be summed up as follows:

- 1) Estimates are based on a very limited number of experiments; in most cases only on one experiment:

Cod: 1 experiment with sprat, n approx. 30, 1 size class (Daan 1973).

Whiting: 2 experiments with sandeel, n approx. 30, 1 size class (Hislop et al. 1983)

Haddock: no experiments: it was assumed that rations amount to 86% of that of whiting of the same size

Mackerel: 2 experiments with euphausiids, n=830, several size classes (Mehl & Westgard 1983)

Saithe: 1 experiment with Norway pout, n=16, 1 size class (Gislason 1983)

- 2) Due to the limited number of experiments in most cases only one prey type has been used in the experiments. It is known from the work of Jones (1974) and dos Santos & Jobling (1992, 1995) that evacuation differs substantially for different food items.
- 3) Values for the mean stomach content, which is combined with the gastric evacuation rates to give the daily ration, were derived from the 1981 stomach content data base. From an analyses of data sets from subsequent sampling program in 1985, 1986, 1987 and 1991 it appeared that for some species mean stomach contents in some quarters may have been rather atypical.
- 4) The consumption models presently used are the Daan (1973) model for the gadoids, and Eggers (1977) model for saithe and mackerel, which is based on exponential evacuation. The Daan model fixes the allometric weight exponent of consumption to 0.67 based on assumptions in the model. In most other models the allometric exponent has to be derived from the data, which requires significant weight variation in the data set. There is an ongoing discussion about the best way to formulate evacuation and consumption models. Different approaches have been suggested by Jones (1974), Bromley (1988, 1991), dos Santos & Jobling (1992, 1995) and Temming & Andersen (1994).

5.2 New experimental results to be used for the improvement of ration estimates

Since the rations were fixed to the presently used values a lot of experimental work has been performed, which was partly reviewed at the workshop on gastric evacuation rates, held in Lowestoft in 1989. At this workshop a database format was agreed upon, defining a data structure for the results of evacuation experiments. The idea was to create an international database on gastric evacuation data. All scientists producing such data were invited to contribute to the database; allowing a variety of scientists independently to analyse the data. New experimental work has mainly been conducted for cod, whiting and mackerel:

Cod: experiments with more than 1400 individual fish have been performed by dos Santos & Jobling (1992, 1995) covering a wide range of temperatures, predator weights and prey items. An additional number of experiments covering approx. 1000 individual fish was performed by Temming (unpublished), focussing on weight and meal size variation and typical North Sea prey. Additional data from group feeding experiments have been produced by Bromley (1991).

Whiting: Experiments covering over 1000 individual fish were performed by Andersen & Temming (unpublished) covering a variety of temperatures, predator weights and North Sea prey species. Additional experimental work was conducted by Bromley (1988) and Robb (1990).

Mackerel: 6 experiments with 813 fish were performed by Bohle *et al.* (in prep) covering 2 temperatures, 1 size group and prey species sprat, sandeel and krill.

Haddock: improvement can be achieved by reanalysing the Jones (1974) data and comparing with the results of the other gadoids.

5.3 What improvement can be expected with regard to problems identified above?

- 1) For three of the key predators (cod, whiting and mackerel) ration estimates can now be based on a substantial number of experimental data, which should greatly increase the reliability of the results. In the case of haddock revised estimates can be derived in a more systematic way from a reanalysis of data given in Jones (1974).
- 2) For cod, whiting and mackerel experimental results are now available which were derived using a variety of relevant food items. It will have to be discussed, however, how prey-specific parameters should be used in the calculations. One way of making use of these data is to use prey-specific evacuation rates to convert the relative composition of the stomachs into the relative species composition of the predators' consumption. These estimates of the relative species composition of the consumption will then be entered into MSVPA instead of the relative species composition of the stomachs. A simple test of the magnitude of the effect of using different evacuation rates would be to alternatively use of the fastest and the slowest rates observed for relevant prey species.
- 3) Because additional data on the mean stomach content by quarter are available now for the years 1985, 1986, 1987 (Q1 and Q3 cod and whiting) and 1991 (all species all Q), some idea about the variability can be derived from these. In the case that no decision can be made about the 'true' values, at least some 'what if' scenarios can be computed.
- 4) Different models will be parameterized using the new data sets available, to reveal how dependent the actual consumption figures by age are on the formulation of a particular model. Preliminary work on this aspect was presented in Anon (1991).

5.4 What has to be prepared intersessionally?

All data should be made available to interested persons ahead of the meeting, leaving enough time to parameterize different models with these data. Fitting of

evacuation models to data should be done prior to the next meeting of the coordinators of the 1991 ICES stomach sampling project.

The dos Santos & Jobling (1992) model requires assumptions about the initial meal size. Often a value of two times the average stomach is applied. If this model is to be applied with more sophisticated ways of estimating the initial meal size, these procedures have to be developed and tested prior to the next meeting of the coordinators of the ICES stomach sampling project 1991.

For the Jones (1974) or Temming & Andersen (1994) models to be applied, correction factors have to be derived which take into account the effects of the stomach content distribution functions on the estimated rations. In these models individual stomach content values have to be raised to a power B ($0 < B < 1$) before the average is calculated. Because in the North Sea data sets the majority of data represents pooled samples, this cannot be done properly. With subsets of individual stomachs however, a correction factor can be applied to account for the bias. This analysis has to be completed prior to the next meeting of the coordinators of the 1991 ICES stomach sampling project.

In order to transform the relative species composition of the stomach contents into the relative species composition of the predators consumption, the prey specific and non prey specific evacuation parameters of several consumption models have to be made available ahead of the next meeting of the coordinators of the 1991 ICES stomach sampling project.

6. NORTH SEA MSVPA

The Working Group had not planned to conduct intensive analyses of the North Sea MSVPA at this meeting. However, as expected (see the last Working Group report (Anon 1994)), intersessional work led to revisions in the 1991 stomach data set, correcting problems with earlier data processing steps. It was important to determine if the revised data set meant that any of the conclusions from the 1993 meeting should be altered. Therefore contrasts were made among the "old" and "new" 1991 stomach data, and between some important MSVPA outputs using each of the data sets.

It was decided that a new key run should NOT be made at this meeting, however. Custodians of the 1991 stomach data wish to confirm the accuracy of the new data before endorsing a definitive MSVPA run. Moreover, there are concerns about inconsistencies in the way that prey weights were estimated (Section 6.3). These inconsistencies need to be reconciled so the stomach data sets are internally consistent. Finally, several Working Group members feel the treatment of

ration can be improved greatly (Section 5, Section 10.4), prior to a definitive MSVPA run for the North Sea.

6.1 Revision of the 1991 North Sea stomach contents data

Some time after the 1993 meeting of the MSA Working Group it was discovered that the program used to assemble the 1991 stomach contents data into the age-based predator/prey arrays used as input to MSVPA in 1993 contained errors. The program was repaired and new input files prepared during the current meeting. For some species/quarter combinations the 'old' and 'new' 1991 data differed substantially with respect to both the total weight of food present and the composition of the stomach contents. However, changes to some data values might not translate into equivalent changes in resultant suitabilities and predation mortalities, and both types of values are influenced by many other values in the full data set, and in the population estimates of the predators and prey.

6.2 Comparison of results using old and revised stomach data for 1991

A summary of the main results using only the old and new 1991 stomach data, is given in Table 6.2.1. The overall effect is small, leading to at most a few percent change in the estimates of prey eaten, and to even smaller changes in the biomass estimates.

The yearly amount of prey eaten by each predator is shown in Table 6.2.2. Here, the effect is larger in some cases. This is illustrated in Figure 6.2.1, where the quarterly food composition in 1991 in the diet of each predator, according to each of the two 1991 stomach data sets, is shown. For comparison, the food composition in 1991 as estimated using the 1981 stomach data, is also shown. In some instances, there are substantial differences between the results using the two 1991 data sets, although the food composition estimated from the 1981 stomach data differs far more.

Figure 6.2.2 shows a direct comparison between the individual suitabilities obtained by the old and the revised 1991 stomach data, and indicates that although some suitabilities have changed substantially, the majority are close to their previous value. The discrepancy between the suitabilities obtained using the revised 1991 data and those using the 1981 data is far more dramatic, as shown in Figure 6.2.3.

The difference between the suitabilities obtained using the 1981 stomach data and those using each of the 1991 data sets are compared in Figure 6.2.4. Again, there are only a few instances where these differences have changed. For cod and for haddock as predators, most changes are in the direction of better agreement with the revised 1991 stomach data. For whiting as predator, the

changes are more diverse. For saithe and mackerel as predators, the differences are almost identical.

Figure 6.2.5 shows the similar differences for the predation mortalities induced by each predator. The changes here are generally smaller, indicating that most of the changes in the suitabilities caused by the revision of the 1991 stomach data had only minor effects on the predation mortalities.

Figure 6.2.6 shows the distributions of the differences between suitabilities derived from the 1981 data and from the two sets of 1991 data. Generally, the fraction of large discrepancies has been reduced by the revision of the 1991 stomach data.

The general conclusion from these comparisons is that the changes induced by the present revision of the 1991 stomach data are small. Thus, the conclusions drawn in the studies of the suitabilities at the last meeting (Anon 1994) should still be valid.

6.3 Remaining problems with the North Sea stomach contents data.

The stomach contents data used as input to the MSVPA (for each predator age/prey age combination) are 1) the mean weight of food in the stomach and 2) an estimate of the weight of the prey when it was ingested by the predator. This second parameter has a direct bearing on the estimated weights of prey consumed by the predators.

Calculating the first value is relatively straightforward (although there is a bewildering variety of paths that can be taken to get from the original length-based stomach contents data, derived from fish sampled in individual hauls, to the aged-based total North Sea' value). However, it is not at all easy to assign a 'sensible' mean weight at ingestion to each predator age/prey age combination,

Estimated mean weights-at-age of each prey age class in the sea are available, or could in many cases be calculated without too much difficulty from quarterly survey data. But these are not in fact very useful. A small predator may only be able to eat the smallest individuals of some prey age classes. A large predator, even though it is capable of eating the complete size range of some or all prey age classes, may in practice prey mainly on the bigger individuals. Some information on the weights of prey that are actually eaten can be obtained from the stomach contents themselves. In the case of very fresh prey (which are, unfortunately, encountered rather infrequently), it is possible to determine their size, weight and age. Partially digested prey also provide some information; if it is assumed that all prey were 50% digested, their mean weight at ingestion can be estimated by doubling the mean weights found in the stomachs. This method, which was used for cod and haddock in

1981 and for all species in 1991, can produce some rather unlikely values for relatively scarce prey items, depending on whether these happened to be very fresh or almost completely digested (see Table 13 in Daan, 1989). Alternatively, prey lengths can be used to estimate prey weights. Whichever of these techniques is used, the prey data have to be transformed from weights-at-length into weights-at-age and this process can produce some very untidy results. (It should be possible to obtain direct information on prey weights and ages from the otoliths found in the stomachs; this approach is still being investigated.)

The weights included in the existing MSVPA stomach data input data files were calculated in a variety of ways and there are some large year-to-year differences that probably reflect methodologies rather than real differences. In addition, original input values sometimes had to be modified, often in a more or less arbitrary fashion, to get round particular problems. These changes have not been documented. The present situation is clearly unsatisfactory and there is a pressing need for a thorough examination and revision of the data before a definitive key run can be made.

In addition, there are still some problems concerning the 1981 whiting data. They have at last been re-entered using the IJmuiden ISR program and are available in the exchange tape format. However, a rather large proportion of the fish prey was coded as 'unidentified gadoids', 'unidentified clupeoids' etc. The program used to process the data in 1983 allocated such items to named species and size classes but the ISR analytical programs do not at present incorporate such a routine and consequently most of these unidentified fish do not contribute to the final outputs.

6.4 Summary and Recommendations

In summary, the following has to be done before a new key run is made:

1. The conversion of all stomach data from raw data to mean weights by prey species and age in the stomachs, should be reviewed and properly documented, and revised if necessary.
2. A revision of individual weights at ingestion for each prey category, using a uniform and well documented procedure.
3. Ideally, estimates of the variances should be provided along with these estimates. If necessary, smoothing should be considered as a means of obtaining consistent weights over years, ages and quarters.

Therefore the Working Group **recommends** a meeting of the stomach sampling coordinators should be held. Tasks to be undertaken at the meeting would include:

- a) Develop a consistent and defensible approach to assign prey weights to the stomach contents data. This may involve some smoothing of observations.
- b) Develop a strategy to ensure the approach in #1 is implemented consistently for all stomach data holdings associated with the 1981 and 1991 stomach data sets.
- c) Address other outstanding issues as outlined in Section 6.3, such as the 1981 whiting data.
- d) Establish and implement protocol for ensuring that these and other changes to the stomach data sets are documented, and that researchers will be working with the most current data sets.

These tasks must be completed before a definitive key run for the North Sea can be made.

In addition, the Working Group also **recommends** that methods be examined and an option selected for estimating the variance associated with stomach contents data. This work would be a precursor for moving MSVPA to a more formal statistical basis. This work could be undertaken in conjunction with the meeting above.

7. FUTURE OF MULTISPECIES ASSESSMENT WORKING GROUP AND COMPREHENSIVE FISHERIES EVALUATION WORKING GROUP

7.1 Background

The Working Group considered the Discussion Paper "A Proposal to Revitalize Methodological Working Groups" (Stefansson *et al.* 1995) and the associated Section 18. of the Draft Minutes of the May 1995 ACFM meeting. The Discussion Paper develops the argument that ICES is already moving to including estimation of risk in its assessments, and must expand these activities even more.

However, progress is slow and piecemeal, with bits of the work being done in the Methods Working Group (M Working Group), other bits in the Long-Term Management Measures Working Group (LTMM Working Group), and still other parts in the MSA Working Group. The paper also argues that risk assessment will become much more prominent in future ICES work, as a part of "comprehensive assessments". A good comprehensive assessment should include a full and detailed review of all the biological, economic, and technical processes and parameters which incorporates all features considered important in the context of harvesting the resource.

Also, the Discussion Paper highlights the growing competition for membership in the three existing methodological Working Groups. Because of the overlap in interest in analytical methods and uncertainty, many of the same individuals are desired by, and often want to be at, all three Working Groups. The Discussion

Paper concludes that meaningful progress on risk assessment and evaluation cannot be made within the present approach, and recommends formation of a Comprehensive Assessment Working Group.

ACFM discussed the proposal at length in May 1995, and will revisit the proposal at its September meeting. The conclusion of the May meeting was that a Comprehensive Fishery Evaluation Working Group would be established. The descriptions of the mandate and operations of the CFE Working Group were similar to the CA Working Group proposed in Stefansson *et al.* (1995). The fates of the MSA Working Group and the LTMM Working Group were not specified, but the M Working Group would be convened only on an "as-needed and if-needed basis". The ACFM report does note that the CFE Working Group would both undertake comprehensive assessments and develop necessary methodology, however, so the Multispecies Assessment Working Group infers it would be disbanded when the CFE Working Group was established.

7.2 MSA Working Group Comments

The Working Group has grave concerns that development of multispecies assessment tools will stall, if the MSA Working Group is disbanded. First, outside the Working Group format, actual development work won't get done. Although the development of algorithms and writing of code certainly could continue if individual national laboratories chose to support such work, such activities are only part of development of multispecies (or other) assessment tools. Development of actual assessment tools also includes the testing, modifying, retesting, and revision of those tools, within a peer review framework. Just as peer review of written products is essential for maintaining standards, this peer review of modelling and analysis tools is essential, and only occurs within the Working Group framework. The process of review in a Working Group serves a second function, as well. The process allows both developers and future users of the model to gain familiarity with and confidence in the model and its outputs. Multispecies assessment models are not simple, and without this Working Group review process, even if a good model could be developed it would be unlikely to be used widely.

The second reason for concern over development of multispecies assessment tools stalling if the MSA Working Group is disbanded is that there is immediate work needed on all the multispecies models which the MSA Working Group has reviewed. Although significant progress has been made with MSVPA in the North Sea, particularly with regard to the suitability and forecasting components, several important areas are not yet in a definitive condition. The estimation of ration, ability to provide outputs for quantification of uncertainty in predicted attributes, and the treatment of spatial scales and patterns in MSVPA are examples of

areas needing further work. The Working Group has just begun to participate meaningfully in development and review of multispecies assessment tools for boreal ecosystems. Much more progress can be made with continued focusing of effort.

The Working Group notes that when ACFM endorsed the concept of a CFE Working Group, it gave the CFE Working Group an explicit mandate for model development. The Working Group is simply sceptical that the developmental work would be given a high enough priority for meaningful progress to occur. ACFM nonetheless may be committed to replacing the methodological Working Groups with a CFE Working Group. If so, this Working Group stresses that the CFE Working Group must proceed in a manner which does not sacrifice a broad focus on large methodological issues, as it deals with specific comprehensive assessments. Otherwise it will not succeed in its mandate.

The Terms of Reference of a CFE Working Group are particularly important, because they will influence the ability of researchers to obtain permission to attend meetings. The Terms of Reference must be clear that meetings will simultaneously develop specific comprehensive assessments, and undertake work consistent with large-scale view of the generality of its responsibilities. Otherwise it will not draw in the necessary community of independent methodological expertise, and certainly would not obtain institutional approval for the multiple attendances required for development and application of CFE Working Group tools. The draft Terms of Reference do not yet have a sufficiently broad focus.

If ACFM decides that existing methodological Working Groups will be replaced by the CFE Working Group, this Working Group **recommends** that it still be allowed to meet once more. In the past two meetings of this Working Group, it has become clear that the treatment of food ration in MSVPA can be improved greatly. Much new knowledge has been acquired, and the new results bring into question some aspects of the present treatment of food ration in MSVPA. A thorough revision of the prey weights-at-age in the entire North Sea stomach contents database is also needed. Whether the revised treatment will make a big difference or a small one can be known only when the problems are addressed directly. A "definitive" key run, suitable for use and periodic updating by the area based Working Groups, requires both the improvements to the ration calculations, and use of the feeding data from the 1991 stomach sampling programme. A fully clean version of these data is just becoming available (Section 6.1). These tasks could be undertaken at this next meeting.

Thereafter the Multispecies Assessment Working Group would prefer to continue to exist. It would be suitable to meet on a more irregular basis, however, just as the

M Working Group will meet only as-needed and if-needed. The quality of the tools available for the CFE Working Group to use in addressing multispecies problems will be a good guide to those needs. Many members of the MSA Working Group expect there will be an urgent need for improvements to existing tools, and development and testing of new tools for multispecies assessment. They also believe that a CFE Working Group will find its workload sufficiently burdensome that development and testing of the tools can be achieved only through a Working Group focusing on those specific tasks.

8. SPATIAL DISAGGREGATION

The Working Group discussed Section 5 of the North Sea Demersal Fisheries Working Group report. Therein they review the standing request from the MSA Working Group for quarterly catch data disaggregated by sub-division of the North Sea. They highlight several possible problems posed by that request; some related to sampling schemes and some to the volume of work presented. The Report also notes the potential issues with data confidentiality. Perhaps most importantly, their comments suggest that there would be many potential users for the database, were it available. Therefore, it is important that the database be established in a format which is efficient to maintain and use, and which meets the needs of all (or as many as possible) legitimate users.

The MSA Working Group concurs with all the major points made by the Demersal Fish Committee. We stress, in particular, the point that there are many groups which require data on finer spatial scales than are available routinely at present. We also stress the inefficiencies created for many users through the use of many different patterns of spatial disaggregation of the North Sea. We strongly endorse the call for a Workshop on data issues for the North Sea. We feel both ACFM and ACME should review the data "customers" (to use the phrasing selected by the Demersal Fish Working Group) within their Working Groups, to ensure all appropriate custodians and customers participate in the workshop. We agree that good planning is necessary for a task of this scale to succeed. However, it is becoming increasingly clear that many Working Groups, including the MSA Working Group, require more highly, and more consistently disaggregated data. We **recommend** that ACFM give the workshop a strong mandate, and act to ensure appropriate representation from Working Group throughout ICES and associated partners.

The MSA Working Group further stresses that even if there is no agreement on spatial disaggregation of catch data, catch data disaggregated by quarter are essential, or MSVPAs cannot be run. The MSA Working Group **recommends** that ACFM direct other Working Groups to continue provision of quarterly catch data for the

North Sea, and for other areas in which multispecies assessments may be investigated in future.

9. THE FORM OF USEFUL MEDIUM TERM ADVICE

ACFM has asked that Working Groups "do risk analysis and provide the basis for medium-term advice. Guidelines are needed, although a number of approaches may be acceptable. The MBAL concept is a central component of medium-term advice. It might be an idea to ask [the Multispecies Assessment] Working Group to consider the multispecies effects in medium-term predictions". This topic was reviewed in the light of the results of the boreal multispecies assessment runs and the accumulated experience of the Working Group.

The MSA Working Group noted there were two major ways in which multispecies effects may influence predictions; through variable meeting of rations to predators and through variable predation mortality on prey. Moreover, the degree to which these processes affect advice may differ between boreal and more temperate fisheries systems.

Based on the models reviewed at this meeting, and analyses at this and previous meetings, growth dynamics are a stronger signal in boreal stocks. These in turn reflect more interannual variation in the success predators have meeting their feeding requirements. Therefore medium-term advice for boreal predators should be made relative to the habitat's ability to continue to provide reference levels of food. This in turn suggests that medium term advice will require forecasting of the dynamics of prey populations and linking predator growth to prey populations. In the North Sea, growth seems more systematic, suggesting less need for forecasting patterns of growth as functions of multispecies interactions.

Multispecies processes also can affect recruitment per spawner, and similar stock - recruit relationships. This is a more widespread process, with implications for estimates of yield and recruitment processes in temperate as well as in more boreal systems. In fact, MBAL itself has an implicit stock-recruit foundation. Target escapements for fisheries management must allow for variation in predator abundance, particularly when its variance is large.

This meeting's work indicated that cannibalism can be a significant source of mortality in 0 group to about age 3 cod. In terms of forecasting and estimating future yields, cannibalism functions like a special case of "multispecies interactions", although a case which can have strong impacts on the shape of the stock-recruit relationship. There is a larger suite of predators in the North Sea, so feedback of a particular species of predator is likely to be less direct and apparent. Nonetheless, past work by the

Working Group, in forecasting effects of effort changes, found different predictions for haddock using single and multispecies analysis methods (Anon 1988). This work illustrates a useful mode for presentation of medium-term results in a multispecies context.

According to current ICES terminology, risk assessment applied to medium or long-term advice necessarily includes forecasting recruitment in some way, so again multispecies effects on recruitment need to be considered. When time series are resampled as part of a risk assessment, to produce reliable estimates of uncertainty the resampling strategy must reflect the strength of the predator - prey dynamics (including predation by older ages on younger) as well as autocorrelative properties of the time series.

It is easy to provide a list of ways in which multispecies concerns are related to medium-term advice. It is less clear exactly what methods to advise using. Multispecies assessment models provide many of the desired predation estimates (or ration estimates), but require substantial work to parameterize and test prior to use. MSVPA has reached an operational point in a few temperate systems (North Sea, Baltic Sea), and the boreal models tested at this meeting show promise. Further work on multispecies assessment methods, including further developments of MSVPA, needs to raise the statistical rigour of model operations and predictions. Only then will ICES be in a position to include multispecies effects analytically in risk assessment and scientific advice. A continued review of analytical methods, of the type provided by the MSA Working Group, will be essential if ICES is to implement reliable tools for including multispecies effects in medium-term advice.

In fact, if the full complexity of multispecies interactions is taken into consideration, it can be argued that fisheries systems are too complex for complete and meaningful risk assessment. Nonetheless, there are analytical multispecies tools which can complement and contribute to the other analytical tools used to provide medium-term advice. If ICES is serious about undertaking risk assessments as part of its fisheries advice, it is important that these tools be used, and used wisely.

10. FOOD FOR THOUGHT

This section reports on ancillary findings or lines of inquiry which arose during the meeting, but which may not address core Terms of Reference or may not be developed sufficiently to be included as a basis for advice from the Working Group. In the past, several topics which began as Food for Thought have developed into noteworthy advances in multispecies assessments, and core activities of the Working Group.

10.1 A method of estimating the natural mortality rates of fish at different ages (exemplified by North-East Arctic cod)

This method was tabled by Dr. V. Tretyak, and modified for use as an alternative set of estimates of natural mortality.

The change in rates of fish natural mortality with age is presented by a convex downward one-minimum function tending to infinity when the age tends to the maximum possible of fish living under actual ecological conditions.

The function is:

$$\frac{dm}{dt} = a(t - t_s) / (t_e - t)$$

where :

- t_e - maximum possible of fish living under actual ecological conditions
- t_s - mean age of mature fish
- a - parameter

A method of estimating this function's parameters which has been already applied to the North-East arctic cod is suggested. They are equal to 0.105414 and 7.76761 respectively. Rates of natural mortality of cod at ages 3 to 15 are presented in the table below :

age, years	3	4	5	6	7	8
M	0,144	0,124	0,107	0,094	0,085	0,080

age, years	9	10	11	12	13	14	15
M	0,080	0,085	0,097	0,114	0,134	0,172	0,214

The results were discussed, compared with those available and may be used in analysing the dynamics of the North-East arctic cod.

10.2 Smoothing Estimates of Yield from the Barents sea MSFOR

The MSFOR method provides estimates of future steady state yield for the Barents Sea under changes in effort in the cod, capelin, shrimp and herring fisheries. Past studies of the North Sea (Anon. 1988 and 1994) indicated that a multispecies Schaefer model (quadratic approximation function in effort(cod), effort(capelin), effort(shrimp), effort(herring) formed quite good approximations to the results of MSFOR and hence provided a simple method of predicting the reaction of MSFOR to specific effort changes.

The model formulation for cod yield is:

$$\text{Yield(cod)} = F(\text{cod}) * \{a + b * F(\text{cod}) + c * F(\text{capelin}) + d * F(\text{shrimp}) + e * F(\text{herring})\}$$

Where F(cod)= proportional change in effort(cod) from current level etc.

Similar equations are used for the other species. Fitting model coefficients is achieved by using the current yield + the values of yield when each effort is reduced to 90% in turn.

The model predictions are likely to be similar to MSFOR for modest effort changes but may differ if substantial changes are made. Table 10.2.1 shows the results of the status quo and 10% change Quadratic and MSFOR simulations of long-term steady states. It also shows the results of a simulation of an "immediate post war" situation with both cod and herring effort reduced to 1/3 of current levels and no capelin or shrimp fishing. While not identical the two methods tell similar stories.

Experiments with varying effort indicated that changing the effort on any of the three prey species only affected the target species but that changes in cod effort produced more general results. Hence yield curves were drawn for each species with respect to change in the targeted effort and changes in the cod effort. These are shown in Figure 10.2.1 (cod yield), Figure 10.2.2 (capelin yield), Figure 10.2.3 (shrimp yield) and Figure 10.2.4 (herring yield). These indicate that cod is near maximum yield at current effort (N.B. MSFOR does not contain stock recruitment effects). Both capelin and herring benefit strongly by increasing effort on cod, and shrimp benefits marginally.

10.3 Notes on M2 as estimated in BORMICON

Annual predation mortality of capelin due to cod is not quite trivial to compute from the general BORMICON model since the maturation cohorts die after spawning in April in the model. M2 is therefore computed based on the change in the number of capelin in an age group between 31 December and 31 March along with the number consumed in the period. Similar computations are done for the period 30 September - 31 December.

Since migration patterns differ for mature and immature capelin, so will M2 differ by maturity stage and age.

Figures 10.3.1-10.3.4 show the M2 values for capelin as a function of cod biomass. The figures contain one point for each age group (1-3), maturity stage (i or m) and year (85-92), although years with indeterminate M2 (due to extinction) have been omitted.

The first two figures (10.3.1-2) show the results for the three-area simulation. It is seen that M2 can be quite neatly described as a linear function of 3+ cod biomass, although a separate line is required for each age and maturity stage.

On the other hand, Figures 10.3.3-4 show that in the 16-area scenario there is no such clear relationship.

Some care has to be taken in drawing conclusions from these examples and it must be remembered that neither example constitutes an endorsed model of the real ecosystem but they are simply simulation models intended as examples. It is clear, however, that it is possible for some parameterizations of BORMICON to obtain M2 values which bear simple linear relationships with cod biomass. It is equally clear that for other parameterizations no such relationship will exist, since it can easily be completely distorted due to variable overlap between the two stocks. Which of the two conclusions holds for the real system remains to be seen, but this may be clarified as the model is further developed so as to better reflect the real system (as indicated by the goodness of fit to various data sources).

10.4 A Review of New Work and Ideas on Ration Size

Food consumption by fish can be calculated by combining data on stomach content with models for gastric evacuation rate. In boreal systems, the stomach content and hence the consumption is highly variable. In the MULTSPEC project, we have used models for gastric evacuation rate of cod based on the work of Jorge dos Santos and Malcolm Jobling at the University of Tromsø (dos Santos and Jobling 1992, 1995).

Based on experiments with the Norwegian coastal cod using relevant prey items, relevant temperatures and a wide range of meal sizes, dos Santos and Jobling (1992) presented the following model for gastric evacuation rate for cod:

$$S_{it} = S_0 \exp \left[-\ln 2 \left(\frac{t}{H_i \exp(-cT) \left(\frac{S_0}{W} \right)^b} \right)^{K_i} \right] \quad (1)$$

where S_{it} is the stomach content at time t (hours) of prey i , S_0 is the initial meal size, W is the fish body weight (both in g) and H_i is the evacuation rate constant which is a theoretical value expressing for a given prey i the half-life (hours) of a meal of the same size as the fish body weight at 0° C. The shape parameter K_i determines the shape of the evacuation curve. Although the inclusion of the shape parameter K_i in this relationship increases its precision, setting $K_i=1$ for all prey does not detract substantially from the accuracy of the predictions, and greatly simplifies the model. When the parameter K_i is allowed to take any value we refer to equation (1) as the evacuation model in 'free form' in contrast to the situation where $K_i=1$ which is the 'restricted form'. When $K_i=1$, the values of the constants are $b=0.54$, $c=0.11$, $H=205$ (krill), 533 (shrimp), 452 (herring) and 283 (capelin).

For sequential meals, the best fit was found when the term S_0/W was changed following each new meal, assuming that the 'new' total stomach content is the stimulus driving the evacuation. If one assumes that over a period of days or weeks the fish reaches a steady state, i.e. the amount ingested equals the amount evacuated, then the consumption of prey i (assuming $K_i=1$) is given by:

$$C_i = -\frac{dS}{dt} = \frac{\ln 2 \exp(cT) W^b S_i}{H_i S_0^b} \quad (2)$$

Another problem here arises since the initial meal size S_0 is normally not known in field work. As a simplification S_0 may be approximated by a constant factor times the observed stomach content S . This was done e.g. by Bogstad and Mehl (1992), who set the meal size to 2.0 times the observed average total stomach content. Using the average stomach content instead of the individual stomach contents (which are available for the Barents Sea), introduces a bias which is dependent on the distribution function of the stomach content. A theoretical foundation for modelling of predation, which can be used to approach the meal size problem is given by Magnusson (1992). Tjelmeland and Alvarez (1994) attempted to overcome the meal size problem by fitting a simple feeding model for cod to the distribution of stomach contents from field data of individual cod stomachs. Another approach to the meal size problem using information on digestion degree of prey is presented in WD 4 and WD 7. The work in these papers could be combined and extended to describe how the feeding pattern of cod changes when feeding on different prey. This may give information on which meal size to use in different feeding situations, and also give more insight into the nature of predation processes.

In dos Santos and Jobling (1995), equation (1) is amended to:

$$S_{it} = S_0 \exp \left[-\left(\frac{t}{H_i \exp(-cT) S_0^b W^{-d}} \right)^{K_i} \ln 2 \right] \quad (3)$$

giving the following expression for the consumption:

$$C_i = -\frac{dS}{dt} = \frac{\ln 2 \exp(cT) W^d S_i}{H_i S_0^b} \quad (4)$$

In the restricted form, the value of the constants are now $b=0.52$, $c=0.13$, $d=0.26$, $H=41$ (krill), 103 (shrimp), 88 (herring), 58 (capelin), 30 (the polychaete *Arenicola*), 78

(squid), 68 (redfish), 62 (long rough dab), 84 (haddock) and 59 (polar cod). We see that the constants b and c (meal size and body weight dependence) have been very little changed from dos Santos and Jobling (1992), while the constant d (which in dos Santos and Jobling (1992) was equal to b , i.e. 0.52), has been significantly reduced to 0.26, and this has also led to a reduction of H_i for all species. The ratios between the values of H_i have changed very little, though. The decrease in d leads to a faster evacuation rate for small fish and slower rate for large fish using the model from dos Santos and Jobling (1995) compared to dos Santos and Jobling (1992). This is in good agreement with the results on food conversion efficiency obtained by Bogstad and Mehl, who found a too high food conversion efficiency for young fish using the model in dos Santos (1992). dos Santos and Jobling (1995) also tested the reliability of the consumption model by feeding cod sequential meals according to different feeding regimes using three prey species in long experimental series. At the end of each series, which lasted for at least 23 days, stomach content of the cod were analysed, and the daily food intake of each individual estimated using the consumption model. In most situations no statistically significant differences were detected between the estimated food intake and the observed steady-state consumption rate, which was set as the arithmetic mean consumption in the last 14 days of each series. This comparison was done using the evacuation rate model in 'free' form, but we think that using the 'restricted' form would not have made much difference in this respect.

According to Temming and Andersen (1994) the meal size problem can be avoided by reformulating the model. Using the same data set as dos Santos and Jobling (1992), they compared the fit of a model with and without meal size. They found that for capelin as prey, the model with meal size included explained 93 % of the variance, while without meal size, 89 % was explained. For herring the effect of excluding the meal size was much less and for shrimp it was negligible. Without meal size included, they obtain the following equation for consumption:

$$C_i = - \frac{dS}{dt} = \frac{S^i (c_i T) W^{d_i}}{H_i} \quad (5)$$

The exponent f_i in equation (5) can be compared with $1-b$ in equations (2) and (4) in order to see which power the stomach content is raised to in the various equations for consumption calculations, and it is then seen that these exponents are not very different.

The parameter values can be summed up in the following table (extracts from Table 2a in Temming and Andersen (1994)).

Prey	c_i	H_i	f_i
Capelin	0.13	190	0.47
Herring	0.14	35	0.43
Shrimp	0.11	74	0.27

For this model to be used in consumption calculations, parameter values for other prey items than capelin, herring and shrimp are needed, but this should be straightforward to obtain using the data in dos Santos and Jobling (1995). The different shape parameters for different prey items will make it difficult to use this equation for calculating the consumption based on individual stomachs with several prey items. It would be interesting to see how good the fit with and without meal size is if it is assumed that only H is prey-specific.

The models presented by dos Santos and Jobling (1995) and Temming and Andersen (1994) should be compared using the sequential meal experiments in dos Santos and Jobling (1995). Also, the effect of calculating the consumption based on individual stomachs vs. average stomach content should be investigated using a real data set from the Barents Sea.

In all the three papers on models for gastric evacuation rate mentioned, the confidence limits for the parameters are given. One should calculate the uncertainty in the consumption calculated for cod in the wild as a result of uncertainty in the evacuation rate model, and compare that to the uncertainty due to the field sampling. In Ajiad *et al.* (1994), a bioenergetic model for cod is applied, and it showed that the data on food consumption, as calculated using the work by dos Santos and Jobling (1992), and on growth of cod were in good agreement with each other. Such bioenergetic approaches can be a valuable supplement to consumption calculations as described above in order to determine ration size.

11. CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

1. Even the species interactions on boreal systems, which were the subject of analyses at this meeting, have not received definitive treatment. More work is required on several fronts. One area of special importance is the need for more sampling across the year, to describe better the seasonal changes in overlap of predators and prey, and other associated factors.
2. The availability of several multispecies models for boreal systems should be considered a desirable objective, rather than a redundant luxury.
3. It is important to use enhanced versions of MSVPA for modelling boreal systems, and to include quarter-

- and year- specific parameters wherever it is possible: rations, weight at age (in catches, in the sea and in stomachs) and residual natural mortality.
4. The tuning procedures applied in the boreal MSVPA (and potentially in other boreal models) has a number of shortcomings, both ideological and practical. The development of an automated procedure for multispecies tuning seems to be very important.
 5. The Working Group concludes that within an MSVPA approach, the post-spawning mortality must be included explicitly, or else the quarterly estimates of capelin numbers are likely to be seriously in error, even if the mean estimate for the year is reasonable.
 6. All three boreal models seemed to perform well at some things, but each also performed less well at some other things. Generally, however, where a model performed poorly at present (say, an inability to reconstruct proper lengths at age for cod as predators), the problem was not due to some structural error in the model. Rather, performance could be improved through simply obtaining better estimates for some model parameters.
 7. The participation by scientists from both the Murmansk and Moscow laboratories was extremely helpful to the Working Group, both for the long term data sets they provided and the models brought to the meeting. Continued participation by scientists from both VNIRO and PINRO is encouraged strongly.
 8. Among the most important questions identified by the Working Group, with regard to further developments in boreal multispecies models are:
 - a) The MSVPA results suggested medium term predictions of cod and capelin may be influenced strongly by herring as well. This result should be explored further, and if possible looked at in the other models.
 - b) What happens to "other prey"?
 - c) The multispecies information needs of fisheries managers in boreal systems need to be made more explicit.
 - d) The dynamics of F_{MSY} in the Barents Sea MSVPA (Section 2.6) suggest patterns which should be looked for in MULTSPEC and BORMICON. The influence of occasional large recruitments on the location of a multispecies F_{MSY} should also be explored.
 - e) Putting more things into the likelihood functions seem to have some beneficial effects on model performance, and should be explored further.
 9. The changes induced by the present revision of the 1991 stomach data are small. Thus, the conclusions drawn in the studies of the suitabilities at the last meeting (Anon 1994) should still be valid.
 10. The following has to be done before a new key run is made for the North Sea:
 - A: The conversion of all stomach data from raw data to mean weights by prey species and age in the stomachs, should be reviewed and properly documented, and revised if necessary.
 - B: A revision of individual weights at ingestion for each prey category, using a uniform and well documented procedure.
 - C: Ideally, estimates of the variances should be provided along with these estimates. If necessary, smoothing should be considered as a means of obtaining consistent weights over years, ages and quarters.
 11. With regard to the ACFM decision to create a Comprehensive Fishery Evaluation Working Group, the Multispecies Assessment Working Group would prefer to continue to exist (even after the meeting associated with recommendation #6. It would be suitable to meet on a more irregular basis; only as-needed and if-needed. The quality of the tools available for the CFE Working Group to use in addressing multispecies problems will be a good guide to those needs. The Working Group feels another meeting to review progress on boreal multispecies models, and apply further tests as warranted, would be very useful in about 3 years time.
 12. Many members of the MSA Working Group expect there will be an urgent need for improvements to existing tools, and development and testing of new tools for multispecies assessment. They also believe that a CFE Working Group will find its workload sufficiently burdensome that development and testing of the tools can be achieved only through a Working Group focusing on those specific tasks.
 13. The MSA Working Group expects little progress on matters addressing predation by O-group fish or MSVPA-related differences between northern and southern North Sea without clear direction on the types of activities needed (and their benefits) and strong encouragement to national laboratories to undertake such work.

11.2 Recommendations

1. During the meeting inconsistencies were discovered in some of the stomach-content data files for the Barents Sea. The Working Group **recommends** that a thorough review of the stomach-content data files should be made to permit a definitive key run for the Barents Sea.

2. In order to make Barents Sea multispecies modelling with MSVPA more reliable, the Working Group **recommends** use of joint Russian and Norwegian data on a quarterly basis: catch at age and weight at age (in catches and in the sea).
3. None of the three boreal multispecies models reviewed at this meeting have reached a state of development and testing which allows this Working Group to **recommend** their use for routine assessment applications. However, results of all three models were very promising, and warrant further development. The Working Group does feel each of the models could be applied with caution, and in conjunction with other approaches to individual problems.
7. The Working Group **recommends** that ACFM give the workshop on spatial disaggregation of catch data (originating with the Demersal Fish Committee) a strong mandate, and act to ensure appropriate representation from Working Groups throughout ICES and associated partners.
8. The MSA Working Group further stresses that even if there is no agreement on spatial disaggregation, catch data disaggregated by quarter are essential, or MSVPAs cannot be run. The MSA Working Group **recommends** that ACFM direct other Working Groups to continue provision of quarterly catch data for the North Sea, and for other areas which multispecies assessments may be investigated in future.

The Working Group **recommends** a meeting of the stomach sampling coordinators should be held. Tasks to be undertaken at the meeting would include:

- a) Develop a consistent and defensible approach to assign prey weights to the stomach contents data. This may involve some smoothing of observations.
- b) Develop a strategy to ensure the approach in #1 is implemented consistently for all stomach data holdings associated with the 1981 and 1991 stomach data sets.
- c) Address other outstanding issues as outlined in Section 6.3, such as the 1981 whiting data.
- d) Establish and implement protocol for ensuring that these and other changes to the stomach data sets are documented, and that researchers will be working with the most current data sets.

These tasks must be completed before a definitive key run for the North Sea can be made.

5. The Working Group **recommends** that methods be examined and an option selected for estimating the variance associated with stomach contents data. This work would be a precursor for moving MSVPA to a more formal statistical basis. This work could be undertaken in conjunction with the meeting above.
6. Even if ACFM decides that existing methodological Working Groups will be replaced by the CFE Working Group, this Working Group **recommends** that it still be allowed to meet once more. A "definitive" key run, suitable for use and periodic updating by the area based Working Groups, requires both the improvements to the ration calculations, and use of the feeding data from the 1991 stomach sampling programme. These tasks could be undertaken at this next meeting, and a key run produced. Because of the required data holdings and programmes, the meeting should be at ICES Headquarters.

12. REFERENCES

- Anon. 1988 Report of the Multispecies Assessment Working Group. ICES, Doc. C.M.1988/Assess:23
- Anon. 1991. Report of the Multispecies Assessment Working Group. ICES, Doc.C.M.1991/ Assess:7.
- Anon. 1992 Report of the Multispecies Assessment Working Group. ICES, Doc. C.M.1992 /Assess:16.
- Anon. 1993a. Report of the Arctic Fisheries Working Group. ICES, Doc. C.M.1995/Assess:1.
- Anon. 1993b. Report of the Atlanto-Scandian Herring and Capelin Working Group. ICES, Doc. C.M.1993/Assess:6.
- Anon. 1994 Report of the Multispecies Assessment Working Group. ICES Doc. C.M.1994/Assess:9.
- Anon. 1995a. Report of the Arctic Fisheries Working Group. ICES, Doc. C.M.1995/Assess:3.
- Anon 1995b. Report of the Atlanto-Scandian Herring and Capelin Working Group. ICES, Doc. C.M.1995/Assess:9. 101 pp.
- Anon. 1995c. Report of the Planning Group on Multispecies Assessment of Boreal Systems. ICES, Doc.C.M. 1995/Assess:10.
- Ajiad, A.M. , Smedstad, O. and Korsbrekke, K. 1994. Can a Bioenergetics Model Explain Growth of the Northeast Arctic Cod? ICES, Doc.C.M. 1994/G:7.
- Bogstad, B and H. Gjøsæter. 1994. A method for estimating the consumption of capelin by cod in the Barents Sea. ICES J.mar.Sci. 51: 273-280.

- Bogstad, B., Hauge, K.H. and Ulltang, Ø. 1995. Results of simulation studies using a multispecies model for the Barents Sea (MULTSPEC). International Whaling Commission, SC/47/NA1. 33 pp.
- Bogstad, B., Lilly, G.R., Mehl, S., Pálsson, O.K. and Stefansson, G. 1994. Cannibalism and year-class strength in Atlantic cod (*Gadus morhua* L.) in Arcto-Boreal ecosystems (Barents sea, Iceland and eastern Newfoundland). ICES mar. Sci. Symp., 198:576-599.
- Bogstad, B. and Mehl, S. 1992. The North-East arctic cod stock's consumption of various prey species 1984-1989. Pp. 59-72 in Bogstad, B. and Tjelmeland, S. (eds.). Interrelations between fish species in the Barents Sea. Proceedings of the fifth PINRO-IMR symposium, Murmansk 12 - 16 August 1991.
- Bohle B., Skagen D., Knutsen F., (in prep), Experimental studies of stomach evacuation in mackerel (*Scomber scombrus* L.).
- Bromley, P. G., 1988: Gastric digestion and evacuation in whiting, *Merlangius merlangus* (L.). J.Fish Biol., 33, 331-338.
- Bromley P., 1991, Gastric evacuation in cod (*Gadus morhua* L.), ICES mar.Sci.Symp., 193, 93-98.
- Daan, N. 1973. A quantitative analysis of the food intake of North Sea cod, *Gadus morhua*. Neth.J.Sea.Res., 8(1), 27-48.
- Daan, N. 1989. Data base report of the stomach sampling project 1981. ICES, Coop. Res. Rep 1989, No. 164, 144 pp.
- dos Santos, J. and Jobling, M. 1992. A model to describe gastric evacuation in cod, *Gadus morhua*, fed natural prey. ICES Journal. mar. Sci. 49, 145-154.
- dos Santos, J. and Jobling, M. in press. Test of a food consumption model for the Atlantic cod. ICES J. mar. Sci. 52.
- Eggers, D.M., 1977: Factors in interpreting data obtained by diel sampling of fish stomachs. J.Fish.Res.Board.Can., 34, 290-294.
- Gislason H., 1983: A preliminary estimate of the yearly intake of fish by saithe in the North Sea. ICES C.M.1983/G:52.
- Hamre J. and S. Tjelmeland 1982. Sustainable yield estimates of the Barents Sea capelin stock. ICES C.M. 1982/H:45.
- Hamre, J., 1985. Assessment and management of Barents Sea capelin pp. 5-24 in Gjoesaeter, H.-ed., Proceedings of the Soviet-Norwegian Symposium on the Barents Sea Capelin *Mallotus villosus*, IMR, Bergen, Norway
- Hilborn, R. 1990. Determination of fish movement patterns from tag recoveries using maximum likelihood estimators. Can. J. Fish. Aquat. Sci. 47:635-643.
- Hislop J., Robb A., Brown M, Armstrong D., 1983: A preliminary report on the analysis of the whiting stomach content collected during the 1981 North Sea Sampling Project. Int. Counc. Explor.Sea, C.M. 1983/G:59.
- Jobling, M. 1988. A review of the physiological and nutritional energetics of cod, *Gadus morhua* L., with particular reference to growth under farmed conditions. Aquaculture 70: 1-19.
- Jones R., 1974: The rate of elimination of food from the stomachs of haddock *Melanogrammus aeglefinus*, cod *Gadus morhua* and whiting *Merlagius merlagius*. J.cons.Int. Counc. Explor .Sea, 35(3), 225-243.
- Jørgensen, T. 1992. Long-term changes in growth of North-east Arctic cod (*Gadus morhua*) and some environmental influences. ICES J. mar. Sci. 49: 263-277.
- Magnusson, K.G. 1992. A model of predation. Science Institute, University of Iceland, RH-16-92.
- Magnússon, K. G. and Pálsson, Ó. K. 1989. Predator-prey interactions of cod and capelin in Icelandic waters. pp 153-170 in: N. Daan and M. Sissenwine, eds. Multispecies Models Relevant of Management of Living Marine Resources. ICES mar. Sci. Symp. 193.
- Mehl, S., and K. Sunnanå. 1991. Changes in growth of Northeast Arctic cod in relation to food consumption in 1984-1988. ICES mar. Sci. Symp. 193: 109-112.
- Mehl S. and Westgard T., 1983: Gastric evacuation rate in mackerel (*Scomber scombrus* L.). ICES, Doc.C.M. 1983/H:33.
- Rice, J.C., Daan, N., Pope J.G. and Gislason, H. 1991. The stability of estimates of suitabilities in MSVPA over four years of data from predator stomachs. pp. 34-45 in Daan, N. Sissenwine, M.P. eds. : Multispecies Models Relevant to Management of Living Resources Symp., The Hague (Netherlands), 2-4 Oct. 1989. ICES, Symposium vol. 193.

- Robb, A.P. 1990. Gastric evacuation in the whiting (*Merlangus merlangus* L.) ICES, Doc. C.M.1990/G:51, 9 pp.
- Starr, P. and Hilborn, R. 1988. Reconstruction of harvest rates and stock contribution in gauntlet salmon fisheries: Application to British Columbia and Washington sockeye (*Oncorhynchus nerka*). Can. J. Fish. Aquat. Sci. 1988. vol. 45 No. 12, pp. 2216-2229
- Stefansson, G, and O. Palsson. 1995. The BORMICON Manual. Privately published by the Iceland lab., and listed in the list of working papers.
- Stefansson, G. Stokes, K.L. and Rice, J.C. 1995. A proposal to Rejuvenate the Methodological Working Groups of ICES. Working paper for ACFM meeting, May 1995, ms.
- Steinarsson, B. Æ., and G. Stefansson. 1991. An attempt to explain cod growth variability. ICES, Doc.C.M. 1991/G:42.
- Temming, A. and Andersen, N. G. 1994. Modelling gastric evacuation without meal size as a variable A model applicable for the estimation of the daily ration of cod (*Gadus morhua* L.) in the field. ICES J. mar. Sci., 51:429-438,
- Tjelmeland, S. and Alvarez, J. 1994. Estimating initial stomach content using stochastic simulation. ICES C.M. 1994/G:16.
- Tjelmeland, S. and Bogstad, B. 1993. The Barents Sea Capelin Stock Collapse - A Lesson to Learn. In S.J. Smith, J.J. Hunt and D. Rivard [eds]. Risk Evaluation and Biological Reference Points for Fisheries Management. Can. Spec. Publ.Aq. Sci. 120: 127-139.
- Tretyak, V.L. 1984. A method of estimating the natural mortality rates of fish at different ages (exemplified by the Arcto-Norwegian cod-stock). pp. 238-271, in: Godoe, O.R.; Tilseth, S. eds. Soviet-Norwegian Symp. on Reproduction and Recruitment of Arctic Cod, Leningrad (USSR), 26 Sept. 1983. Institute of Marine Research Bergen, Norway.
- Tretyak, V.L. 1993. A Method of Estimating the Natural Mortality Rates of Fish at Different Ages (Exemplified by the Arcto-Norwegian Cod Stock. pp 241-274 in The Proceedings of the Soviet-Norwegian Symposium on Reproduction and Recruitment of Arctic Cod.

WORKING DOCUMENTS

Working Papers and documents distributed at the 1995 meeting of the Multispecies Assessment Working Group.

- WD 1 Models for Calculating the Food Consumption by Cod - B. Bogstad.
- WD 2 How are the Suitabilities used in MULTSPEC derived? - B. Bogstad.
- WD 3 A Method for Estimation of Predation Mortalities on Capelin Using a Cod-Capelin Model for the Barents Sea - B. Bogstad & S. Tjelmeland.
- WD 4 How to Estimate the Initial Meal Weight Parameter W_0 of the dos Santos Model of Evacuation for Various Regimes of Nutrition - T. Bulgakova, & D. Vasilyev.
- WD 5 The Results of Multispecies Analysis for the Barents Sea Fishery Community (Cod, Capelin, Shrimp, and Herring - T. Bulgakova, D. Vasilyev, V. Korzhev, & V. Tretyak.
- WD 6 Some Special Algorithms for the Barents Sea Fish Stomach Content Data Base Processing - T. Bulgakova, D. Vasilyev, A. Dolgov, & Z. Frolova.
- WD 7 VPA method with cannibalism for the Arcto-Norwegian Cod - V. Korzhev, V. Tretyak, & A. Dolgov.
- WD 8 Seasonal and Yearly Dynamics of the Barents Sea Cod Rations - T. Bulgakova, D. Vasilyev, A. Dolgov, and Z. Frolova.
- WD 9 Stefansson, G. and O. Palsson. 1995. BORMICON - A Boreal Migration and Consumption Model.

Other documents reviewed by the Working Group.

- Bogstad, B., M. Pennington, & J.H. Volstad. 1995. Cost-efficient survey designs for estimating food consumption by fish. *Fisheries Research* 23:37-46.
- Modin, J. 1994. General Comments to the Report of the Multispecies Assessment Working Group. mss.
- Shackell, N.L., P.A. Shelton, J.M. Hoenig, & J.E. Carscadden. 1994. Age- and Sex-Specific Survival of Northern Grand Bank Capelin (*mallotus villosus*). *Can. J. Fish. Aquat. Sci.* 51:642-649.

Table 2.2.1 Effect on the capelin spawning stock of changing initial capelin stock and initial meal size to mean stomach content ratio by 50%												
	Reference	50% in sto	50%inc in									
1984	365	1040	407									
1985	211	806	243									
1986	5	72	9									
1987	8	10	6									
1988	8	9	6									
1989	264	424	274									
1990	81	157	94									
1991	1877	3247	1960									
1992	1605	2802	1657									
Max cons	0.0054	0.0041	0.0039									
Half value	1.21	1.05	0.9									
Likelihood	459	390	421									

	Ref. run	One area	Cst. migr.	Cst. cons.	Suit. by ag	Cst. mat.			
1984	365	335	360	276	372	46			
1985	211	212	200	89	217	146			
1986	5	71	21	3	3	7			
1987	8	41	24	0	6	10			
1988	8	10	7	0	5	3			
1989	264	226	233	159	263	33			
1990	81	69	118	62	79	40			
1991	1877	1122	1900	1952	1895	0			
1992	1605	501	1628	1518	1598	841			
Halfvalue	0.0054	0.0015	0.006		0.005	0.005			
Max. cons	1.21	1.61	1.17	0.75	1.2	1.2			

Table 2.3.1. BORMICON. Initial and estimated values of selected parameters corresponding to the three runs.

	Parameter	Initial value run	Values obtained in estimation	Three area run
1	Cod(imm)-Cap(imm) suitab.-2	1.38	1.68	**
2	Cod(imm)-Cap(imm) suitab.-3	1.00	3.56	
3	Cod(imm)-Cap(mat) suitab.-2	1.38	0.71	
4	Cod(imm)-Cap(mat) suitab.-3	1.00	2.81	
5	Suitab. of imm. cod for "other food"	0.058	0.06	
6	Cod imm halffeeding value	4000	3867	
7	Cod(imm) migration -1	0.05	0.06	
8	Cod(imm) migration -2	0.05	0.01	
9	Cod(imm) migration -3	0.05	-0.02	
10	Cod maturity1	-8.08	-7.73	
11	Cod maturity2	0.062	0.066	
12	Cod maturity3	0.74	0.73	
13	Cod(mat)-Cap(imm) suitab.-2	1.38	2.01	
14	Cod(mat)-Cap(imm) suitab.-3	1.00	3.58	
15	Cod(mat)-Cap(imm) suitab.-2	1.38	-0.93	
16	Cod(mat)-Cap(imm) suitab.-3	1.00	1.84	
17	Suitab. of mat. cod for "other food"	0.058	0.051	
18	Cod matpredatorhalffeeding value	4000	4086	
19	Cap (imm) migration-1	0.15	0.05	
20	Cap (imm) migration-2	0.10	0.00	
21	Cap (imm) migration-3	0.01	0.03	
22	Cap (imm) migration-4	0.10	0.00	
23	Cap (imm) migration-5	0.20	0.18	
24	Cap (imm) migration-6	0.06	0.08	
25	Cap (imm) migration-7	0.12	0.00	
26	Cap (imm) migration-8	0.85	0.00	
27	Capelin recr. no.0	1.00	1.57	
28	Capelin recr. no.7	1.00	2.00	
29	Capelin recr. no.14	1.00	1.92	
30	Capelin recr. no.21	1.00	1.93	
31	Capelin recr. no.28	1.00	-0.06	
32	Capelin recr. no.35	1.00	0.04	
33	Capelin recr. no.42	1.00	1.45	
	SSE	3.84	2.00	4.02

Functions of parameters:

1&3: Optimum of the ln(length) relationship between predator and prey.

2&4: Peak value of the suitability function

5&17: Suitability of "o.f." for imm. cod : Constant suitability

6&18: Half feeding values of cod.

7-9: Coefficients describing dispersion, and west and south-east migrations, respectively.

10-12: Describe maturation of cod.

13-16: Same as 1-4.

19-26: Capelin migration parameters.

27-34: Capelin recruitment scaling parameters for 1985-91, respectively.

** These final parameter values were not available at the end of the meeting. The SSE presented in the table was the minimum reached during the time available.

Table 2.4.1 F,N,M,2 For Barents Sea, from baseline MSVPA Run

a) Cod

BARENTS SEA WITH DATA FOR 1980 - 1993
WITH STOMACH CONTENT DATA FOR COD 1984-1992

MULTISPECIES VPA (average suitability)

FISHING MORTALITY

COD

AGE 1980 1981 1982 1983 1984 1985 1986

0	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0445	.0284	.0629	.0193	.0261	.0524	.0269
4	.1583	.1386	.2380	.4332	.3576	.1674	.2056
5	.4164	.2711	.1812	.3535	.3425	.3921	.5241
6	.7057	.5900	.6285	.5410	.6378	.6503	.7899
7	.7564	.9531	.8920	.8722	1.1342	1.0797	.9952
8	.7905	1.1840	1.0994	1.1273	1.3021	1.1111	1.1298
9	1.0141	1.3906	1.2377	1.0711	1.3296	1.1502	.8069
10	1.1678	1.2451	.7767	.9031	.9409	.7809	.9643
11	1.4059	1.0957	.8096	.5333	.7805	.4699	.8375
12	.8308	.7885	1.0321	.4676	.7079	.4366	.8195
13	.9488	1.1402	.4206	.6116	.6388	.5051	.3149
14	1.6841	.3882	.5011	.5164	.2014	2.2184	.6399
15	1.0067	.4989	.5173	.3909	.1202	.9355	.6988

MEAN F (UNWEIGHTED) FOR AGES 5 TO 13

.8929 .9620 .7864 .7201 .8682 .7307 .7980

FISHING MORTALITY

COD

AGE 1987 1988 1989 1990 1991 1992 1993

0	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0009	.0002
2	.0000	.0000	.0000	.0004	.0012	.0011	.0008
3	.0278	.0592	.0306	.0108	.0142	.0352	.0157
4	.1796	.2699	.1601	.0547	.0724	.1469	.0963
5	.6063	.5425	.2482	.1128	.2057	.3094	.3720
6	1.1104	.7141	.4377	.1977	.2577	.4452	.7076
7	1.1195	1.2237	.7038	.2600	.3692	.3973	.5399
8	1.2330	.8632	1.0109	.3614	.3242	.3906	.3319
9	1.0879	1.1625	1.7418	.3732	.3405	.3403	.2863
10	1.1030	1.6694	.9078	.5384	.2738	.2829	.3353
11	.8007	2.0079	.5820	.2353	.1645	.1703	.2524
12	.9793	1.3913	.4551	.3169	.0578	.5961	.4130
13	.4672	1.6723	.1702	.7584	.0301	.0256	1.4877
14	.4242	.9333	1.9191	.3089	.1547	.3289	.2860
15	1.1271	.9883	.9860	.9692	.1023	.4397	.2820

MEAN F (UNWEIGHTED) FOR AGES 5 TO 13

.9453 1.2496 .6953 .3505 .2248 .3286 .5251

STOCK NUMBERS		COD					
AGE	1980	1981	1982	1983	1984	1985	1986
0	0.	0.	0.	0.	0.	0.	0.
1	237646.	251278.	450467.	573409.	1130310.	386286.	417416.
2	145717.	174752.	192884.	350153.	447428.	855588.	272698.
3	95020.	129351.	154654.	170707.	313476.	401181.	763285.
4	122893.	77161.	103642.	123900.	144166.	263488.	328982.
5	252027.	91743.	58748.	71443.	70263.	88178.	194922.
6	82215.	148111.	62346.	43679.	44708.	44460.	53091.
7	34438.	36731.	74292.	30090.	23008.	21379.	20994.
8	14029.	14784.	12953.	27849.	11505.	6770.	6643.
9	5674.	5863.	4168.	3974.	8310.	2883.	2053.
10	4785.	1900.	1347.	1116.	1257.	2030.	842.
11	929.	1371.	504.	571.	417.	452.	856.
12	146.	208.	419.	205.	306.	175.	258.
13	39.	57.	85.	135.	116.	136.	102.
14	34.	13.	16.	49.	64.	54.	72.
15	17.	11.	16.	20.	105.	68.	9.

TOTAL STOCK BIOMASS ON 1.JANUARY							
	782585.	810269.	768663.	650986.	941595.	912812.	1239324.
SPAWNING STOCK BIOMASS ON 1.JANUARY							
	214922.	265797.	259657.	240513.	216256.	164699.	172049.
TOTAL STOCK BIOMASS ON Q=2							
	708144.	680948.	543539.	658939.	867656.	732159.	1168407.
TOTAL STOCK BIOMASS ON Q=3							
	664343.	586784.	562312.	858759.	941151.	1108239.	1204249.
TOTAL STOCK BIOMASS ON Q=4							
	647421.	688107.	675103.	846154.	819921.	1057576.	1150646.

STOCK NUMBERS		COD					
AGE	1987	1988	1989	1990	1991	1992	1993
0	0.	0.	0.	0.	0.	0.	0.
1	282502.	328446.	670565.	1315252.	1606260.	1484615.	1176511.
2	215561.	160101.	185701.	440956.	879807.	996578.	911468.
3	236116.	179036.	137801.	155960.	367102.	731149.	822269.
4	641428.	194534.	140917.	103398.	125651.	295411.	586002.
5	234252.	468746.	129897.	105014.	85616.	102222.	223059.
6	102857.	113854.	242840.	90317.	83605.	62111.	66858.
7	21805.	30661.	50443.	141838.	67059.	58461.	36008.
8	7098.	6511.	8249.	22826.	100027.	42400.	35941.
9	1977.	1906.	2530.	2765.	14651.	66638.	26431.
10	846.	615.	550.	409.	1758.	9622.	43773.
11	296.	259.	107.	204.	220.	1231.	6681.
12	339.	121.	32.	54.	148.	171.	949.
13	103.	115.	27.	18.	36.	126.	85.
14	65.	57.	19.	20.	7.	31.	108.
15	45.	54.	28.	4.	56.	12.	53.

TOTAL STOCK BIOMASS ON 1.JANUARY							
	1092412.	998279.	871920.	1084689.	1442642.	2265984.	3636308.
SPAWNING STOCK BIOMASS ON 1.JANUARY							
	176204.	186548.	232810.	369413.	625926.	973980.	892282.
TOTAL STOCK BIOMASS ON Q=2							
	1115939.	916324.	876544.	901352.	1182664.	1809363.	3309945.
TOTAL STOCK BIOMASS ON Q=3							
	1010246.	973978.	905263.	1153748.	1565567.	2675068.	3072452.
TOTAL STOCK BIOMASS ON Q=4							
	1049662.	957203.	895914.	1284555.	1848324.	2857331.	2877152.

PREDATION MORTALITY			COD				
AGE	1980	1981	1982	1983	1984	1985	1986
0	.2109	.1088	.0806	.0612	.0619	.0765	.1495
1	.1874	.1444	.1319	.1280	.1585	.2282	.5408
2	.0391	.0422	.0421	.0306	.0291	.0342	.0640
3	.0437	.0731	.0388	.0296	.0276	.0260	.0270
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000	.0000
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000
14	.0000	.0000	.0000	.0000	.0000	.0000	.0000
15	.0000	.0000	.0000	.0000	.0000	.0000	.0000

PREDATION MORTALITY			COD				
AGE	1987	1988	1989	1990	1991	1992	1993
0	.1792	.3457	.1723	.1665	.1105	.1052	.1891
1	.4479	.4502	.2992	.2821	.3573	.3670	.5407
2	.1057	.0700	.0945	.1029	.1039	.1111	.1440
3	.0459	.0602	.1366	.0853	.0831	.0661	.0750
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000	.0000
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000
14	.0000	.0000	.0000	.0000	.0000	.0000	.0000
15	.0000	.0000	.0000	.0000	.0000	.0000	.0000

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

Table 2.4.1 F,N,M,2 For Barents Sea, from baseline MSVPA Run (Cont'd)

b) Capelin

FISHING MORTALITY			CAPELIN				
AGE	1980	1981	1982	1983	1984	1985	1986
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0038	.0028	.0056	.0274	.0670	.0340	.0000
2	.0443	.0337	.1256	.2865	.3256	.3013	.0040
3	.2103	.4437	.4639	.5869	.5398	.6624	.2248
4	.6127	1.6571	.8303	1.7540	1.2019	2.2260	.9210
5	.8857	3.2496	2.1206	4.3752	1.3306	2.0108	.1268
6	1.5259	3.9480	.3528	2.7421	.7424	2.7479	.0326
MEAN F (UNWEIGHTED) FOR AGES 2 TO 5			.8851	1.7506	.8495	1.3001	.3192

FISHING MORTALITY			CAPELIN				
AGE	1980	1981	1982	1983	1984	1985	1986
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0038	.0028	.0056	.0274	.0670	.0340	.0000
2	.0443	.0337	.1256	.2865	.3256	.3013	.0040
3	.2103	.4437	.4639	.5869	.5398	.6624	.2248
4	.6127	1.6571	.8303	1.7540	1.2019	2.2260	.9210
5	.8857	3.2496	2.1206	4.3752	1.3306	2.0108	.1268
6	1.5259	3.9480	.3528	2.7421	.7424	2.7479	.0326
MEAN F (UNWEIGHTED) FOR AGES 2 TO 5			.8851	1.7506	.8495	1.3001	.3192

FISHING MORTALITY			CAPELIN				
AGE	1987	1988	1989	1990	1991	1992	1993
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0190	.0249	.0000
2	.0000	.0000	.0000	.0000	.0362	.1072	.0068
3	.0000	.0000	.0000	.0000	.6345	.2954	.1337
4	.0000	.0000	.0000	.0000	.3026	1.0603	1.9324
5	.0000	.0000	.0000	.0000	1.0858	1.3418	1.1196
6	.0000	.0000	.0000	.0000	1.3894	2.6931	.1584
MEAN F (UNWEIGHTED) FOR AGES 2 TO 5			.0000	.0000	.5148	.7011	.7982

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

STOCK NUMBERS		CAPELIN					
AGE	1980	1981	1982	1983	1984	1985	1986
0	0.	0.	0.	0.	0.	0.	0.
1	321469200.	322307200.	261047400.	151745300.	53015520.	26246240.	112703600.
2	178066100.	206219200.	206978000.	167223000.	95230500.	31002340.	14848840.
3	255603200.	145082400.	170879300.	156860300.	107694900.	57342940.	17970510.
4	126142000.	99307330.	44843300.	52206910.	42315260.	28821300.	11798990.
5	7423426.	25745360.	7365208.	7761616.	3624264.	4808204.	1013960.
6	104927.	1173081.	575650.	364508.	49223.	381037.	321920.

TOTAL STOCK BIOMASS ON 1.JANUARY							
	8033330.	7111669.	6517561.	5222332.	3278484.	1915168.	925428.
SPAWNING STOCK BIOMASS ON 1.JANUARY							
	5726186.	4763106.	3882446.	3696950.	2282926.	1531183.	456871.
TOTAL STOCK BIOMASS ON Q=2							
	4191242.	4588660.	4071468.	4179526.	1986734.	913385.	617244.
TOTAL STOCK BIOMASS ON Q=3							
	7446342.	6025571.	5057129.	3917455.	2677275.	879944.	1100092.
TOTAL STOCK BIOMASS ON Q=4							
	7484357.	5776064.	5542395.	4273603.	2107517.	889548.	962947.

STOCK NUMBERS		CAPELIN					
AGE	1987	1988	1989	1990	1991	1992	1993
0	0.	0.	0.	0.	0.	0.	0.
1	79022780.	139658100.	332401300.	435525200.	169339700.	143439600.	5973453.
2	60529540.	45238920.	81144890.	197896700.	263179500.	97266270.	79442480.
3	9865892.	43120740.	33641640.	64503440.	160268000.	199054200.	64343040.
4	4132741.	2753037.	14678870.	12660060.	26532400.	34431000.	57938200.
5	937892.	736831.	571202.	3680879.	3877769.	5987485.	3536208.
6	299670.	273306.	260837.	261838.	1256102.	413300.	632863.

TOTAL STOCK BIOMASS ON 1.JANUARY							
	892470.	1469644.	2874234.	5069627.	6106425.	4702095.	2311852.
SPAWNING STOCK BIOMASS ON 1.JANUARY							
	237283.	698077.	1038530.	1598736.	3069979.	3455938.	1792269.
TOTAL STOCK BIOMASS ON Q=2							
	602851.	1113619.	2306229.	3229684.	4249752.	3430747.	1380412.
TOTAL STOCK BIOMASS ON Q=3							
	1131521.	1771213.	3056034.	5428856.	5231960.	2782952.	974115.
TOTAL STOCK BIOMASS ON Q=4							
	1459674.	2311919.	4639888.	5420082.	5197953.	2871676.	1142975.

PREDATION MORTALITY			CAPELIN				
AGE	1980	1981	1982	1983	1984	1985	1986
0	.0066	.0072	.0060	.0062	.0081	.0112	.0117
1	.0702	.0703	.0699	.0686	.0996	.1656	.2516
2	.0726	.0663	.0637	.0656	.0937	.1560	.3168
3	.1551	.1505	.1419	.1433	.1983	.3386	.6650
4	.2766	.2445	.2238	.2137	.2729	.4213	.9112
5	.2478	.1993	.1931	.1911	.2283	.3427	.7756
6	.1103	.1068	.1046	.1395	.1369	.1779	.4216

PREDATION MORTALITY			CAPELIN				
AGE	1987	1988	1989	1990	1991	1992	1993
0	.0114	.0097	.0117	.0111	.0171	.0275	.0373
1	.1878	.1730	.1486	.1337	.1654	.1960	.3083
2	.2511	.2082	.1415	.1229	.1551	.2180	.3427
3	.6964	.4976	.3973	.3084	.3234	.3588	.6489
4	1.0243	.8727	.6833	.4832	.4861	.5156	.9381
5	.9657	.7989	.5381	.4334	.4574	.4893	.8160
6	.3825	.2904	.2437	.2476	.4767	.3140	.4609

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

Table 2.4.1 F,N,M,2 For Barents Sea, from baseline MSVPA Run (Cont'd)

c) Shrimp

FISHING MORTALITY			SHRIMP				
AGE	1980	1981	1982	1983	1984	1985	1986
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0742	.0716	.0513	.1229	.1110	.1617	.1379
3	.3648	.1796	.1702	.3109	.5456	.5197	.2667
4	.3074	.1812	.1387	.2022	.2459	.4674	.1329
5	.6570	.2678	.4278	.2071	.3197	.2378	.2439
MEAN F (UNWEIGHTED) FOR AGES 2 TO 4			.1201	.2120	.3008	.3829	.1792

FISHING MORTALITY			SHRIMP				
AGE	1987	1988	1989	1990	1991	1992	1993
0	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0205	.0445	.0131	.0378	.0210	.0250	.0711
3	.3190	.1665	.1746	.1243	.1913	.1418	.0976
4	.1002	.1143	.1021	.2278	.0822	.1390	.0687
5	.2890	.3722	.4366	.2506	.3022	.0771	.6495
MEAN F (UNWEIGHTED) FOR AGES 2 TO 4			.0966	.1300	.0982	.1019	.0791

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

STOCK NUMBERS		SHRIMP					
AGE	1980	1981	1982	1983	1984	1985	1986
0	0.	0.	0.	0.	0.	0.	0.
1	59425630.	67003310.	46398080.	68235210.	76440740.	41860140.	93703560.
2	37994860.	45675820.	52238620.	36133530.	52696630.	57985580.	29919840.
3	20557770.	30289110.	36872280.	43228140.	27782800.	40042260.	39388450.
4	7597514.	12182370.	21850790.	27098640.	27773430.	13884250.	19688440.
5	1535135.	4762137.	8741980.	16369880.	19002350.	18354670.	7108753.

TOTAL STOCK BIOMASS ON 1. JANUARY							
	244582.	365507.	506261.	619039.	623894.	569435.	454411.
SPAWNING STOCK BIOMASS ON 1. JANUARY							
	109649.	193476.	314120.	439846.	440003.	360821.	287683.
TOTAL STOCK BIOMASS ON Q=2							
	233117.	346474.	476278.	572621.	569031.	504543.	392741.
TOTAL STOCK BIOMASS ON Q=3							
	212767.	313228.	433849.	502267.	465677.	384630.	328116.
TOTAL STOCK BIOMASS ON Q=4							
	178954.	275493.	376123.	409440.	360581.	279320.	268026.

STOCK NUMBERS		SHRIMP					
AGE	1987	1988	1989	1990	1991	1992	1993
0	0.	0.	0.	0.	0.	0.	0.
1	86956760.	127617700.	67677240.	102764700.	160002300.	73550180.	61102590.
2	61675750.	57450660.	92550650.	51069210.	77645620.	111240200.	50414070.
3	19471200.	45696430.	43380610.	74908140.	40594090.	60917890.	85120370.
4	22976300.	10627400.	29511250.	28822390.	54562950.	27633680.	42718290.
5	13307360.	16516330.	7594853.	22248860.	19243690.	41443350.	19406640.

TOTAL STOCK BIOMASS ON 1. JANUARY							
	521231.	575528.	661454.	856846.	940046.	1096086.	823507.
SPAWNING STOCK BIOMASS ON 1. JANUARY							
	332850.	330948.	369288.	574062.	655566.	729705.	542620.
TOTAL STOCK BIOMASS ON Q=2							
	430093.	478241.	608761.	775751.	870806.	982321.	743808.
TOTAL STOCK BIOMASS ON Q=3							
	363848.	385478.	543370.	655957.	749042.	807289.	615674.
TOTAL STOCK BIOMASS ON Q=4							
	308602.	327885.	484255.	561552.	636595.	578486.	507294.

PREDATION MORTALITY		SHRIMP					
AGE	1980	1981	1982	1983	1984	1985	1986
0	.0775	.0723	.0800	.0829	.1466	.2667	.5171
1	.0632	.0489	.0500	.0584	.0763	.1358	.2182
2	.0725	.0625	.0580	.0599	.0836	.1450	.2117
3	.0785	.0670	.0578	.0515	.0681	.1102	.1923
4	.0397	.0307	.0301	.0328	.0483	.0820	.1388
5	2.1801	1.7951	1.6864	1.4041	1.6644	2.4996	4.5067

PREDATION MORTALITY		SHRIMP					
AGE	1987	1988	1989	1990	1991	1992	1993
0	.3451	.1668	.1199	.0852	.1437	.3055	.5742
1	.2145	.1213	.0816	.0803	.1635	.1777	.2999
2	.1994	.1565	.1184	.1118	.1416	.1626	.2708
3	.2065	.1908	.1542	.1126	.1133	.1331	.2348
4	.1099	.1016	.0603	.0561	.0728	.0944	.1627
5	4.4544	4.2027	3.4992	3.6106	3.8244	3.9103	5.9566

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

Table 2.4.1 F,N,M,2 For Barents Sea, from baseline MSVPA Run (Cont'd)

d) Herring

FISHING MORTALITY		HERRING					
AGE	1980	1981	1982	1983	1984	1985	1986
0	.0093	.0129	.0299	.0013	.0153	.0090	.0534
1	.0002	.0022	.0025	.0093	.0000	.0090	.0007
2	.0004	.0077	.0006	.0060	.0079	.0051	.0036
3	.0116	.0062	.0143	.0156	.0256	.1113	.0205
4	.0080	.0111	.0157	.0295	.0357	.1252	.1342
5	.0065	.0152	.0140	.0245	.1170	.1531	.1698
6	.0096	.0081	.0143	.0250	.0622	.4036	.2149
7	.0108	.0068	.0092	.0201	.0679	.3056	.7027
8	.0122	.0073	.0098	.0078	.0608	.4900	.8392
9	.0006	.0122	.0068	.0114	.0573	.3867	.9258
10	.0000	.0096	.0055	.0106	.0530	.1094	1.2737
11	.2386	.0674	.0044	.0083	.0120	.1404	.3297
12	.0360	.0295	.0295	.0393	.0295	.0299	.9768

MEAN F (UNWEIGHTED) FOR AGES 5 TO 10							
	.0066	.0099	.0099	.0166	.0697	.3081	.6877

FISHING MORTALITY		HERRING					
AGE	1987	1988	1989	1990	1991	1992	1993
0	.0205	.0017	.0004	.0002	.0000	.0000	.0000
1	.0378	.0062	.0003	.0000	.0008	.0000	.0000
2	.0293	.0983	.0933	.0039	.0004	.0005	.0000
3	.0376	.0872	.0538	.1292	.0038	.0026	.0211
4	.0259	.0683	.0071	.0712	.0285	.0205	.0310
5	.2141	.0373	.0205	.0302	.0511	.0680	.0720
6	.0582	.1668	.0289	.0519	.0505	.0581	.1683
7	.1486	.0834	.0886	.0264	.0570	.0542	.2642
8	.4194	.1888	.0244	.0448	.0335	.0496	.1921
9	.3100	.4229	.0306	.0615	.1199	.0457	.2347
10	.5737	.4177	.1643	.1261	.0248	.1755	.1143
11	.2120	.3458	.1079	.1821	.0073	.0453	.0001
12	.2355	.2261	.0634	.0518	.0417	.0404	.0001

MEAN F (UNWEIGHTED) FOR AGES 5 TO 10							
	.2873	.2195	.0595	.0568	.0561	.0752	.1743

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

STOCK NUMBERS		HERRING					
AGE	1980	1981	1982	1983	1984	1985	1986
0	0.	0.	0.	0.	0.	0.	0.
1	3374683.	701312.	604079.	705146.	89473970.	2081183.	2979527.
2	1536095.	2219323.	463719.	399666.	461952.	58814480.	1332770.
3	797721.	962268.	1406448.	296156.	253788.	288921.	36901520.
4	887187.	504013.	616315.	884979.	186361.	159362.	166922.
5	423661.	692338.	392089.	477280.	675929.	141455.	110609.
6	1040784.	331090.	536409.	304128.	366356.	473002.	95476.
7	1783396.	810918.	258345.	415983.	233337.	270820.	248510.
8	44238.	1387755.	633585.	201351.	320713.	171492.	156932.
9	16716.	34378.	1083745.	493553.	157154.	237390.	82642.
10	2695.	13142.	26713.	846734.	383855.	116738.	126851.
11	15350.	2120.	10239.	20898.	659070.	286363.	82313.
12	35.	40268.	6600.	32910.	69016.	2165935.	278147.

TOTAL STOCK BIOMASS ON 1. JANUARY							
	1824377.	1633852.	1511360.	1407293.	1960265.	2934790.	2507839.
SPAWNING STOCK BIOMASS ON 1. JANUARY							
	1462569.	1321245.	1198352.	1204213.	1063825.	1543051.	711426.
TOTAL STOCK BIOMASS ON Q=2							
	1709264.	1530466.	1411192.	1321057.	1803708.	2821623.	2223124.
TOTAL STOCK BIOMASS ON Q=3							
	1693556.	1489268.	1340144.	2034536.	2063501.	3362667.	2086127.
TOTAL STOCK BIOMASS ON Q=4							
	1610201.	1424597.	1261495.	1749625.	2246611.	3955355.	1903464.

STOCK NUMBERS		HERRING					
AGE	1987	1988	1989	1990	1991	1992	1993
0	0.	0.	0.	0.	0.	0.	0.
1	236836.	630199.	8596472.	18919740.	6108460.	79945500.	135978600.
2	1877698.	145540.	398817.	5635653.	12427230.	3981022.	51685380.
3	749118.	1053589.	77095.	226553.	3439152.	7224819.	2072842.
4	23227370.	450069.	606298.	45953.	117864.	1938547.	4165531.
5	114816.	17803550.	330667.	473549.	33664.	90115.	1493937.
6	73419.	72910.	13491440.	254839.	361409.	25162.	66227.
7	60581.	54487.	48541.	10310100.	190320.	270294.	18677.
8	96812.	41073.	39430.	34947.	7898737.	141417.	201409.
9	53335.	50069.	26749.	30270.	26285.	6008626.	105863.
10	25758.	30771.	25803.	20408.	22392.	18340.	4515365.
11	27919.	11417.	15941.	17222.	14151.	17183.	12104.
12	123038.	47687.	24283.	44480.	45990.	45194.	60522.

TOTAL STOCK BIOMASS ON 1. JANUARY							
	3618689.	3783241.	3746421.	3931687.	3924590.	4652372.	6594068.
SPAWNING STOCK BIOMASS ON 1. JANUARY							
	1614398.	3193533.	3571792.	3436982.	2954924.	2730915.	2531843.
TOTAL STOCK BIOMASS ON Q=2							
	3387036.	3526508.	3499503.	3596145.	3572044.	4472518.	5031834.
TOTAL STOCK BIOMASS ON Q=3							
	3216047.	3403631.	3608585.	3973156.	4574146.	6137423.	8769353.
TOTAL STOCK BIOMASS ON Q=4							
	2993295.	3209835.	3382793.	4127235.	4276514.	6194492.	7563195.

PREDATION MORTALITY		HERRING					
AGE	1980	1981	1982	1983	1984	1985	1986
0	.0173	.0102	.0103	.0100	.0152	.0235	.0438
1	.0189	.0115	.0105	.0136	.0195	.0366	.0611
2	.0673	.0484	.0478	.0481	.0614	.0610	.1725
3	.0476	.0393	.0490	.0476	.0398	.0373	.0425
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000	.0000

PREDATION MORTALITY		HERRING					
AGE	1987	1988	1989	1990	1991	1992	1993
0	.0315	.0333	.0151	.0157	.0181	.0296	.0499
1	.0491	.0514	.0219	.0203	.0274	.0362	.0595
2	.1486	.1371	.0722	.0900	.1420	.2521	.2776
3	.0719	.0654	.0636	.1242	.1695	.1481	.1739
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000	.0000

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

Table 2.4.2 Mean values of F, N and M2 over period 1980-1991 for Barents Sea, from baseline MSVPA run.

a)

COD		MEAN VALUES OVER YEARS BY AGE GROUP		
RANGE OF YEARS : 1980 - 1991				
AGE	MEAN F	MEAN N *)	MEAN D	MEAN M2
0	.00000	928352.	117977.	.14364
1	.00000	637487.	143047.	.27966
2	.00013	360112.	21428.	.06319
3	.03360	258641.	10845.	.05641
4	.20296	197513.	0.	.00000
5	.34969	154237.	0.	.00000
6	.60507	92674.	0.	.00000
7	.86325	46062.	0.	.00000
8	.96140	19937.	0.	.00000
9	1.05885	4730.	0.	.00000
10	.93927	1455.	0.	.00000
11	.81023	516.	0.	.00000
12	.69028	201.	0.	.00000
13	.63985	81.	0.	.00000
14	.82414	39.	0.	.00000
15	.69510	36.	0.	.00000

*) STOCK NUMBER ON 1. JANUARY (Except for the 0-group which is on 1. July)

b)

CAPELIN		MEAN VALUES OVER YEARS BY AGE GROUP		
RANGE OF YEARS : 1980 - 1991				
AGE	MEAN F	MEAN N *)	MEAN D	MEAN M2
0	.00000	223207500.	2065134.	.00985
1	.01330	200373500.	18228250.	.13369
2	.09643	128963100.	12487970.	.14278
3	.31387	101902800.	14309910.	.33465
4	.79212	38849360.	4925773.	.50945
5	1.26543	5628885.	523221.	.44762
6	1.12342	443508.	51532.	.23654

*) STOCK NUMBER ON 1. JANUARY (Except for the 0-group which is on 1. July)

c)

SHRIMP		MEAN VALUES OVER YEARS BY AGE GROUP		
RANGE OF YEARS : 1980 - 1991				
AGE	MEAN F	MEAN N *)	MEAN D	MEAN M2
0	.00000	113379800.	19413000.	.17532
1	.00000	83173780.	8096767.	.10933
2	.07230	54419730.	5673610.	.11840
3	.27776	38517600.	3568913.	.11690
4	.19188	23047980.	1300762.	.06693
5	.33431	12898840.	10159160.	2.94399

*) STOCK NUMBER ON 1. JANUARY (Except for the O-group which is on 1. July)

d)

HERRING		MEAN VALUES OVER YEARS BY AGE GROUP		
RANGE OF YEARS : 1980 - 1991				
AGE	MEAN F	MEAN N *)	MEAN D	MEAN M2
0	.01282	21826360.	291566.	.02034
1	.00575	11200970.	205840.	.02850
2	.02139	7142745.	464671.	.09136
3	.04305	3871028.	166218.	.06647
4	.04669	2321058.	0.	.00000
5	.07112	1805800.	0.	.00000
6	.09116	1450105.	0.	.00000
7	.12728	1223778.	0.	.00000
8	.17817	918922.	0.	.00000
9	.19547	191024.	0.	.00000
10	.23069	136822.	0.	.00000
11	.13800	96917.	0.	.00000
12	.14907	239866.	0.	.00000

*) STOCK NUMBER ON 1. JANUARY (Except for the O-group which is on 1. July)

Table 2.4.3 Biomass consumed by predators compared to stock and yield to fishery for Barents Sea, from baseline MSVPA run.

a)

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREY

PREY	COD			
PREDATOR	COD			
1980	7175.	7175.	782585.	315752.
1981	8462.	8462.	810269.	340502.
1982	7429.	7429.	768663.	312673.
1983	11169.	11169.	650986.	326714.
1984	15740.	15740.	941595.	321419.
1985	13363.	13363.	912812.	259322.
1986	17929.	17929.	1239324.	367584.
1987	10919.	10919.	1092412.	466524.
1988	18007.	18007.	998279.	486352.
1989	20887.	20887.	871920.	307902.
1990	40468.	40468.	1084689.	186532.
1991	63152.	63152.	1442642.	310369.
1992	79005.	79005.	2265984.	503596.
1993	143902.	143902.	3636308.	581639.

b)

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREY

PREY	CAPELIN			
PREDATOR	COD			
1980	798466.	798466.	8033330.	1503491.
1981	672222.	672222.	7111669.	2080444.
1982	517898.	517898.	6517561.	1558408.
1983	429761.	429761.	5222332.	2238301.
1984	382086.	382086.	3278484.	1257889.
1985	302433.	302433.	1915168.	743637.
1986	288946.	288946.	925428.	105935.
1987	245298.	245298.	892470.	0.
1988	379885.	379885.	1469644.	0.
1989	558117.	558117.	2874234.	0.
1990	789582.	789582.	5069627.	0.
1991	1072124.	1072124.	6106425.	910820.
1992	1038454.	1038454.	4702095.	1060408.
1993	710810.	710810.	2311852.	502552.

c) TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREY

PREY SHRIMP

PREDATOR COD

PREDATOR	COD			
1980	22421.	22421.	244582.	45196.
1981	48386.	48386.	365507.	42510.
1982	69979.	69979.	506261.	63196.
1983	123245.	123245.	619039.	97738.
1984	151011.	151011.	623894.	115834.
1985	184203.	184203.	569435.	120439.
1986	122765.	122765.	454411.	59774.
1987	181178.	181178.	521231.	37696.
1988	203591.	203591.	575528.	43546.
1989	119238.	119238.	661454.	51415.
1990	236416.	236416.	856846.	90245.
1991	225890.	225890.	940046.	71909.
1992	448797.	448797.	1096086.	64866.
1993	254562.	254562.	823507.	49687.

d) TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREY

PREY HERRING

PREDATOR COD

PREDATOR	COD			
1980	10418.	10418.	1824377.	18428.
1981	9435.	9435.	1633852.	12574.
1982	10744.	10744.	1511360.	16528.
1983	8736.	8736.	1407293.	21881.
1984	18963.	18963.	1960265.	53285.
1985	88587.	88587.	2934790.	177387.
1986	76359.	76359.	2507839.	223488.
1987	10535.	10535.	3618689.	124904.
1988	8935.	8935.	3783241.	135153.
1989	6581.	6581.	3746421.	100269.
1990	42526.	42526.	3931687.	86512.
1991	154221.	154221.	3924590.	84626.
1992	219262.	219262.	4652372.	104153.
1993	569568.	569568.	6594068.	243969.

e) TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREDATOR

PREDATOR		COD						
PREY	COD	CAPELIN	SHRIMP	HERRING				
1980	7175.	798466.	22421.	10418.	838480.	1035400.	782585.	315752.
1981	8462.	672222.	48386.	9435.	738505.	937692.	810269.	340502.
1982	7429.	517898.	69979.	10744.	606050.	864026.	768663.	312673.
1983	11169.	429761.	123245.	8736.	572911.	868136.	650986.	326714.
1984	15740.	382086.	151011.	18963.	567800.	1143052.	941595.	321419.
1985	13363.	302433.	184203.	88587.	588586.	1555077.	912812.	259322.
1986	17929.	288946.	122765.	76359.	506000.	2191887.	1239324.	367584.
1987	10919.	245298.	181178.	10535.	447929.	2305654.	1092412.	466524.
1988	18007.	379885.	203591.	8935.	610418.	2064790.	998279.	486352.
1989	20887.	558117.	119238.	6581.	704823.	1811203.	871920.	307902.
1990	40468.	789582.	236416.	42526.	1108992.	1757175.	1084689.	186532.
1991	63152.	1072124.	225890.	154221.	1515387.	2161530.	1442642.	310369.
1992	79005.	1038454.	448797.	219262.	1785518.	2741404.	2265984.	503596.
1993	143902.	710810.	254562.	569568.	1678843.	3633135.	3636308.	581639.

f) TOTAL BIOMASSES CONSUMED BY ALL PREDATORS, COMPARED TO TOTAL STOCK BIOMASS AND TOTAL YIELD

YEAR	TOTAL BIOM.	AV. BIOM.	TOTAL YIELD	TOTAL EATEN	TOTAL OTH. FOOD EATEN
1980	10884870.	8627146.	1882866.	838480.	1035400.
1981	9921296.	7578302.	2476031.	738505.	937692.
1982	9303845.	7112792.	1950805.	606050.	864026.
1983	7899650.	6558939.	2684634.	572911.	868136.
1984	6804239.	5388022.	1748427.	567800.	1143052.
1985	6332205.	5318928.	1300785.	588586.	1555077.
1986	5127002.	4301185.	756782.	506000.	2191887.
1987	6124802.	5507809.	629125.	447929.	2305654.
1988	6826691.	6186370.	665051.	610418.	2064790.
1989	8154029.	7822654.	459586.	704823.	1811203.
1990	10942850.	10000960.	363288.	1108992.	1757175.
1991	12413700.	10813360.	1377723.	1515387.	2161530.
1992	12716540.	11130840.	1733023.	1785518.	2741404.
1993	13365740.	11510410.	1377847.	1678843.	3633135.

Table 2.4.4 Short-term forecast of catches. Barents Sea MSVPA

SHORTTERM MULTI SPECIES PREDICTION, CONSTANT RECRUITMENT
SPECIES: COD

AVERAGE CATCH BY FLEET				
FLEET/YEAR	1994	1995	1996	1997
FLEET_COD	770303.	862608.	934453.	923597.
TOTAL	770303.	862608.	934453.	923597.
TOTAL BIOMASS	2332735.	2427308.	2374494.	2274381.
SSB	809732.	744701.	848821.	994066.
RECRUITMENT	1404274.	1404274.	1404274.	1404274.
AV. BIOMASS	1879902.	1931401.	1851281.	1748807.

SHORTTERM MULTI SPECIES PREDICTION, CONSTANT RECRUITMENT
SPECIES: CAPELIN

AVERAGE CATCH BY FLEET				
FLEET/YEAR	1994	1995	1996	1997
FLEET_COD	0.	0.	0.	0.
TOTAL	0.	0.	0.	0.
TOTAL BIOMASS	1042592.	426764.	201556.	75010.
SSB	866167.	322453.	159036.	49772.
RECRUITMENT	7314600.	7314600.	7314600.	7314600.
AV. BIOMASS	530738.	220344.	90418.	49642.

SPECIES: SHRIMP

AVERAGE CATCH BY FLEET				
FLEET/YEAR	1994	1995	1996	1997
FLEET_COD	40449.	20625.	13284.	13571.
TOTAL	40449.	20625.	13284.	13571.
TOTAL BIOMASS	749059.	556219.	324651.	295209.
SSB	598046.	437732.	204784.	156373.
RECRUITMENT	111709008.	111709008.	111709008.	111709008.
AV. BIOMASS	499972.	282429.	204116.	207262.

SPECIES: HERRING

AVERAGE CATCH BY FLEET				
FLEET/YEAR	1994	1995	1996	1997
FLEET_COD	485397.	519909.	479738.	578380.
TOTAL	485397.	519909.	479738.	578380.
TOTAL BIOMASS	9586497.	11730715.	11462076.	10650996.
SSB	3012314.	4600580.	7212706.	9167167.
RECRUITMENT	12472867.	12472867.	12472867.	12472867.
AV. BIOMASS	8183320.	9773138.	10076639.	9333475.

SPECIES: ALL SPECIES COMBINED

AVERAGE CATCH BY FLEET				
FLEET/YEAR	1994	1995	1996	1997
FLEET_COD	1296149.	1403142.	1427475.	1515548.
TOTAL	1296149.	1403142.	1427475.	1515548.

Table 2.4.5 Short-term forecast - biomasses of prey consumed. Barents Sea MSVPA

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREY

PREY COD

PREDATOR	COD	TOTAL	BIOMASS	YIELD
1994	84647.	84647.	2332735.	770303.
1995	90385.	90385.	2427308.	862608.
1996	86104.	86104.	2374494.	934453.
1997	59736.	59736.	2274381.	923597.

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREY

PREY CAPELIN

PREDATOR	COD	TOTAL	BIOMASS	YIELD
1994	541644.	541644.	1042592.	0.
1995	274760.	274760.	426764.	0.
1996	140874.	140874.	201556.	0.
1997	50125.	50125.	75010.	0.

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREY

PREY SHRIMP

PREDATOR	COD	TOTAL	BIOMASS	YIELD
1994	399164.	399164.	749059.	40449.
1995	442876.	442876.	556219.	20625.
1996	193018.	193018.	324651.	13284.
1997	142338.	142338.	295209.	13571.

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREY

PREY HERRING

PREDATOR	COD	TOTAL	BIOMASS	YIELD
1994	955768.	955768.	9586497.	485397.
1995	641310.	641310.	11730720.	519909.
1996	177742.	177742.	11462080.	479738.
1997	189443.	189443.	10651000.	578380.

Table 2.4.6 Short-term forecast - summary table of biomasses consumed by Cod and overall - Barents Sea MSVPA

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREDATOR

PREDATOR COD

PREY	COD	CAPELIN	SHRIMP	HERRING	TOTAL	OTH. FOOD	ST.BIOM.	YIELD
1994	84647.	541644.	399164.	955768.	1981223.	4039964.	2332735.	770303.
1995	90385.	274760.	442876.	641310.	1449331.	4724023.	2427308.	862608.
1996	86104.	140874.	193018.	177742.	597739.	5346484.	2374494.	934453.
1997	59736.	50125.	142338.	189443.	441643.	4795820.	2274381.	923597.

MULTI SPECIES PREDICTION, CONSTANT RECRUITMENT

TOTAL BIOMASSES CONSUMED BY ALL PREDATORS, COMPARED TO TOTAL STOCK BIOMASS AND TOTAL YIELD

YEAR	-----MSVPA SPECIES-----					
	TOTAL BIOMASS	AVERAGE BIOMASS	TOTAL YIELD	TOTAL FISH EATEN	TOT. OTH. MORTALITY	TOT. OTH. FOOD EATEN
1994	13710880.	11093930.	1296149.	1981223.	3489029.	4039964.
1995	15141010.	12207310.	1403142.	1449331.	3444264.	4724023.
1996	14362780.	12222450.	1427475.	597739.	2779292.	5346484.
1997	13295600.	11339190.	1515548.	441643.	2550781.	4795820.

Table 2.4.7 Short-term MSVPA forecast of F, N, and M2 for Cod in Barents Sea

SHORTTERM

FISHING MORTALITY			COD	
AGE	1994	1995	1996	1997
0	.0000	.0000	.0000	.0000
1	.0001	.0001	.0001	.0001
2	.0004	.0004	.0004	.0004
3	.0271	.0271	.0271	.0271
4	.1347	.1347	.1347	.1347
5	.3088	.3088	.3088	.3088
6	.4823	.4823	.4823	.4823
7	.6212	.6212	.6212	.6212
8	.6380	.6380	.6380	.6380
9	.7696	.7696	.7696	.7696
10	.7282	.7282	.7282	.7282
11	.6040	.6040	.6040	.6040
12	.5790	.5790	.5790	.5790
13	.4763	.4763	.4763	.4763
14	.6206	.6206	.6206	.6206
15	.7034	.7034	.7034	.7034

MEAN F (UNWEIGHTED) FOR AGES 5 TO 13
 .5786 .5786 .5786 .5786

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

STOCK NUMBERS			COD	
AGE	1994	1995	1996	1997
0	0.	0.	0.	0.
1	1267748.	864967.	774336.	773385.
2	605356.	578501.	303818.	230169.
3	724247.	477663.	409417.	200401.
4	660922.	553851.	341109.	272682.
5	463083.	505174.	423334.	260726.
6	140946.	303053.	330599.	277041.
7	30042.	78733.	169287.	184674.
8	19360.	14764.	38693.	83196.
9	23397.	9424.	7187.	18835.
10	18242.	10004.	4030.	3073.
11	28767.	8113.	4449.	1792.
12	4774.	14371.	4053.	2223.
13	567.	2411.	7259.	2047.
14	17.	311.	1321.	3978.
15	103.	50.	164.	676.

TOTAL STOCK BIOMASS ON 1. JANUARY
 2332735. 2427308. 2374494. 2274381.
 SPAWNING STOCK BIOMASS ON 1. JANUARY
 809732. 744701. 848821. 994066.

SHORTTERM MULTI SPECIES PREDICTION, CONSTANT RECRUITMENT

PREDATION MORTALITY			COD	
AGE	1994	1995	1996	1997
0	.4046	.5153	.5165	.3701
1	.6644	.9261	1.0931	.9352
2	.1565	.2653	.3357	.3277
3	.1211	.1896	.2593	.2501
4	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000
13	.0000	.0000	.0000	.0000
14	.0000	.0000	.0000	.0000
15	.0000	.0000	.0000	.0000

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

Table 2.4.8 Short-term MSVPA forecast of F, N and M2 for Barents Sea Capelin

FISHING MORTALITY			CAPELIN	
AGE	1994	1995	1996	1997
0	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000

MEAN F (UNWEIGHTED) FOR AGES 2 TO 5	.0000	.0000	.0000	.0000

Mortality of 0-group is for 3rd and 4th quarter only				
STOCK NUMBERS			CAPELIN	
AGE	1994	1995	1996	1997
0	0.	0.	0.	0.
1	37511060.	5905057.	5912507.	5919124.
2	3033592.	18515410.	2727247.	2544858.
3	51293010.	1873333.	10408440.	1468290.
4	16481230.	13201310.	351540.	1605010.
5	1626937.	2472429.	1183323.	19255.
6	414203.	413149.	402356.	167477.

TOTAL STOCK BIOMASS ON 1. JANUARY	1042592.	426764.	201556.	75010.
SPAWNING STOCK BIOMASS ON 1. JANUARY	866167.	322453.	159036.	49772.

PREDATION MORTALITY			CAPELIN	
AGE	1994	1995	1996	1997
0	.0391	.0378	.0367	.0352
1	.3360	.4025	.4730	.3930
2	.3940	.4880	.5312	.4431
3	.7772	1.0932	1.2895	1.0970
4	1.1970	1.7120	2.2046	1.8545
5	1.0369	1.4125	1.8649	1.6428
6	.4207	.6099	.9175	1.0152

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

Table 2.4.9 Short-term MSVPA forecast of F, N and M2 for Barents Sea Shrimp

FISHING MORTALITY			SHRIMP	
AGE	1994	1995	1996	1997
0	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000
2	.0185	.0185	.0185	.0185
3	.1276	.1276	.1276	.1276
4	.0874	.0874	.0874	.0874
5	.1973	.1973	.1973	.1973

MEAN F (UNWEIGHTED) FOR AGES 2 TO 4	.0778	.0778	.0778	.0778

Mortality of O-group is for 3rd and 4th quarter only				
STOCK NUMBERS			SHRIMP	
AGE	1994	1995	1996	1997
0	0.	0.	0.	0.
1	45636240.	56145610.	62614070.	67665100.
2	37208090.	27336150.	34062020.	38716400.
3	33108600.	24721570.	17347120.	21633440.
4	56384040.	19817960.	13572420.	8986747.
5	30053250.	38326090.	13125820.	8896412.

TOTAL STOCK BIOMASS ON 1. JANUARY	749059.	556219.	324651.	295209.
SPAWNING STOCK BIOMASS ON 1. JANUARY	598046.	437732.	204784.	156373.

PREDATION MORTALITY			SHRIMP	
AGE	1994	1995	1996	1997
0	.5879	.4789	.4013	.2481
1	.3125	.2998	.2807	.2543
2	.3104	.3563	.3555	.2898
3	.3056	.3920	.4501	.3622
4	.1790	.2048	.2150	.1667
5	7.2823	9.1092	10.8492	9.6216

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

Table 2.4.10 Short-term MSVPA forecast of F, N and M2 for Barents Sea Herring

FISHING MORTALITY		HERRING		
AGE	1994	1995	1996	1997
0	.0034	.0034	.0034	.0034
1	.0067	.0067	.0067	.0067
2	.0337	.0337	.0337	.0337
3	.0469	.0469	.0469	.0469
4	.0330	.0330	.0330	.0330
5	.0628	.0628	.0628	.0628
6	.0618	.0618	.0618	.0618
7	.0684	.0684	.0684	.0684
8	.1134	.1134	.1134	.1134
9	.1478	.1478	.1478	.1478
10	.2211	.2211	.2211	.2211
11	.1343	.1343	.1343	.1343
12	.0983	.0983	.0983	.0983
MEAN F (UNWEIGHTED) FOR AGES 5 TO 10				
	.1126	.1126	.1126	.1126

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

STOCK NUMBERS		HERRING		
AGE	1994	1995	1996	1997
0	0.	0.	0.	0.
1	8732461.	9557315.	9579893.	9646736.
2	85718900.	5408241.	5815665.	5852016.
3	26151760.	44385580.	2567448.	2490273.
4	1108449.	14992400.	25172830.	1228466.
5	3213829.	843611.	11410320.	19158370.
6	1065369.	2374102.	623188.	8428966.
7	44256.	787826.	1755615.	460839.
8	11337.	32512.	578766.	1289741.
9	128531.	7962.	22833.	406461.
10	65868.	87215.	5402.	15493.
11	3171907.	41536.	54998.	3407.
12	57442.	2222446.	1613152.	1187988.
TOTAL STOCK BIOMASS ON 1. JANUARY				
	9586497.	11730720.	11462080.	10651000.
SPAWNING STOCK BIOMASS ON 1. JANUARY				
	3012314.	4600580.	7212706.	9167167.

SHORTTERM MULTI SPECIES PREDICTION, CONSTANT RECRUITMENT

PREDATION MORTALITY		HERRING		
AGE	1994	1995	1996	1997
0	.0628	.0605	.0535	.0348
1	.0724	.0900	.0862	.0606
2	.2245	.3113	.4145	.3774
3	.1095	.1203	.2903	.3581
4	.0000	.0000	.0000	.0000

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

Table 2.4.11 Values of quarterly natural mortality used in MSVPA and MSFOR single species runs

Age\Species	Cod	Capelin	Shrimp	Herring
0	.0800	.1850	.0730	.1300
1	.0600	.1850	.1770	.1400
2	.0400	.1880	.0600	.2300
3	.0388	.5045	.0600	.2000
4	.0335	.6675	.0600	.0600
5	.0288	.6800	.9640	.0600
6	.0250	.6800		.0600
7	.0223			.0600
8	.0205			.0600
9	.0200			.0600
10	.0205			.0600
11	.0225			.0600
12	.0260			.0600
13	.0313			
14	.0385			
15	.0480			

Table 2.4.12. Baseline values from longterm Multispecies Forecasts, Constant Recruitment.					
Species	Total Biom	SSB	Recruits	Av. Biom.	Catch
Cod	1388974	401132	846209	1235113	497155
Capelin	2724200	1393679	209516912	2286128	499063
Shrimp	688747	457200	115975184	496535	85353
Herring	3653038	2410250	14690909	3308888	268957
Total	8454960	4662261	341029214	7326664	1300528

Table 2.4.13 MSFOR longterm predictions of the percentage change in biomass, SSB and catch resulting from a 10% reduction in the fisheries for in cod, capelin, shrimp and herring in the Barents Sea. Results from multispecies (MS) and single species (SS) predictions.							
Fishery	Species	Biomass		SSB		Catch	
		MS	SS	MS	SS	MS	SS
Cod	Cod	4	9	17	22	-1	4
	Capelin	-1		-1		-2	
	Shrimp	0		0		0	
	Herring	3		-3		-3	
Capelin	Cod	0		0		0	
	Capelin	2	0	3	0	-5	-9
	Shrimp	0		0		0	
	Herring	0		0		0	
Shrimp	Cod	0		0		0	
	Capelin	0		0		0	
	Shrimp	3	2	4	3	-7	-8
	Herring	0		0		0	
Herring	Cod	0		0		0	
	Capelin	0		0		0	
	Shrimp	0		0		0	
	Herring	3	2	4	4	-6	-6

TABLE 2.7.1 Predation Mortality rates calculated using direct method (See Section 2.6.1)

PREDATION MORTALITY RATE - M2

AGE	YEAR OF FISHERY						
	1980	1981	1982	1983	1984	1985	1986
1	.765	.690	.549	.242	.349	.011	1.552
2	.774	.712	.668	.418	.511	.176	1.165
3	.661	.585	.748	.631	.000	.473	.053
4-15	.000	.000	.000	.000	.000	.000	.000
TOTAL	2.200	1.986	1.964	1.291	.860	.660	2.770

AGE	YEAR OF FISHERY						
	1987	1988	1989	1990	1991	1992	1993
1	1.864	.372	.000	.353	.578	.627	.498
2	.000	.019	.088	.130	.987	.298	.495
3	.304	.240	.077	.001	.208	.024	.272
4-15	.000	.000	.000	.000	.000	.000	.000
TOTAL	2.168	.631	.165	.485	1.772	.949	1.265

Table 2.7.2. Estimates of Partial Predation Mortalities for Cod Eating Cod								
		Natural mortality rates						
predator age		prey age	1					
	1980	1981	1982	1983	1984	1985	1986	1987
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0.234
4	0.052	0.045	0.05	0.025	0	0.01	0	0.869
5	0.457	0.205	0.155	0.083	0.145	0	0.776	0.269
6	0.125	0.28	0.117	0.046	0.092	0	0.137	0.182
7	0.04	0.045	0.097	0.021	0	0	0.22	0
8	0.02	0.02	0.019	0.022	0.007	0	0.036	0
9	0.004	0.004	0.003	0.001	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
Sum	0.698	0.599	0.441	0.198	0.244	0.01	1.169	1.554
		Natural mortality rates						
predator age		prey age	2					
	1980	1981	1982	1983	1984	1985	1986	1987
3	0	0	0	0	0	0	0	0
4	0.003	0.002	0.002	0.002	0	0.01	0	0
5	0.169	0.057	0.045	0.038	0.08	0.046	0.1	0
6	0.208	0.349	0.153	0.093	0.026	0.023	0.487	0
7	0.144	0.122	0.276	0.094	0.04	0.046	0.268	0
8	0.033	0.025	0.024	0.044	0.007	0	0.032	0
9	0.095	0.073	0.06	0.049	0.26	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
Sum	0.652	0.628	0.56	0.32	0.413	0.125	0.887	0

predator age	Natural mortality rates							1987
	1980	1981	1982	1983	1984	1985	1986	
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0.001	0
6	0.024	0.043	0.016	0.012	0	0	0.025	0
7	0.262	0.236	0.463	0.182	0	0.251	0.014	0.217
8	0.212	0.174	0.147	0.307	0	0.135	0	0
9	0.031	0.026	0.018	0.017	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
Sum	0.529	0.479	0.644	0.518	0	0.386	0.04	0.217
predator age	1988	1989	1990	1991	1992	1993		
	0	0	0	0	0	0		
	0	0	0	0	0	0		
4	0	0	0.061	0	0.028	0.133		
5	0	0	0.171	0.027	0.098	0.23		
6	0.139	0	0.097	0.106	0.129	0.056		
7	0.108	0	0	0.068	0.014	0.029		
8	0	0	0.006	0.324	0.156	0.037		
9	0	0	0	0	0.177	0.013		
10	0	0	0	0	0	0		
11	0	0	0	0	0	0		
12	0	0	0	0	0	0		
13	0	0	0	0	0	0		
14	0	0	0	0	0	0		
15	0	0	0	0	0	0		
Sum	0.247	0	0.335	0.525	0.602	0.498		
predator age	1988	1989	1990	1991	1992	1993		
	0	0	0	0	0	0		
4	0	0	0.01	0	0	0.005		
5	0	0	0.041	0	0	0.06		
6	0.013	0	0.04	0.093	0.125	0.066		
7	0	0	0	0.111	0.049	0.073		
8	0	0	0.017	0.532	0	0.044		
9	0	0.057	0	0.007	0.105	0.246		
10	0	0	0	0	0	0		
11	0	0	0	0	0	0		
12	0	0	0	0	0	0		
13	0	0	0	0	0	0		
14	0	0	0	0	0	0		
15	0	0	0	0	0	0		
Sum	0.013	0.057	0.108	0.743	0.279	0.494		

predator age	1988	1989	1990	1991	1992	1993		
4	0	0	0	0	0	0		
5	0	0	0	0	0	0		
6	0	0	0.001	0.004	0	0.004		
7	0	0	0	0.007	0	0.072		
8	0.169	0	0	0.093	0	0.153		
9	0	0.053	0	0.042	0.015	0.045		
10	0	0	0	0	0	0		
11	0	0	0	0	0	0		
12	0	0	0	0	0	0		
13	0	0	0	0	0	0		
14	0	0	0	0	0	0		
15	0	0	0	0	0	0		
Sum	0.169	0.053	0.001	0.146	0.015	0.274		

Table 2.7.3

ANOVA table

Model	SSQ	DF	%change
Mean only	143.08	1109	
PS+LWR+LWR^2	110.39	1104	23
PS+PS.LWR+LWR^2	110.14	1101	23
PS+Q.LWR+LWR^2	110.06	1101	23
PS.Q+LWR+LWR^2	95.28	1092	33
PS.PA+LWR+LWR^2	64.03	1087	55
PS.PA.Q+LWR+LWR^2	40.99	1034	71

Table 2.7.4

Parameter Estimates of Fit to PS+LWR+LWR^2

Estimate	S.E.	Factor
-5.206	0.2897	PS(1)
-4.808	0.3014	PS(2)
-3.866	0.2954	PS(3)
-5.362	0.3103	PS(4)
-1.002	0.1128	LW
-0.1126	0.01077	L2

Table 2.7.5 Coefficients of equation

$$\text{Suit} = \alpha \cdot \exp(-0.5 \cdot ((\text{Ln Ratio}) - \mu) / \sigma)^2$$

	prey			
	cod	capelin	shrimp	herring
alpha	5.10E-02	7.59E-02	1.95E-01	4.36E-02
mu	-4.44938	-4.4493783	-4.44937833	-4.44938
sigma	2.107249	2.10724876	2.10724876	2.107249
pred wt	85.57373	85.5737289	85.5737289	85.57373
prey wt				

Table 2.7.6

'Parameter Estimates of Fit to PS.PA+LWR+LWR^2

estimate	s.e.	parameter
-0.7457	0.08413	LW
-0.07782	0.008378	L2
-4.92	0.3921	PS(1).PA(1)
-4.711	0.2573	PS(1).PA(2)
-5.041	0.2669	PS(1).PA(3)
-4.655	0.2387	PS(1).PA(4)
-5.41	0.4483	PS(2).PA(1)
-5.144	0.2964	PS(2).PA(2)
-4.913	0.2739	PS(2).PA(3)
-4.63	0.2582	PS(2).PA(4)
-4.12	0.2411	PS(2).PA(5)
-4.392	0.2483	PS(2).PA(6)
-4.185	0.2516	PS(2).PA(7)
-3.813	0.3779	PS(3).PA(1)
-4.826	0.3412	PS(3).PA(2)
-4.832	0.2853	PS(3).PA(3)
-5.622	0.3398	PS(3).PA(4)
-6.037	0.3757	PS(3).PA(5)
-2.508	0.2198	PS(3).PA(6)
-6.951	0.7018	PS(4).PA(1)
-7.086	0.5302	PS(4).PA(2)
-4.296	0.2427	PS(4).PA(3)
-4.873	0.2582	PS(4).PA(4)

Table 2.7.7 Coefficients of equation $SUIT = \alpha(\text{age}) \cdot \exp(-0.5 \cdot ((\text{Ln Ratio}) - \mu) / \sigma)^2$

	prey			
	cod	capelin	shrimp	herring
alpha1	4.36E-02	2.67E-02	1.32E-01	5.72E-03
alpha2	5.37E-02	3.48E-02	4.79E-02	4.99E-03
alpha3	3.86E-02	4.39E-02	4.76E-02	8.13E-02
alpha4	5.68E-02	5.82E-02	2.16E-02	4.57E-02
alpha5		9.69E-02	1.43E-02	
alpha6		7.39E-02	4.86E-01	
alpha7		9.08E-02		
mu	-4.79118	-4.7911848	-4.79118479	-4.79118
sigma	2.534775	2.53477485	2.53477485	2.534775
pred wt	120.444	120.443984	120.443984	120.444
prey wt				

Table 2.7.8 UM2 Anova Table

Model	SSQ	DF	% Change
Mean only	0.000149	314	
PS+LWR+LWR^2	8.55E-05	309	43
PS+PS.LWR+LWR^2	8.45E-05	306	43
PS.PA+LWR+LWR^2	2.48E-05	292	83

Table 2.7.9

Parameter Estimates of Fit to PS+LWR+LWR^2

Estimate	S.E.	Factor
-19.09	0.61	PS(1)
-18.79	0.63	PS(2)
-17.54	0.62	PS(3)
-19.50	0.64	PS(4)
-1.62	0.24	LW
-0.17	0.02	L2

Table 2.7.10 Coefficients of equation $UM2 = \alpha * \exp(-0.5 * ((\ln \text{Ratio}) - \mu) / \sigma)^2$

	prey			
	cod	capelin	shrimp	herring
alpha	2.30E-07	3.11E-07	1.09E-06	1.53E-07
mu	-4.68822	-4.6882217	-4.68822171	-4.68822
sigma	1.699069	1.69906917	1.69906917	1.699069
pred wt	108.6598	108.659779	108.659779	108.6598
prey wt				

Table 2.7.11

'Parameter Estimates of Fit to PS.PA+LWR+LWR^2

estimate	s.e.	parameter
-1.35	0.13	LW
-0.14	0.01	L2
-19.16	0.42	PS(1).PA(1)
-18.34	0.36	PS(1).PA(2)
-18.64	0.37	PS(1).PA(3)
-18.62	0.37	PS(1).PA(4)
-20.03	0.69	PS(2).PA(1)
-18.97	0.41	PS(2).PA(2)
-18.79	0.39	PS(2).PA(3)
-18.37	0.37	PS(2).PA(4)
-17.87	0.35	PS(2).PA(5)
-18.12	0.36	PS(2).PA(6)
-18.39	0.37	PS(2).PA(7)
-17.22	0.40	PS(3).PA(1)
-18.21	0.44	PS(3).PA(2)
-18.85	0.42	PS(3).PA(3)
-19.18	0.44	PS(3).PA(4)
-19.67	0.48	PS(3).PA(5)
-16.03	0.33	PS(3).PA(6)
-20.97	0.78	PS(4).PA(1)
-21.00	0.69	PS(4).PA(2)
-18.29	0.36	PS(4).PA(3)
-18.80	0.38	PS(4).PA(4)

Table 2.7.12 Coefficients of equation $UM2 = \alpha(\text{age}) * \exp(-0.5 * ((\text{Ln Ratio}) - \mu) / \sigma)^2$

	prey			
	cod	capelin	shrimp	herring
alpha1	1.28E-07	5.37E-08	8.92E-07	2.10E-08
alpha2	2.91E-07	1.55E-07	3.31E-07	2.04E-08
alpha3	2.16E-07	1.86E-07	1.75E-07	3.06E-07
alpha4	2.20E-07	2.82E-07	1.26E-07	1.84E-07
alpha5		4.66E-07	7.70E-08	
alpha6		3.63E-07	2.93E-06	
alpha7		2.77E-07		
mu	-4.86341	-4.8634076	-4.86340762	-4.86341
sigma	1.895926	1.89592624	1.89592624	1.895926
pred wt	129.4646	129.464618	129.464618	129.4646
prey wt				

TABLE 6.2.1 (A) KEY RUN WITH ONLY OLD 1991 STOMACH DATA
NORTH SEA DATA 1974 - 1992

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

TOTAL BIOMASSES CONSUMED BY ALL PREDATORS, COMPARED TO TOTAL STOCK
BIOMASS AND TOTAL YIELD

-----MSVPA					
SPECIES-----			-----OTHER		
PREDATORS-----					
YEAR	TOTAL	AVERAGE	TOTAL	TOTAL FISH	TOT. OTH.
TOT. OTH.	AVERAGE	TOTAL FISH	TOT. OTH.	EATEN	MORTALITY
FOOD EATEN	BIOMASS	BIOMASS	YIELD	FOOD EATEN	
	BIOMASS	EATEN	FOOD EATEN		
1974	10308212.	10008712.	3157578.	7044253.	4631378.
6809870.		0.	0.	0.	
1975	9369680.	9320326.	3272390.	5994487.	4249344.
7126496.		0.	0.	0.	
1976	8587810.	8069091.	3276641.	5143235.	3600605.
5939450.		0.	0.	0.	
1977	7277347.	6964559.	2634517.	4519470.	3123458.
5162649.		0.	0.	0.	
1978	6699421.	6510131.	2667601.	3998300.	2957439.
4451836.		0.	0.	0.	
1979	6325853.	6558557.	2577154.	3971451.	3127528.
4478656.		0.	0.	0.	
1980	6543320.	5920541.	2740116.	3417144.	2654434.
4854012.		0.	0.	0.	
1981	5183689.	5365743.	2558072.	3001468.	2287251.
3903656.		0.	0.	0.	
1982	5815001.	5837770.	2539891.	2491856.	2512438.
3523300.		0.	0.	0.	
1983	5538914.	5929014.	2510925.	2405662.	2525175.
3214963.		0.	0.	0.	
1984	6256045.	6104709.	2769585.	2203438.	2463214.
3386340.		0.	0.	0.	
1985	5528625.	5538043.	2699711.	2355224.	2029576.
3122083.		0.	0.	0.	
1986	5818151.	6770114.	2150906.	2450412.	2662699.
3193580.		0.	0.	0.	
1987	6829388.	7072959.	2613730.	1767862.	2574061.
2730755.		0.	0.	0.	
1988	6024437.	5995395.	2765214.	1634264.	1915247.
2291670.		0.	0.	0.	

1989	5572032.	5455825.	2553965.	1260031.	1762567.
2070339.		0.	0.	0.	
1990	4734956.	4901897.	2090187.	1176787.	1572612.
1978163.		0.	0.	0.	
1991	4810616.	5443908.	2254693.	1342133.	2000048.
2119398.		0.	0.	0.	
1992	5655622.	6360037.	2254968.	1598771.	2637443.
3520606.		0.	0.	0.	

TABLE 6.2.1 (B) KEY RUN WITH ONLY NEW 1991 STOMACH DATA
NORTH SEA DATA 1974 - 1992

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

TOTAL BIOMASSES CONSUMED BY ALL PREDATORS, COMPARED TO TOTAL STOCK
BIOMASS AND TOTAL YIELD

-----MSVPA					
SPECIES-----			-----OTHER		
PREDATORS-----					
YEAR	TOTAL	AVERAGE	TOTAL	TOTAL FISH	TOT. OTH.
TOT. OTH.	AVERAGE	TOTAL FISH	TOT. OTH.	EATEN	MORTALITY
FOOD EATEN	BIOMASS	BIOMASS	YIELD	FOOD EATEN	
	BIOMASS	EATEN	FOOD EATEN		
1974	10770433.	10276494.	3157578.	7041217.	4737746.
6897307.		0.	0.	0.	
1975	9917078.	9746913.	3272390.	6291347.	4492071.
6898391.		0.	0.	0.	
1976	9052367.	8506241.	3276641.	5405235.	3858021.
5741405.		0.	0.	0.	
1977	7837043.	7342188.	2634517.	4631719.	3344540.
5133181.		0.	0.	0.	
1978	7135026.	6768619.	2667601.	4003107.	3103990.
4512030.		0.	0.	0.	
1979	6667266.	6890968.	2577154.	3985418.	3347844.
4592373.		0.	0.	0.	
1980	7110075.	6341004.	2740116.	3539040.	2941550.
4878880.		0.	0.	0.	
1981	5565341.	5548251.	2558072.	3142947.	2393978.
3828024.		0.	0.	0.	
1982	6061450.	6078237.	2539891.	2637242.	2656963.
3446986.		0.	0.	0.	

1983	5834357.	6120544.	2510925.	2460410.	2627503.
3217361.		0.	0.	0.	
1984	6551097.	6326194.	2769585.	2333771.	2588778.
3341462.		0.	0.	0.	
1985	5738746.	5690870.	2699711.	2390168.	2112109.
3147035.		0.	0.	0.	
1986	5994922.	6906248.	2150906.	2413217.	2735764.
3277208.		0.	0.	0.	
1987	7017719.	7229180.	2613730.	1826183.	2673406.
2713909.		0.	0.	0.	
1988	6158997.	6104368.	2765214.	1626057.	1986894.
2315856.		0.	0.	0.	
1989	5708534.	5580625.	2553965.	1293838.	1845894.
2051632.		0.	0.	0.	
1990	4867538.	4967932.	2090187.	1196023.	1609966.
1955319.		0.	0.	0.	
1991	4892415.	5464382.	2254693.	1314104.	2003905.
2163855.		0.	0.	0.	
1992	5730342.	6338388.	2254968.	1546855.	2613746.
3574089.		0.	0.	0.	

TABLE 6.2.2 (A) KEY RUN WITH ONLY OLD 1991 STOMACH DATA
NORTH SEA DATA 1974 - 1992

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

TOTAL BIOMASSES CONSUMED BY INDIVIDUAL PREDATORS, COMPARED TO STOCK
BIOMASS AND YIELD OF PREY

PREDATOR		COD				
PREY	COD	WHITING	HADDOCK	HERRING	SPRAT	N. POUT
SANDEEL						
1974	13687.	112477.	55301.	23862.	63364.	123258.
26420.						
1975	12469.	130662.	30386.	14429.	87194.	108102.
35763.						
1976	14854.	117202.	9307.	9977.	74175.	103951.
23988.						
1977	20147.	140629.	24187.	7699.	80561.	109197.
66720.						
1978	19167.	169828.	26790.	8942.	82616.	94978.
44306.						
1979	25516.	167711.	38686.	11195.	57026.	123420.
37421.						
1980	33413.	207224.	30443.	14292.	63344.	133981.
49025.						
1981	32925.	150978.	25562.	28427.	55614.	119441.
31910.						
1982	20007.	91436.	23081.	31808.	17540.	152901.
31135.						
1983	18670.	73704.	33136.	39382.	12251.	130311.
26526.						
1984	11935.	75705.	27436.	46844.	12449.	105032.
29888.						
1985	13818.	82505.	16162.	52576.	19930.	66544.
19779.						
1986	9692.	83000.	30519.	50037.	8078.	60125.
38143.						
1987	8557.	89286.	12472.	58535.	24035.	50717.
23217.						
1988	6932.	63508.	? 3861.	67807.	23363.	22921.
15892.						
1989	3692.	54110.	4063.	40694.	9613.	30289.
11531.						

1990	4821.	37909.	7508.	36223.	7770.	29135.
8968.						
1991	4400.	23660.	11431.	29209.	9043.	29443.
10748.						
1992	5042.	24732.	69319.	21720.	25922.	49056.
26348.						

PREDATOR COD

PREY	TOTAL	OTH. FOOD	ST. BIOM.	YIELD
1974	418368.	321670.	327457.	202000.
1975	419006.	316907.	286885.	188770.
1976	353454.	367600.	286396.	204400.
1977	449140.	509833.	256654.	195295.
1978	446626.	455080.	348292.	275889.
1979	460975.	513196.	315148.	234721.
1980	531722.	645502.	342971.	258737.
1981	444858.	599182.	420600.	325926.
1982	367907.	524235.	347925.	287894.
1983	333980.	429751.	312108.	246875.
1984	309288.	442583.	258510.	211534.
1985	271314.	382550.	273940.	211969.
1986	279594.	391731.	221191.	189470.
1987	266819.	331497.	236954.	185132.
1988	204284.	271263.	211592.	175639.
1989	153991.	242387.	158923.	128096.
1990	132335.	213934.	143028.	109402.
1991	117934.	226503.	121774.	90484.
1992	222139.	295438.	129596.	94081.

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREDATOR

PREDATOR WHITING

PREY	COD	WHITING	HADDOCK	HERRING	SPRAT	N. POUT
SANDEEL						
1974	1609.	49980.	67343.	26414.	400921.	443219.
601213.						
1975	1310.	69614.	9730.	11402.	460200.	448803.
691860.						
1976	4828.	62238.	13785.	8375.	414696.	402404.
600535.						

1977	5140.	96532.	34130.	13085.	319892.	318646.
850320.						
1978	4314.	107357.	40084.	12315.	312158.	390027.
789325.						
1979	7901.	112240.	64451.	20596.	328723.	514864.
746758.						
1980	11935.	144819.	32578.	44577.	303483.	365028.
660671.						
1981	8445.	52346.	34252.	61013.	183620.	357935.
390322.						
1982	3318.	33536.	17274.	91013.	68763.	352229.
267306.						
1983	2784.	28278.	35460.	55774.	35471.	268491.
299092.						
1984	1215.	33967.	16012.	49994.	41658.	212243.
249734.						
1985	2422.	40818.	16787.	59354.	33823.	164717.
407640.						
1986	1611.	52620.	40556.	81191.	33703.	218310.
481128.						
1987	1881.	52775.	5649.	82787.	97483.	111076.
354395.						
1988	1819.	55357.	7024.	55859.	102340.	138199.
396222.						
1989	1081.	47420.	7969.	67461.	46104.	158271.
276057.						
1990	1205.	24754.	18938.	58359.	53011.	127687.
202196.						
1991	1542.	15406.	18536.	26788.	74992.	137488.
192320.						
1992	782.	5141.	68167.	43507.	88768.	81196.
145196.						

PREDATOR WHITING

PREY	TOTAL	OTH. FOOD	ST.BIOM.	YIELD
1974	1590698.	719126.	596190.	336029.
1975	1692918.	986523.	632687.	270350.
1976	1506861.	869064.	687413.	341950.
1977	1637746.	1035130.	617368.	288723.
1978	1655581.	1100350.	673561.	203973.
1979	1795534.	1150240.	741103.	257505.
1980	1563089.	1445024.	798421.	227373.
1981	1087934.	753959.	707299.	209240.
1982	833439.	600307.	489236.	152632.

1983	725351.	547245.	403902.	170142.
1984	604823.	684984.	358646.	150244.
1985	725561.	693782.	332282.	108796.
1986	909118.	826750.	399539.	159171.
1987	706046.	906837.	447412.	147898.
1988	756819.	805362.	415798.	188375.
1989	604364.	878932.	422257.	156734.
1990	486150.	602421.	385921.	200626.
1991	467072.	413515.	265686.	142339.
1992	432758.	317212.	261467.	119939.

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREDATOR

PREDATOR SAITHE

PREY SANDEEL	COD	WHITING	HADDOCK	HERRING	SPRAT	N. POUT
1974	0.	54096.	113585.	134287.	9125.	1314657.
12091.						
1975	0.	62055.	24300.	95139.	10314.	1218105.
14165.						
1976	0.	59924.	27740.	73348.	3648.	1246364.
14653.						
1977	0.	59929.	38081.	47989.	2449.	887023.
11170.						
1978	0.	49446.	36609.	51514.	1119.	636601.
9041.						
1979	0.	40425.	43366.	57258.	922.	579289.
5976.						
1980	0.	34042.	16370.	59997.	1880.	547273.
3768.						
1981	0.	27343.	36285.	65633.	785.	656742.
8502.						
1982	0.	15493.	16233.	62350.	243.	716697.
5292.						
1983	0.	14194.	38501.	66829.	231.	656867.
5540.						
1984	0.	25288.	22309.	81119.	74.	709813.
5966.						
1985	0.	60359.	41567.	104537.	252.	703257.
15072.						
1986	0.	61389.	84334.	114563.	441.	659592.
14995.						
1987	0.	30596.	6956.	138433.	114.	444577.
7559.						

1988	0.	32665.	8046.	154398.	187.	262387.
6789.						
1989	0.	13524.	5337.	122678.	108.	252646.
3006.						
1990	0.	12044.	20866.	92661.	339.	301105.
4561.						
1991	0.	12956.	30973.	81528.	394.	387718.
6404.						
1992	0.	1215.	80641.	72291.	282.	332599.
3422.						

PREDATOR SAITHE

PREY	TOTAL	OTH.	FOOD	ST.BIOM.	YIELD
1974	1637840.	512011.	796562.	297636.	
1975	1424078.	579712.	745712.	296983.	
1976	1425676.	613031.	702195.	351419.	
1977	1046642.	426219.	493710.	193177.	
1978	784330.	382871.	410862.	141485.	
1979	727237.	316299.	368127.	110451.	
1980	663330.	257013.	364239.	120286.	
1981	795290.	427898.	386393.	116690.	
1982	816308.	348659.	409849.	159959.	
1983	782161.	290299.	413696.	171556.	
1984	844568.	402857.	473046.	216102.	
1985	925044.	615459.	524393.	238496.	
1986	935313.	688968.	497375.	248245.	
1987	628234.	436419.	387118.	207757.	
1988	464473.	343788.	277046.	113025.	
1989	397298.	257264.	257563.	119148.	
1990	431576.	318420.	255288.	92964.	
1991	519973.	367503.	283132.	120713.	
1992	490451.	217748.	259715.	108175.	

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREDATOR

PREDATOR MACKEREL

PREY SANDEEL	COD	WHITING	HADDOCK	HERRING	SPRAT	N. POUT
1974 1613965.	241.	1485.	0.	48142.	651982.	397739.
1975 897163.	160.	448.	0.	14771.	651129.	307857.
1976 845144.	627.	400.	0.	8864.	398660.	232906.
1977 697750.	521.	539.	0.	9256.	323943.	112574.
1978 545468.	281.	526.	0.	6199.	197061.	119896.
1979 416257.	267.	404.	0.	9122.	126774.	108052.
1980 266079.	204.	235.	0.	12178.	96572.	42512.
1981 210189.	190.	51.	0.	12403.	51864.	80732.
1982 171928.	172.	48.	0.	20613.	18934.	72933.
1983 195314.	212.	68.	0.	16389.	11272.	60385.
1984 187024.	57.	92.	0.	13052.	9950.	34642.
1985 100211.	44.	61.	0.	10869.	7465.	13764.
1986 68397.	29.	35.	0.	9119.	4310.	13640.
1987 39990.	12.	25.	0.	5060.	5247.	3009.
1988 62598.	13.	28.	0.	4833.	10085.	9744.
1989 39078.	16.	13.	0.	4480.	6045.	9638.
1990 45301.	22.	12.	0.	5882.	5479.	12234.
1991 61948.	75.	16.	0.	3316.	7364.	27975.
1992 96720.	69.	4.	0.	13272.	13654.	16601.

PREDATOR MACKEREL

PREY	TOTAL	OTH. FOOD	ST.BIOM.	YIELD
1974	2713554.	3565191.	985228.	197821.
1975	1871530.	3843490.	892661.	189289.
1976	1486600.	3184460.	751527.	177178.
1977	1144584.	2493148.	617458.	191235.
1978	869431.	1779118.	454499.	101108.
1979	660877.	1492058.	365085.	70246.
1980	417781.	1438220.	309609.	73141.
1981	355429.	1241580.	256841.	63766.
1982	284628.	1223471.	230757.	45095.
1983	283639.	997795.	209760.	49662.
1984	244817.	750215.	171463.	71700.
1985	132415.	500240.	111485.	58237.
1986	95530.	312257.	70541.	31443.
1987	53342.	223207.	39521.	2863.
1988	87302.	363754.	65191.	6687.
1989	59270.	366654.	54667.	9863.
1990	68930.	476617.	66080.	14137.
1991	100694.	528160.	80905.	13132.
1992	140320.	496346.	89022.	12774.

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREDATOR

PREDATOR HADDOCK

PREY SANDEEL	COD	WHITING	HADDOCK	HERRING	SPRAT	N. POUT
1974	2.	0.	9048.	410.	714.	259552.
414065.						
1975	0.	0.	1333.	297.	402.	126057.
458865.						
1976	2.	0.	1124.	275.	270.	99062.
269912.						
1977	2.	0.	2536.	197.	560.	59798.
178265.						
1978	1.	0.	1843.	108.	107.	71293.
168980.						
1979	1.	0.	1667.	137.	56.	122841.
202127.						

1980	4.	0.	837.	120.	48.	41609.
198605.						
1981	2.	0.	1873.	227.	61.	102599.
213197.						
1982	1.	0.	2516.	725.	70.	77220.
109042.						
1983	1.	0.	3837.	758.	29.	106065.
169840.						
1984	1.	0.	1480.	1161.	15.	58170.
139115.						
1985	2.	0.	1572.	672.	29.	47311.
251303.						
1986	1.	0.	3774.	1598.	25.	72680.
152780.						
1987	1.	0.	629.	1329.	22.	14040.
97399.						
1988	0.	0.	337.	1241.	55.	19483.
100269.						
1989	0.	0.	408.	748.	17.	13804.
30130.						
1990	0.	0.	638.	340.	7.	18142.
38668.						
1991	1.	0.	503.	413.	6.	49931.
85606.						
1992	0.	0.	2324.	114.	14.	112781.
197870.						

PREDATOR HADDOCK

PREY	TOTAL	OTH. FOOD	ST.BIOM.	YIELD
------	-------	-----------	----------	-------

1974	683792.	1691872.	605851.	387645.
1975	586955.	1399864.	801359.	504337.
1976	370645.	905295.	604098.	424403.
1977	241358.	698318.	372983.	249533.
1978	242331.	734418.	284601.	202970.
1979	326828.	1006864.	285233.	184880.
1980	241223.	1068253.	431732.	236571.
1981	317958.	881036.	406847.	221724.
1982	189574.	826629.	410851.	215955.
1983	280530.	949872.	349324.	228053.
1984	199941.	1105701.	434009.	192872.
1985	300889.	930051.	448839.	268761.
1986	230857.	973874.	384536.	257298.
1987	113420.	832795.	362649.	169910.

1988	121386.	507503.	321713.	217446.
1989	45108.	325102.	199808.	126844.
1990	57796.	366771.	126341.	84395.
1991	136460.	583717.	143807.	79514.
1992	313104.	2193863.	262680.	122522.

TABLE 6.2.2 (B) KEY RUN WITH ONLY NEW 1991 STOMACH DATA
NORTH SEA DATA 1974 - 1992

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

TOTAL BIOMASSES CONSUMED BY INDIVIDUAL PREDATORS, COMPARED TO STOCK
BIOMASS AND YIELD OF PREDATOR

PREDATOR COD

PREY SANDEEL	COD	WHITING	HADDOCK	HERRING	SPRAT	N. POUT
1974	9505.	115240.	64319.	23019.	45327.	132241.
59721.						
1975	8082.	141756.	38339.	14812.	58469.	125967.
71495.						
1976	12746.	123366.	12861.	8867.	46390.	133283.
54930.						
1977	16350.	157072.	28108.	6767.	53351.	136540.
111598.						
1978	17001.	182887.	29487.	8190.	42089.	138557.
78948.						
1979	21476.	181136.	42214.	10202.	34664.	151640.
67597.						
1980	26667.	240889.	33510.	13271.	39003.	184025.
77453.						
1981	25384.	160222.	27314.	25621.	21323.	188067.
67000.						
1982	16847.	102070.	28360.	30879.	10710.	169317.
54601.						
1983	14643.	77172.	35125.	37660.	4816.	158107.
53172.						
1984	9149.	89052.	32012.	42288.	8828.	123770.
52029.						
1985	11934.	85470.	18319.	48051.	6226.	90487.
43488.						
1986	7800.	96385.	34748.	50916.	4924.	58958.
58746.						
1987	7066.	96541.	12902.	56745.	10971.	65031.
46607.						
1988	4589.	66393.	5180.	63833.	9790.	37820.
36738.						
1989	2844.	61107.	4874.	39402.	5229.	37989.
21293.						
1990	3146.	40228.	7807.	34090.	3048.	41710.
19104.						

1991	3566.	25737.	12688.	30002.	5340.	32961.
20037.						
1992	4806.	31220.	78185.	21733.	18135.	47878.
42524.						

PREDATOR COD

PREY	TOTAL	OTH. FOOD	ST. BIOM.	YIELD
1974	449372.	302346.	328448.	202000.
1975	458921.	300311.	289247.	188770.
1976	392442.	347098.	293751.	204400.
1977	509786.	463442.	260807.	195295.
1978	497159.	424266.	353982.	275889.
1979	508929.	472179.	319825.	234721.
1980	614819.	566992.	347045.	258737.
1981	514931.	537121.	427881.	325926.
1982	412783.	494792.	350503.	287894.
1983	380694.	392694.	315155.	246875.
1984	357128.	412092.	260060.	211534.
1985	303976.	360041.	278613.	211969.
1986	312476.	364296.	221560.	189470.
1987	295863.	305855.	238137.	185132.
1988	224343.	250978.	211647.	175639.
1989	172737.	223979.	159197.	128096.
1990	149134.	197646.	143200.	109402.
1991	130330.	213406.	122138.	90484.
1992	244481.	274141.	129854.	94081.

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREDATOR

PREDATOR WHITING

PREY	COD	WHITING	HADDOCK	HERRING	SPRAT	N. POUT
SANDEEL						
1974	598.	48978.	41592.	21262.	425668.	488724.
465045.						
1975	438.	60542.	4309.	9655.	521169.	515620.
532028.						
1976	1483.	54314.	6253.	6545.	434062.	507419.
459830.						

1977	1592.	91350.	18157.	9559.	318898.	429046.
635793.						
1978	1457.	102095.	20656.	9609.	319914.	480289.
577278.						
1979	2492.	109748.	32641.	16349.	346634.	691563.
528795.						
1980	3396.	134463.	14511.	35893.	300940.	526951.
477262.						
1981	2384.	51262.	15935.	44205.	155919.	459626.
340155.						
1982	1132.	34459.	8951.	64044.	54871.	413216.
232724.						
1983	964.	27765.	19876.	51477.	31401.	312089.
251069.						
1984	429.	31542.	7716.	42037.	43332.	244386.
212133.						
1985	872.	39275.	9354.	49986.	29083.	209203.
303307.						
1986	596.	52694.	19805.	72811.	35199.	251003.
379552.						
1987	619.	50100.	2754.	75844.	100591.	165510.
267672.						
1988	575.	53236.	3679.	44906.	84606.	193677.
286641.						
1989	340.	43715.	3508.	54550.	46949.	200348.
224524.						
1990	371.	22537.	8899.	50030.	50292.	162762.
169247.						
1991	546.	16195.	10609.	19743.	68295.	155639.
156722.						
1992	328.	5820.	37540.	42945.	96579.	98531.
137578.						

PREDATOR WHITING

PREY	TOTAL	OTH. FOOD	ST.BIOM.	YIELD
1974	1491866.	884238.	602505.	336029.
1975	1643761.	1065458.	662425.	270350.
1976	1469908.	954897.	698165.	341950.
1977	1504395.	1259608.	647730.	288723.
1978	1511297.	1311010.	703702.	203973.
1979	1728222.	1379811.	767562.	257505.
1980	1493416.	1664781.	861717.	227373.
1981	1069486.	846767.	726851.	209240.
1982	809396.	679907.	511852.	152632.
1983	694642.	637497.	409841.	170142.

1984	581575.	770092.	380749.	150244.
1985	641080.	831445.	339078.	108796.
1986	811661.	995043.	424398.	159171.
1987	663090.	984526.	459952.	147898.
1988	667320.	914690.	424798.	188375.
1989	573933.	930635.	435170.	156734.
1990	464139.	636888.	387030.	200626.
1991	427749.	479645.	269914.	142339.
1992	419321.	356129.	270202.	119939.

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREDATOR

PREDATOR SAITHE

PREY SANDEEL	COD	WHITING	HADDOCK	HERRING	SPRAT	N. POUT
1974	0.	54956.	119394.	137693.	653.	1302423.
12853.						
1975	0.	52994.	23424.	94140.	940.	1238228.
14390.						
1976	0.	53892.	25407.	70250.	470.	1267569.
14739.						
1977	0.	53763.	34412.	44548.	303.	918791.
10707.						
1978	0.	44624.	33924.	47660.	333.	661878.
8587.						
1979	0.	37953.	38015.	52526.	126.	602720.
5543.						
1980	0.	26926.	13437.	53435.	80.	592284.
3220.						
1981	0.	25894.	32229.	60952.	116.	691166.
8182.						
1982	0.	13807.	14838.	60133.	36.	731533.
5554.						
1983	0.	14353.	37865.	65462.	76.	661739.
5720.						
1984	0.	22207.	21315.	79270.	48.	723302.
6195.						
1985	0.	57748.	39527.	102533.	83.	718764.
14527.						
1986	0.	55774.	78591.	112064.	362.	685212.
14522.						

1987	0.	25933.	6146.	130946.	57.	477983.
7152.						
1988	0.	28299.	6917.	148395.	56.	286812.
6074.						
1989	0.	10673.	4485.	117231.	42.	274120.
2816.						
1990	0.	10992.	19232.	90596.	250.	312585.
4455.						
1991	0.	12955.	30971.	81566.	351.	387710.
6404.						
1992	0.	1216.	84725.	74078.	68.	321387.
3560.						

PREDATOR SAITHE

PREY	TOTAL	OTH. FOOD	ST.BIOM.	YIELD
1974	1627972.	521880.	796562.	297636.
1975	1424117.	579673.	745712.	296983.
1976	1432326.	606381.	702195.	351419.
1977	1062524.	410337.	493710.	193177.
1978	797006.	370195.	410862.	141485.
1979	736883.	306653.	368127.	110451.
1980	689383.	230959.	364239.	120286.
1981	818539.	404649.	386393.	116690.
1982	825901.	339066.	409849.	159959.
1983	785214.	287246.	413696.	171556.
1984	852338.	395088.	473046.	216102.
1985	933181.	607323.	524393.	238496.
1986	946525.	677756.	497375.	248245.
1987	648217.	416436.	387118.	207757.
1988	476553.	331708.	277046.	113025.
1989	409367.	245194.	257563.	119148.
1990	438110.	311886.	255288.	92964.
1991	519956.	367520.	283132.	120713.
1992	485034.	223164.	259715.	108175.

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREDATOR

PREDATOR MACKEREL

PREY SANDEEL	COD	WHITING	HADDOCK	HERRING	SPRAT	N. POUT
1974	263.	1462.	0.	46980.	743826.	374859.
1708621.						
1975	163.	372.	0.	13180.	701109.	335810.
1018274.						
1976	605.	363.	0.	7755.	431237.	268421.
943676.						
1977	493.	500.	0.	8467.	353710.	125704.
802573.						
1978	285.	483.	0.	5653.	210156.	133465.
621379.						
1979	251.	399.	0.	8287.	130994.	132578.
465711.						
1980	175.	204.	0.	11831.	99346.	49382.
299430.						
1981	166.	50.	0.	11906.	52712.	87952.
234996.						
1982	170.	43.	0.	19852.	21420.	77994.
208957.						
1983	217.	69.	0.	15816.	10847.	62174.
248903.						
1984	60.	82.	0.	12552.	9676.	36450.
226442.						
1985	46.	60.	0.	10642.	7278.	15600.
126923.						
1986	29.	32.	0.	8848.	4383.	14959.
78789.						
1987	12.	22.	0.	4934.	5596.	3758.
49566.						
1988	12.	26.	0.	4696.	10901.	12518.
68224.						
1989	15.	11.	0.	4375.	6800.	11072.
46081.						
1990	21.	11.	0.	5698.	6994.	13162.
59652.						
1991	75.	16.	0.	3228.	7535.	27953.
79498.						
1992	74.	4.	0.	12988.	14001.	15973.
117791.						

PREDATOR MACKEREL

PREY	TOTAL	OTH. FOOD	ST. BIOM.	YIELD
1974	2876011.	3402734.	985228.	197821.
1975	2068907.	3646113.	892661.	189289.
1976	1652056.	3019004.	751527.	177178.
1977	1291447.	2346285.	617458.	191235.
1978	971421.	1677128.	454499.	101108.
1979	738221.	1414713.	365085.	70246.
1980	460367.	1395635.	309609.	73141.
1981	387780.	1209229.	256841.	63766.
1982	328436.	1179663.	230757.	45095.
1983	338026.	943409.	209760.	49662.
1984	285262.	709771.	171463.	71700.
1985	160547.	472108.	111485.	58237.
1986	107040.	300747.	70541.	31443.
1987	63888.	212661.	39521.	2863.
1988	96378.	354678.	65191.	6687.
1989	68353.	357572.	54667.	9863.
1990	85537.	460010.	66080.	14137.
1991	118305.	510549.	80905.	13132.
1992	160832.	475834.	89022.	12774.

TOTAL BIOMASSES CONSUMED BY PREDATORS, COMPARED TO STOCK BIOMASS AND YIELD OF PREDATOR

PREDATOR HADDOCK

PREY	COD	WHITING	HADDOCK	HERRING	SPRAT	N. POUT
SANDEEL						
1974	4.	0.	10754.	419.	178.	115541.
469101.						
1975	1.	0.	1960.	286.	130.	153599.
539666.						
1976	4.	0.	1081.	266.	137.	133025.
323990.						
1977	5.	0.	2123.	182.	74.	41811.
219373.						
1978	3.	0.	2352.	99.	30.	41891.
181851.						
1979	4.	0.	2997.	127.	49.	69478.
200510.						

1980	9.	0.	1984.	111.	22.	50934.
227998.						
1981	5.	0.	1849.	218.	15.	101887.
248235.						
1982	3.	0.	2778.	710.	16.	76032.
181186.						
1983	3.	0.	4113.	747.	7.	55497.
201466.						
1984	2.	0.	3096.	1152.	11.	58725.
194483.						
1985	7.	0.	1892.	662.	7.	51652.
297163.						
1986	3.	0.	4248.	1575.	6.	41951.
187733.						
1987	2.	0.	1146.	1307.	10.	20912.
131749.						
1988	2.	0.	366.	1233.	19.	29905.
129938.						
1989	2.	0.	471.	739.	6.	15533.
52697.						
1990	1.	0.	777.	338.	3.	9508.
48476.						
1991	3.	0.	1159.	418.	8.	19764.
96412.						
1992	2.	0.	8906.	115.	9.	26811.
201345.						

PREDATOR HADDOCK

PREY	TOTAL	OTH.	FOOD	ST.BIOM.	YIELD
1974	595997.	1786109.	613719.	387645.	
1975	695642.	1306837.	811496.	504337.	
1976	458502.	814025.	610637.	424403.	
1977	263566.	653510.	376911.	249533.	
1978	226225.	729431.	286420.	202970.	
1979	273164.	1019016.	289160.	184880.	
1980	281056.	1020513.	436743.	236571.	
1981	352210.	830259.	413869.	221724.	
1982	260725.	753559.	417296.	215955.	
1983	261834.	956516.	352082.	228053.	
1984	257469.	1054419.	437893.	192872.	
1985	351383.	876118.	453285.	268761.	
1986	235516.	939366.	388036.	257298.	
1987	155126.	794430.	363763.	169910.	
1988	161462.	463803.	324594.	217446.	
1989	69448.	294252.	200724.	126844.	
1990	59103.	348890.	126620.	84395.	
1991	117763.	592735.	144221.	79514.	
1992	237188.	2244821.	262252.	122522.	

Table 10.2.1 Results from a quadratic approximation to MSFOR and from MSFOR for various Effort change scenarios.

Fleet	Relative Effort Change					
Scenario	1	2	3	4	5	6
cod	1	0.9	1	1	1	0.33333
capelin	1	1	0.9	1	1	0
shrimp	1	1	1	0.9	1	0
herring	1	1	1	1	0.9	0.33333

Fleet	% Yield Change From Quadratic					
Scenario	1	2	3	4	5	6
cod	0	-1	0	0	0	-44
capelin	0	-2	-5	0	0	-100
shrimp	0	0	0	-7	0	-100
herring	0	-3	0	0	-6	-64

Fleet	% Yield Change from MSFOR					
Scenario	1	2	3	4	5	6
cod	0	-1	0	0	0	-24
capelin	0	-2	-5	0	0	-100
shrimp	0	0	0	-7	0	-100
herring	0	-3	0	0	-6	-78

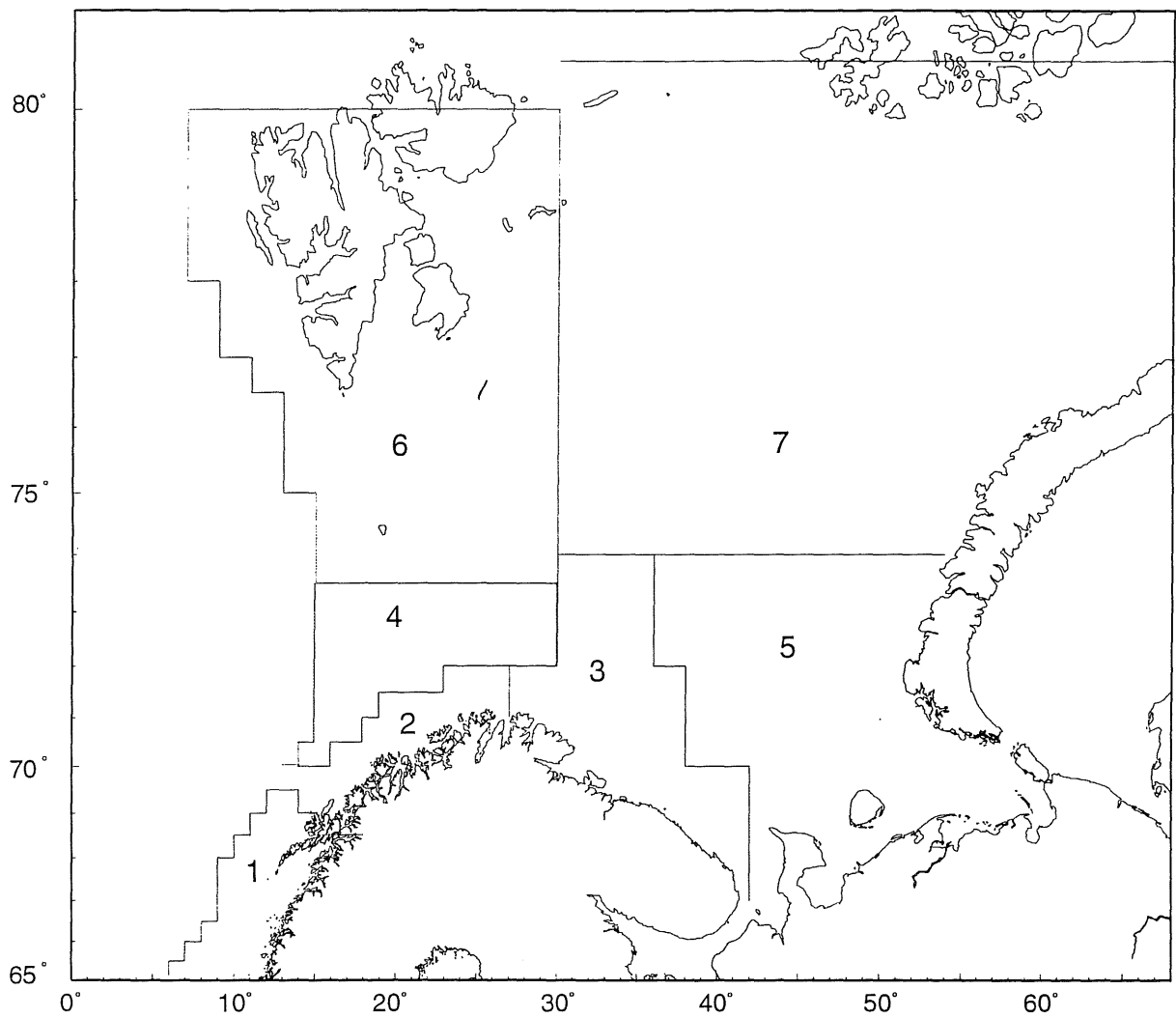


Fig 2.2.1 Map of Barents Sea, showing the six geographic divisions used in MULTSPEC.

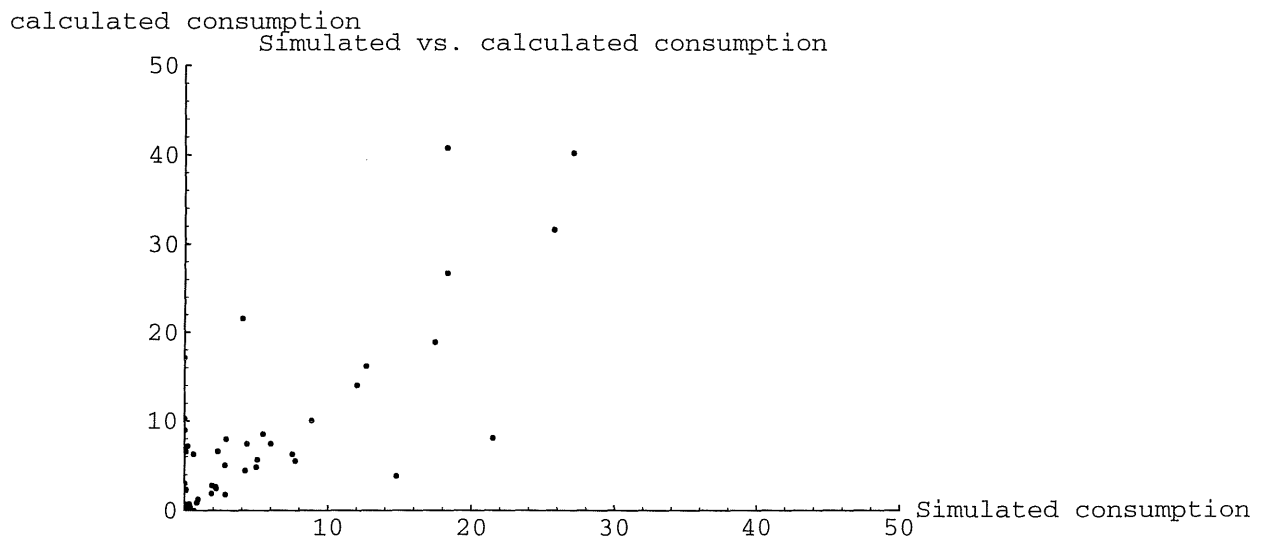


Fig 2.2.2. Scatterplot of consumption of capelin by cod as estimated in the MULTSPEC simulations (x-axis) and as calculated from direct use of stomach contents data and VPA estimates of cod abundance.

Fig 2.2.3 Cod growth vs. capelin abundance from MULTSPEC

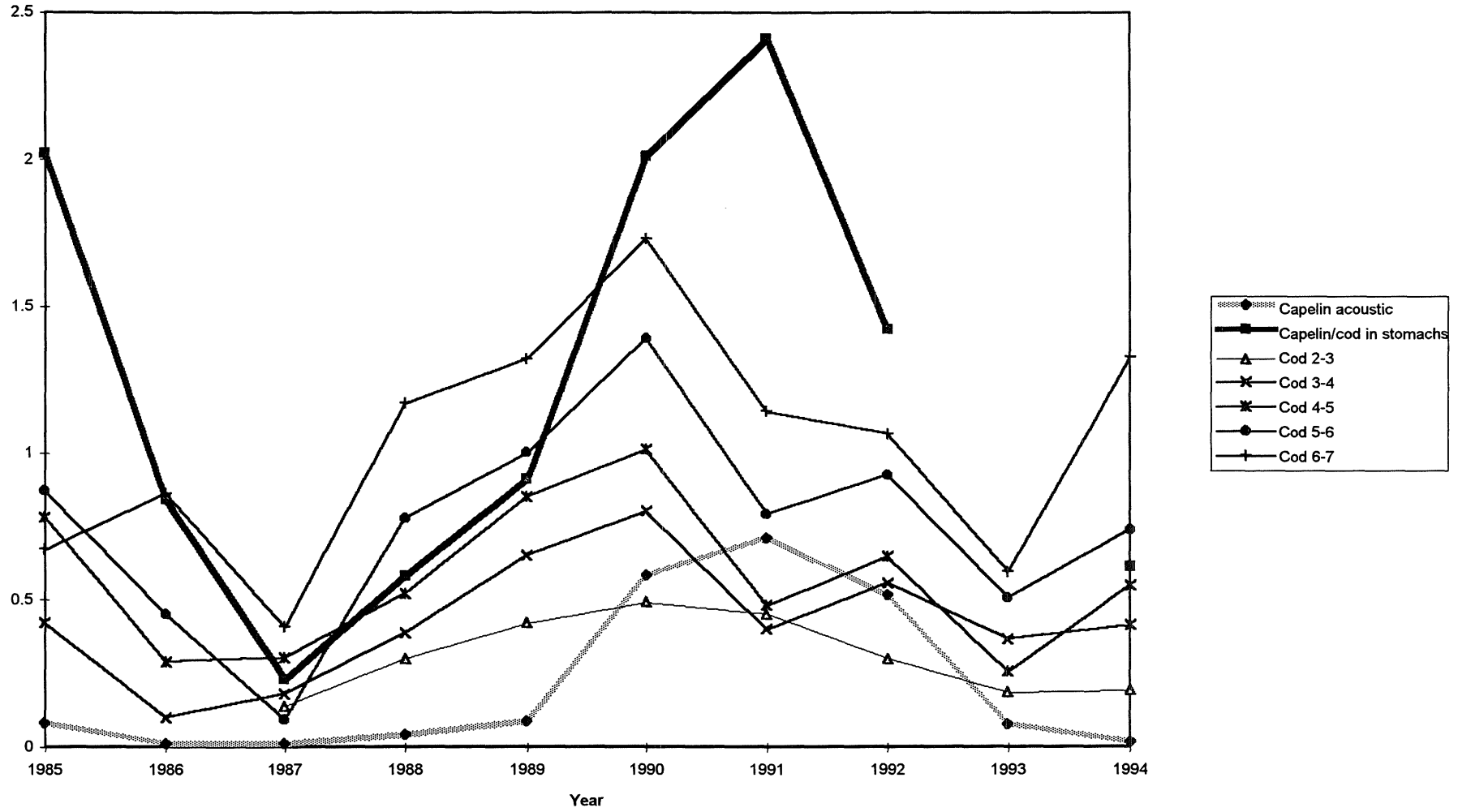
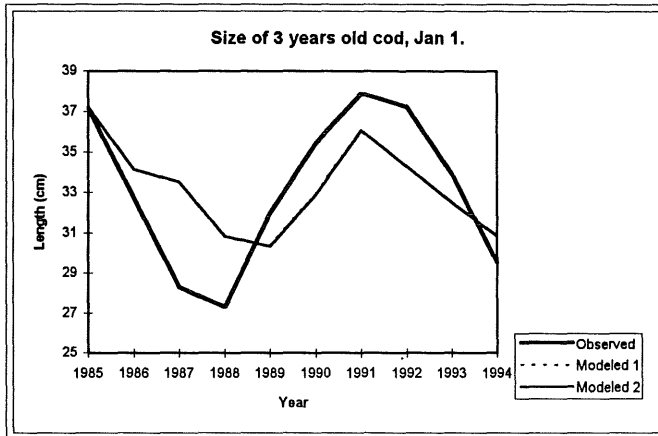


Fig 2.2.4 Length increments over time for ages 3-7 cod, observed in sampling data, and from MULTSPEC with (Modeled 1) and without (modeled 2) updating cod data annually.

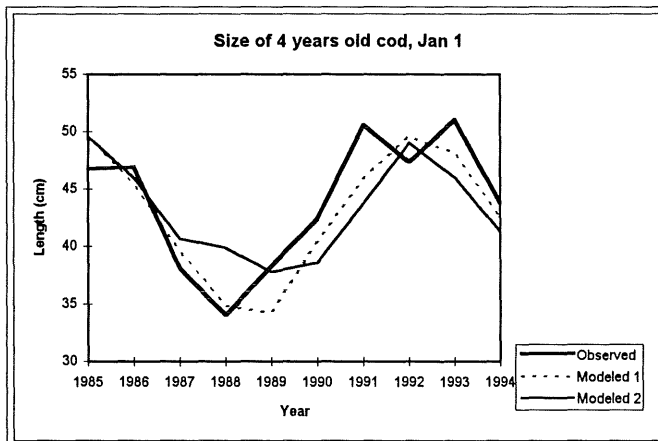
Age group 3

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Observed	37.183	32.758	28.312	27.308	31.988	35.492	37.915	37.269	33.991	29.563
Modeled 1	37.263	34.161	33.55	30.835	30.320	32.931	36.088	34.328	32.546	30.848
Modeled 2	37.263	34.161	33.55	30.835	30.320	32.931	36.088	34.328	32.546	30.848



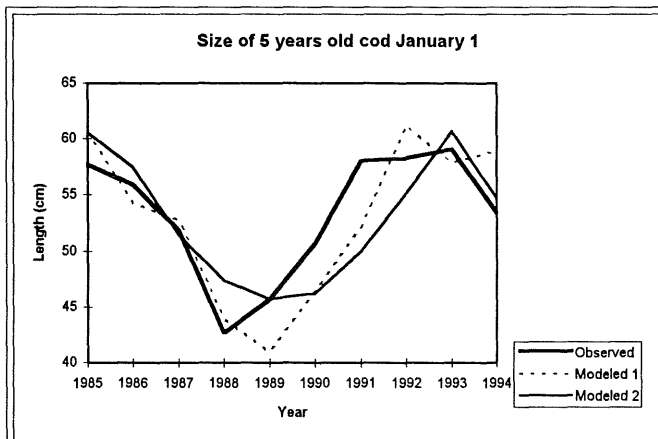
Age group 4

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Observed	46.797	46.967	38.120	34.082	38.350	42.430	50.600	47.408	51.048	43.847
Modeled 1	49.625	45.456	39.634	34.906	34.246	40.373	45.878	49.604	48.225	42.563
Modeled 2	49.625	45.976	40.668	39.901	37.789	38.636	43.786	49.049	46.081	41.338



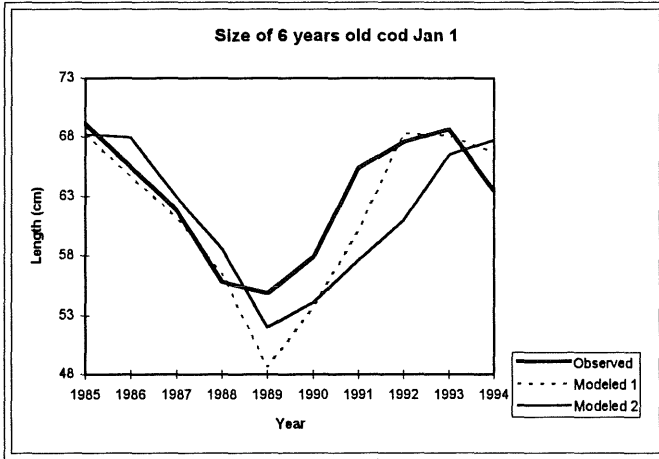
Age group 5

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Observed	57.710	55.916	51.851	42.679	45.752	50.742	58.081	58.302	59.118	53.462
Modeled 1	60.583	54.320	52.778	43.979	40.997	46.373	52.158	61.164	57.910	58.904
Modeled 2	60.583	57.497	51.481	47.412	45.759	46.232	50.027	55.170	60.724	54.746



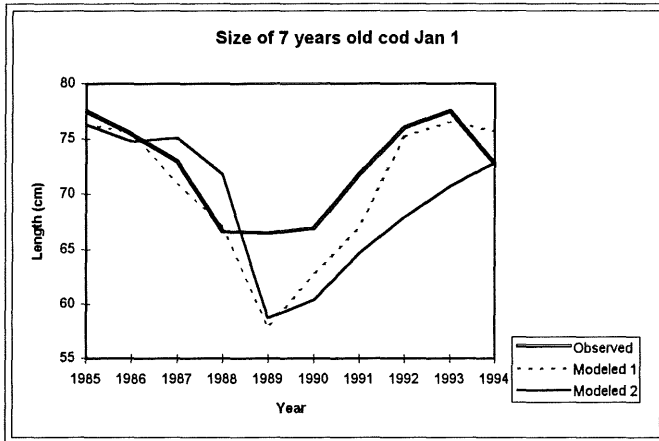
Age group 6

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Observed	69.136	65.499	61.839	55.818	54.830	57.888	65.419	67.580	68.666	63.447
Modeled 1	68.235	64.668	61.226	56.530	48.613	53.625	60.121	68.268	68.143	66.752
Modeled 2	68.235	67.955	62.962	58.614	52.005	54.093	57.629	61.029	66.503	67.780



Age group 7

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Observed	77.583	75.454	72.987	66.667	66.501	66.943	71.847	76.075	77.557	72.829
Modeled 1	76.359	75.644	70.980	67.094	57.801	62.633	66.941	75.226	76.560	75.787
Modeled 2	76.359	74.784	75.118	71.815	58.740	60.406	64.684	67.916	70.692	72.891



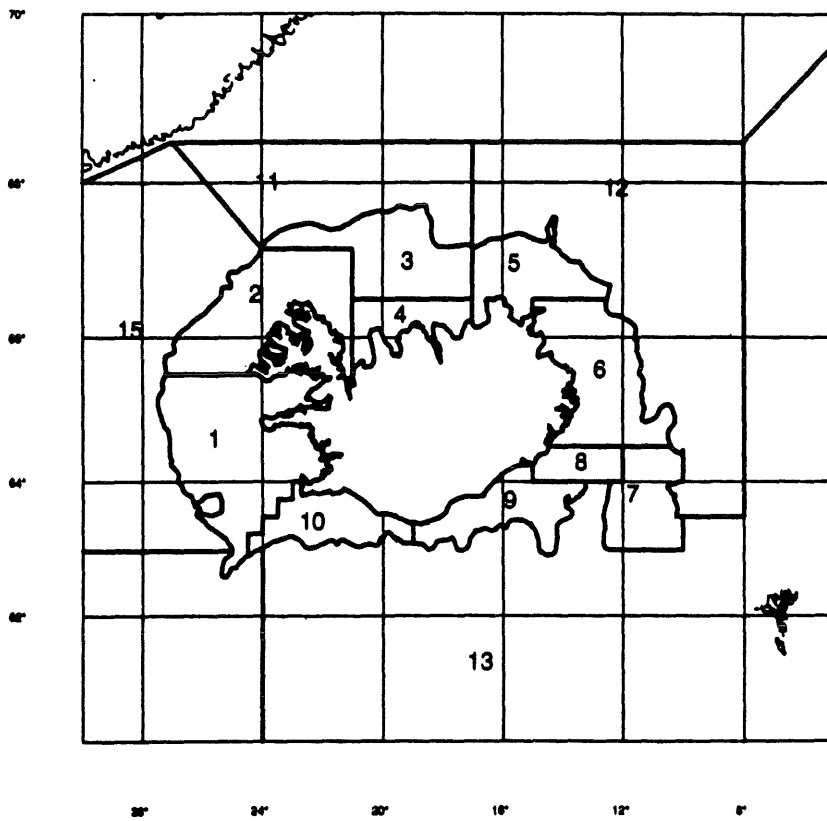


Fig 2.3.1 Map of marine area around Iceland, showing the 16 geographic subdivisions used in BORMICON.

1985

1986

1987

1988

1989

1990

1991

1992

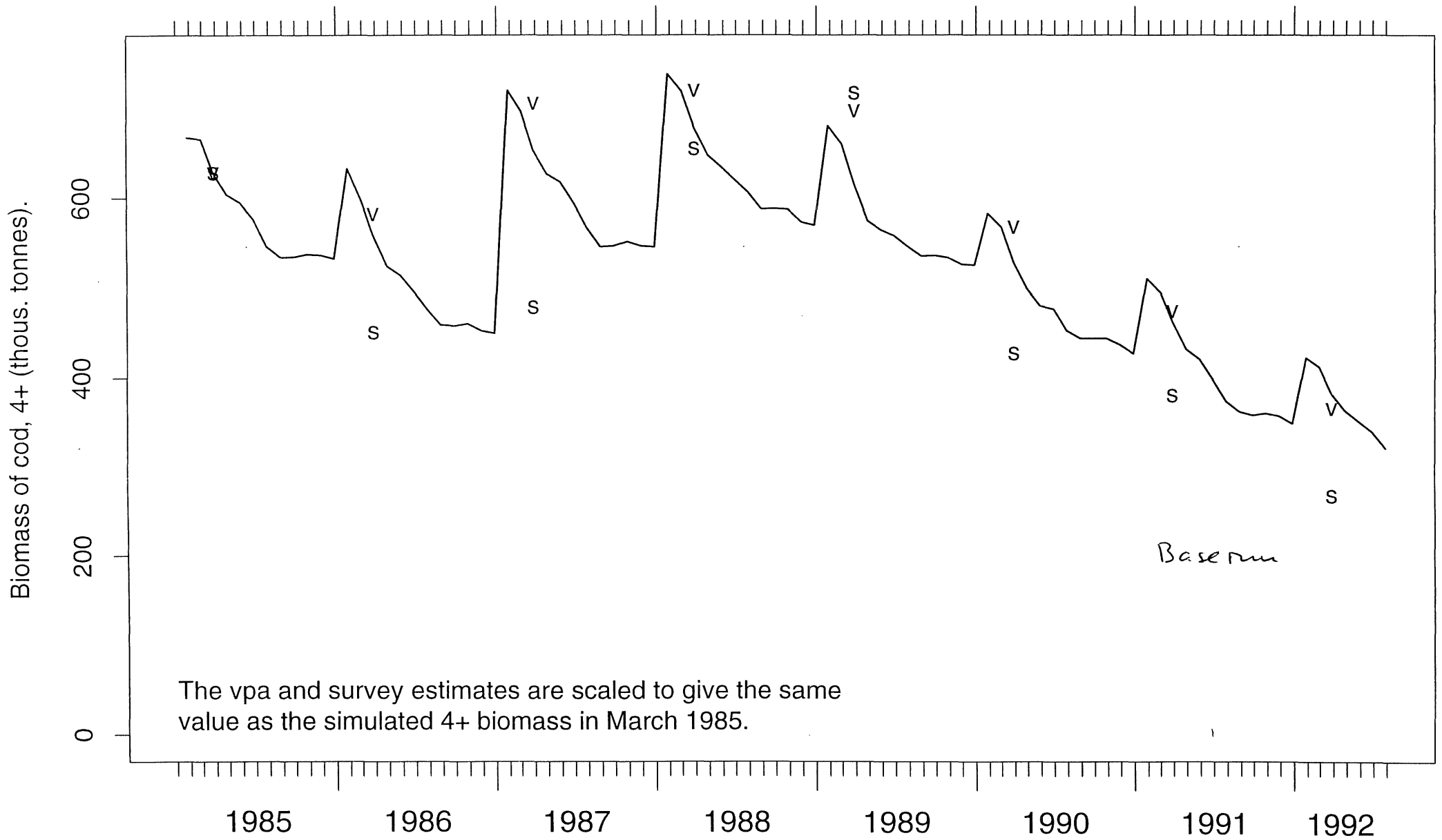


Fig 2.3.2 Baseline BORMICON conditions - biomass of 4+ cod from survey (s), single species VPA (v), and BORMICON (line), all

1985

1986

1987

1988

1989

1990

1991

1992

J A J O J A J O J A J O J A J O J A J O J A J O J A J

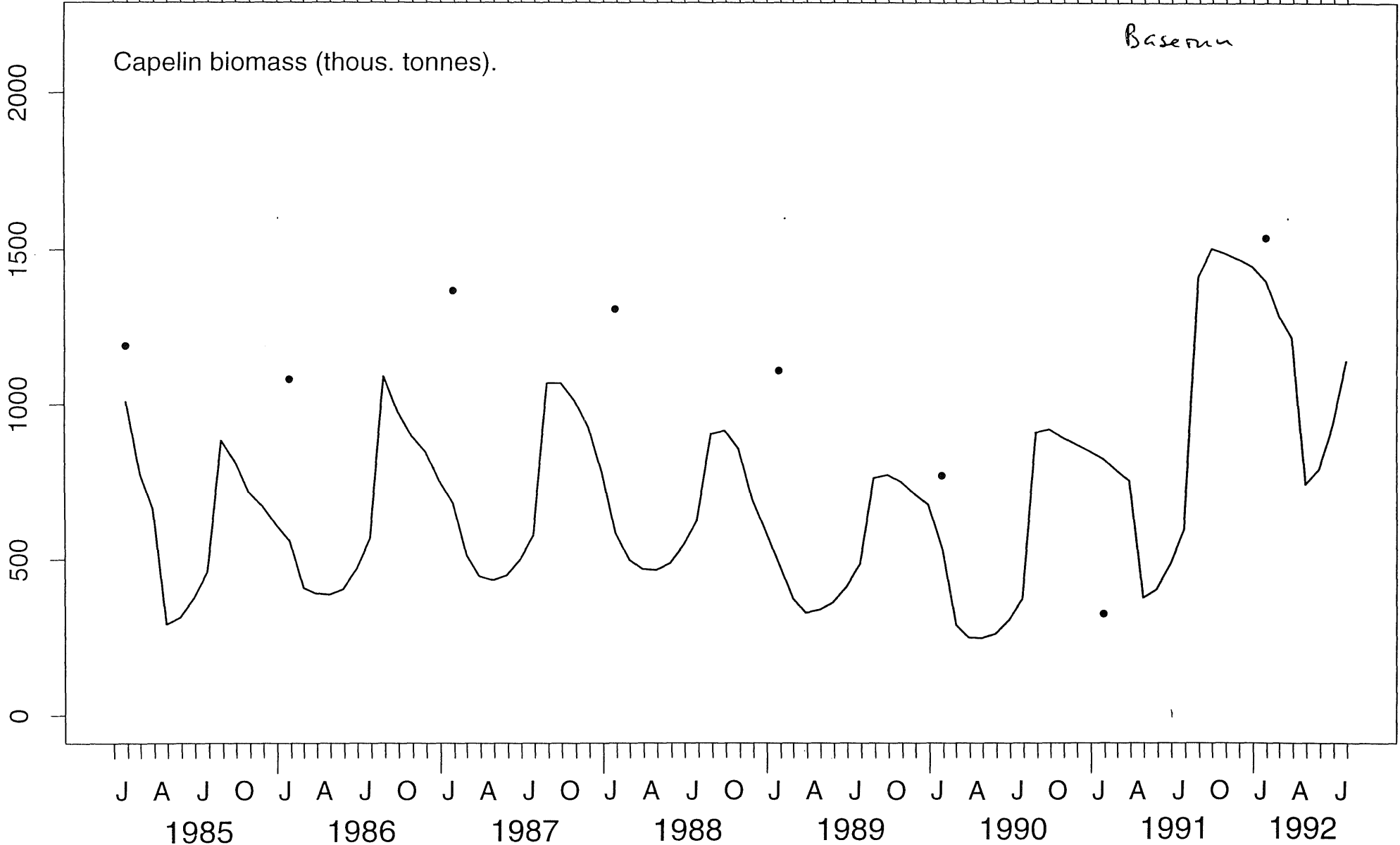


Fig. 2.3.3 Baseline BORMICON conditions - biomass of capelin from acoustic surveys (points) and BORMICON estimates (line), scaled

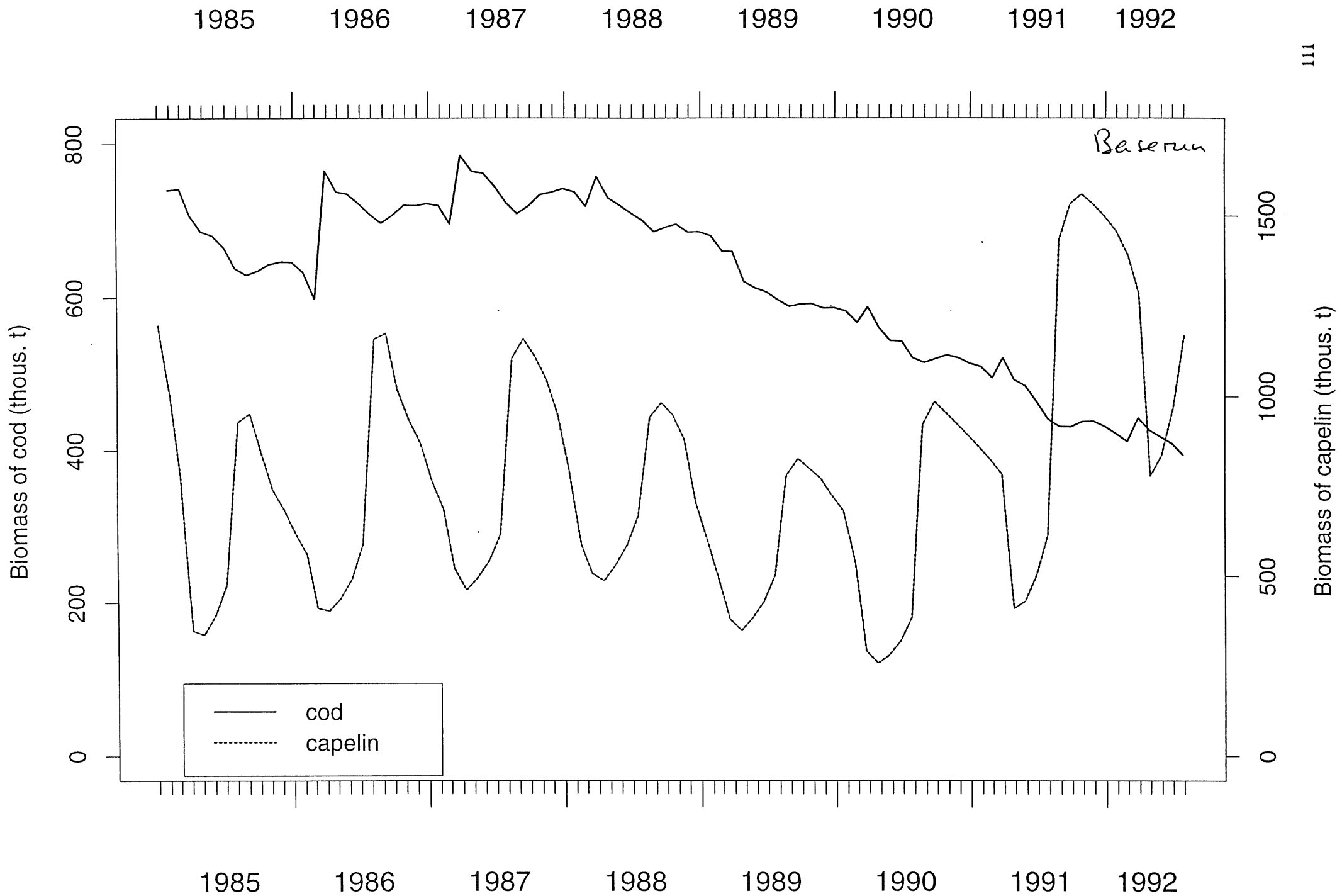


Fig. 2.3.4 Baseline BORMICON conditions - BORMICON estimates of biomass of 4+ cod and capelin plotted together.

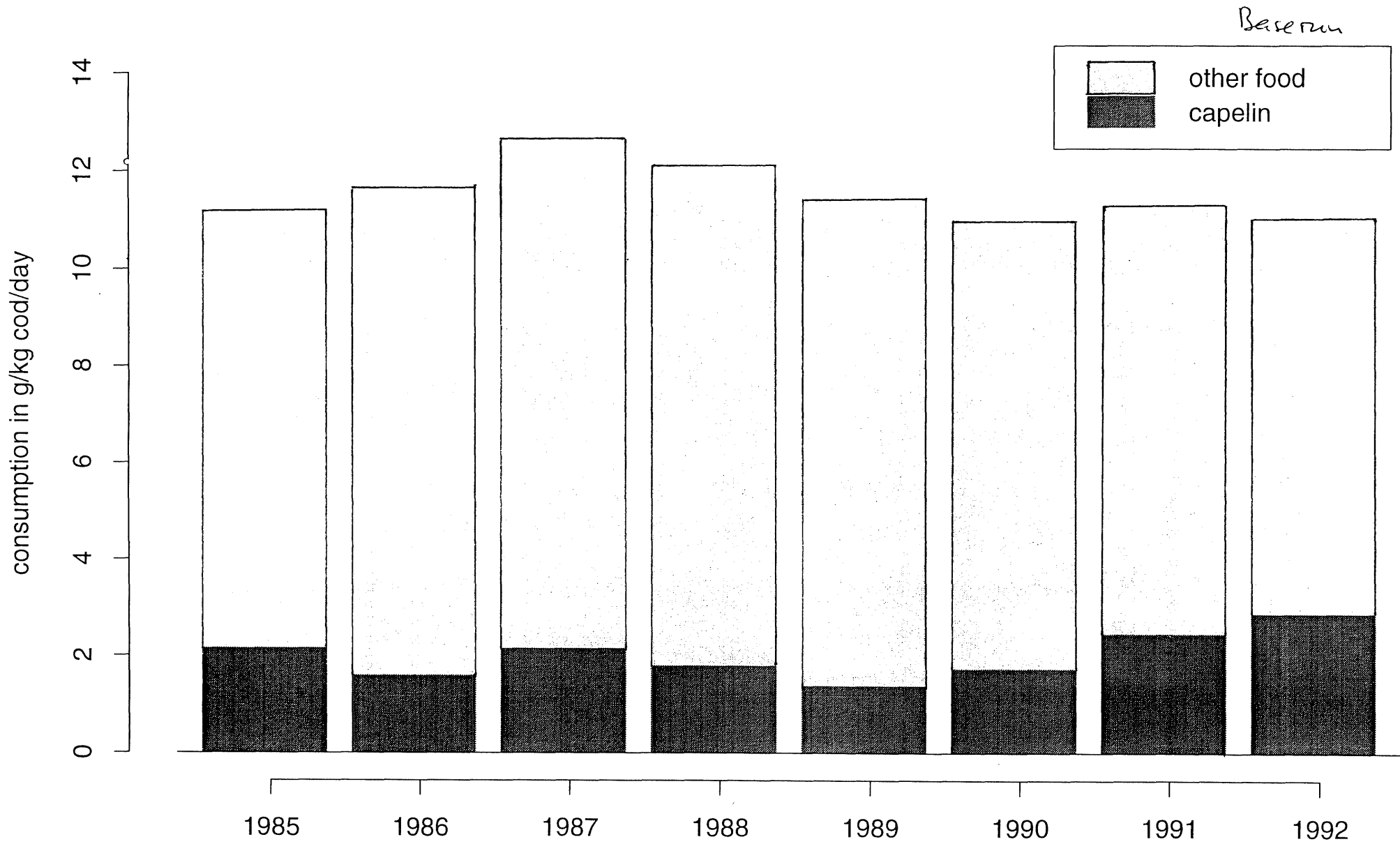


Fig. 2.3.5 Baseline BORMICON conditions - BORMICON estimates of annual consumption of capelin (dark bars) and other food (light bars) by cod from 1985 to 1992.

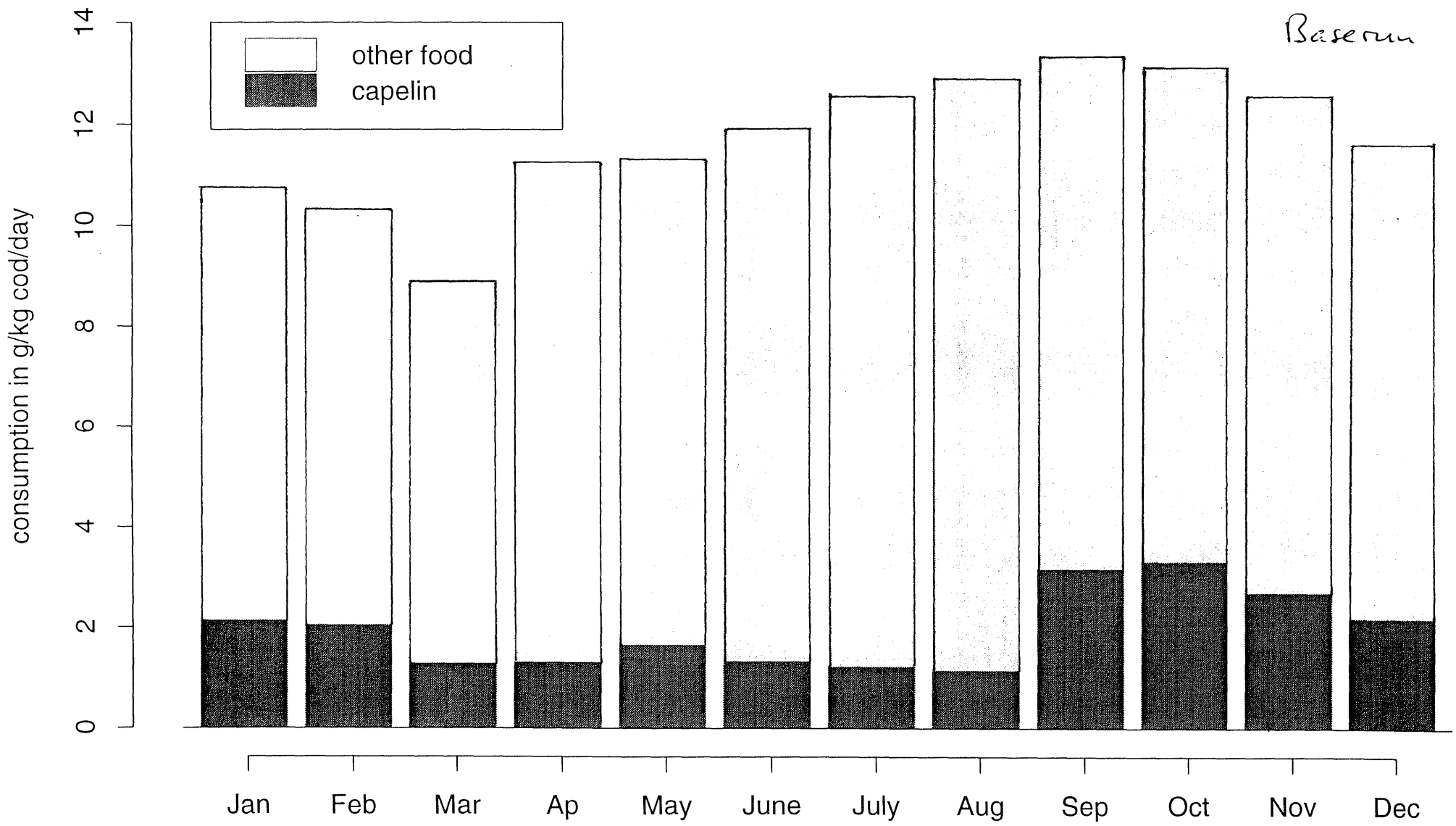


Fig. 2.3.6 Baseline BORMICON conditions - BORMICON estimates of monthly consumption of capelin (dark bars) and other food (light bars) by cod averaged over 1980 to 1992.

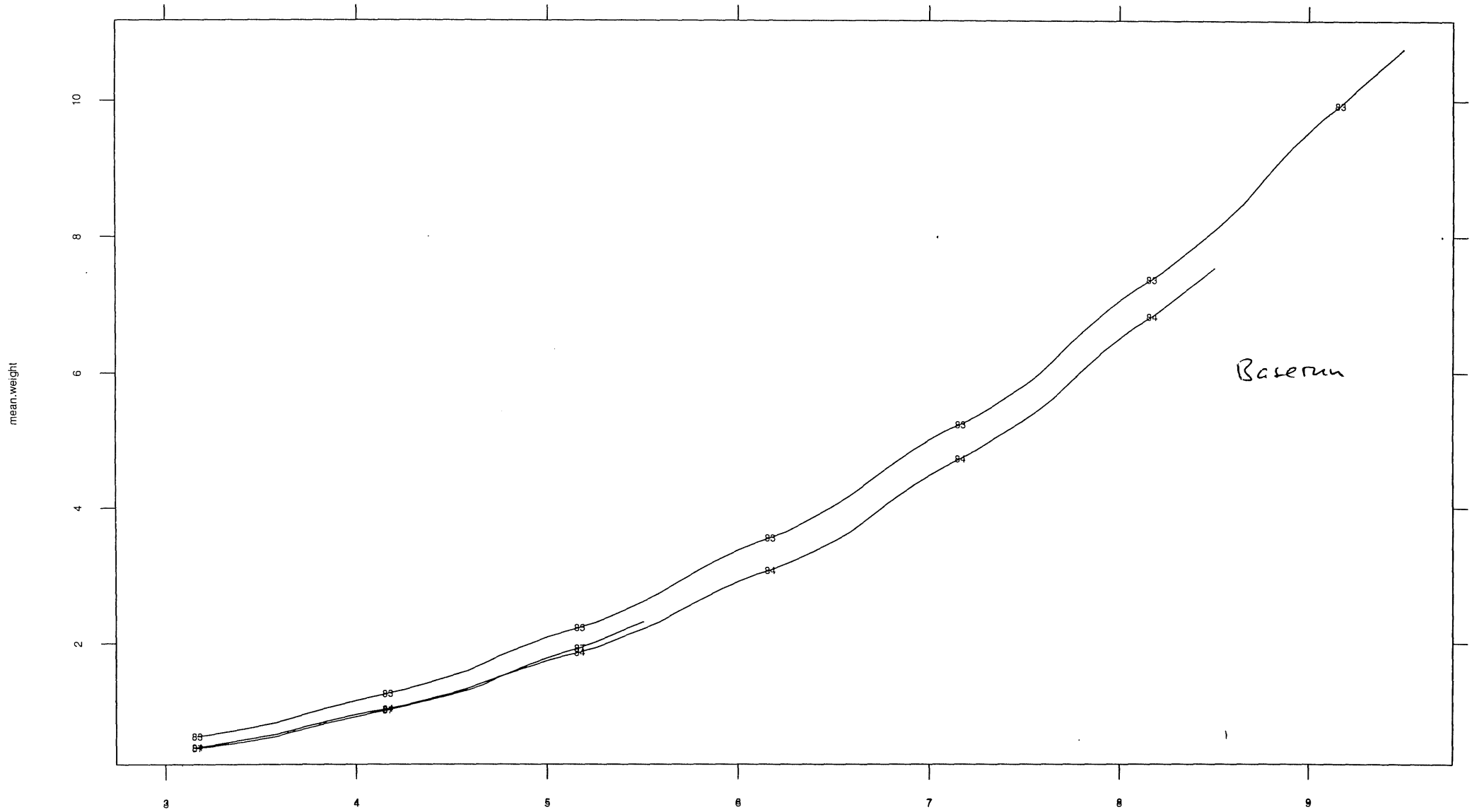


Fig. 2.3.7 Baseline BORMICON conditions - Estimated mean weight at age of cod for the cohorts produced in 1983 (longest line - to upper right corner), 1984 (slightly shorter line - stops above and right of center of figure) and 1987 (shortest line - sto

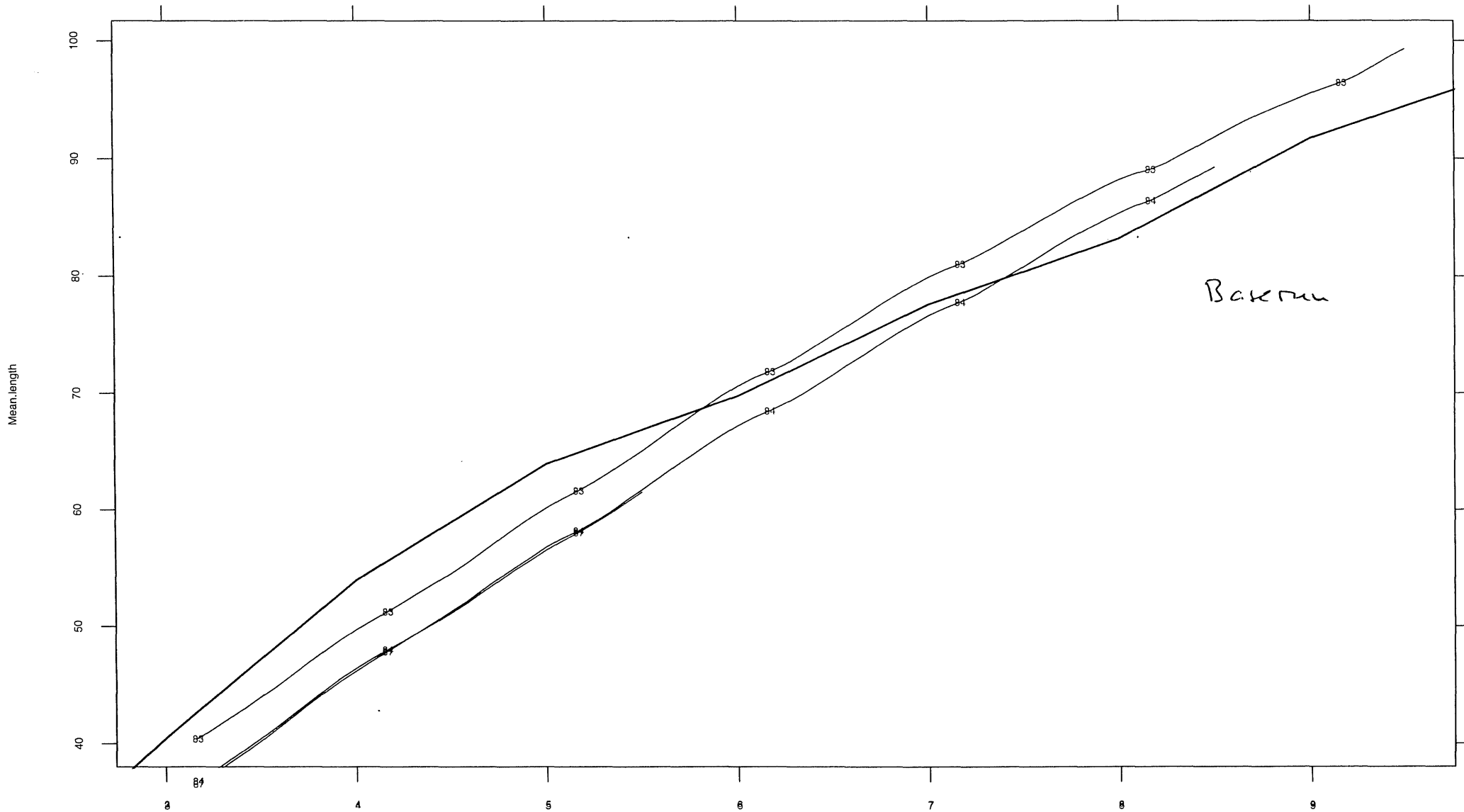


Fig. 2.3.8 Baseline BORMICON conditions - Estimated mean length at age of cod for the cohorts produced in 1983 (longest line - to upper right corner), 1984 (slightly shorter line - stops above and right of center of figure), and 1987 (shortest line - stops below and left of center). Heavy dark line is reference values from single species assessment.

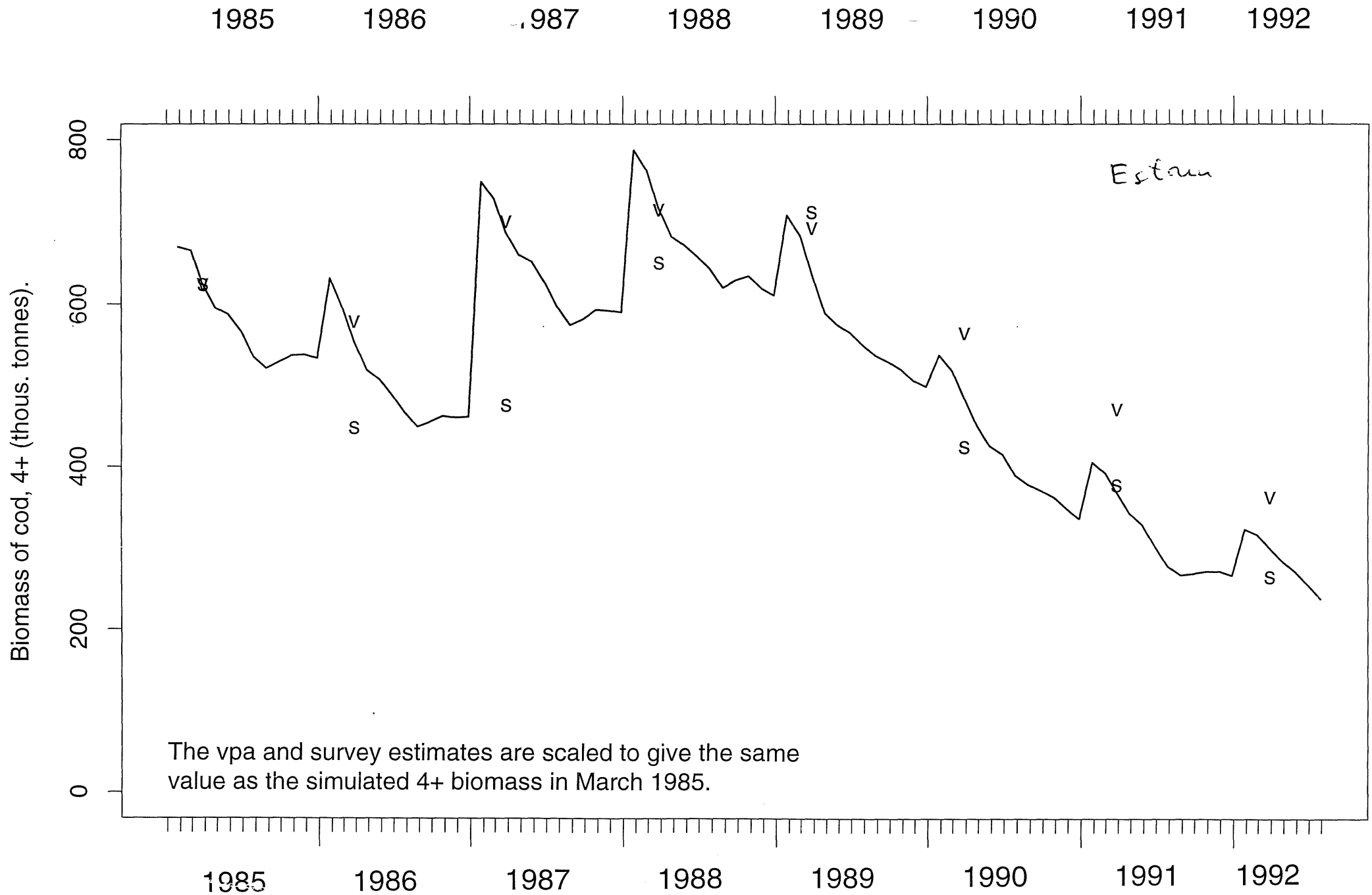


Fig 2.3.9 BORMICON parameter estimation run - biomass of 4+ cod from survey (s), single species VPA (v), and BORMICON (line), all scaled to produce same value in March 1985.

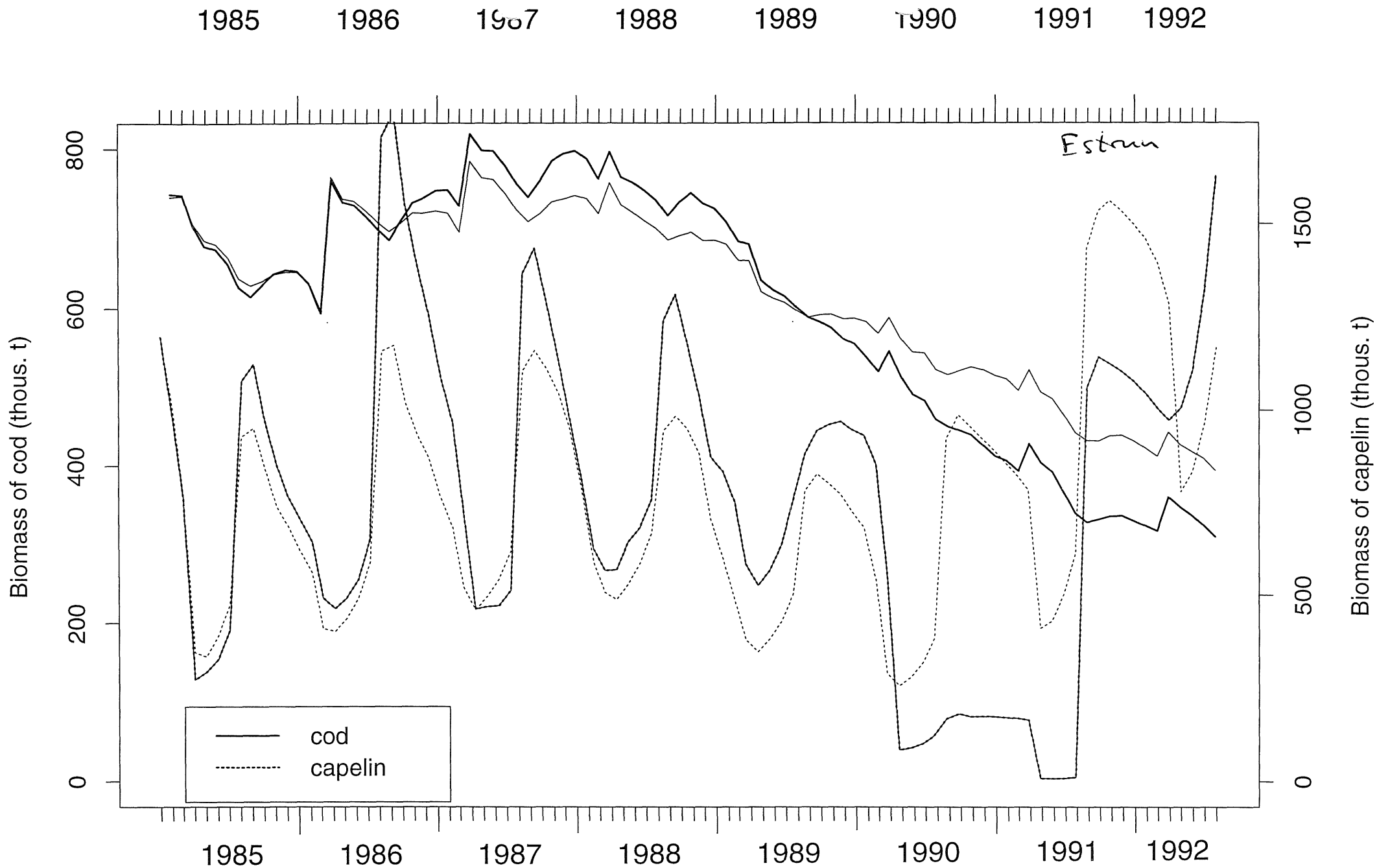


Fig. 2.3.11 BORMICON parameter estimation runs - BORMICON estimates of biomass of 4+ cod and capelin plotted together. Baseline runs for reference as lighter lines.

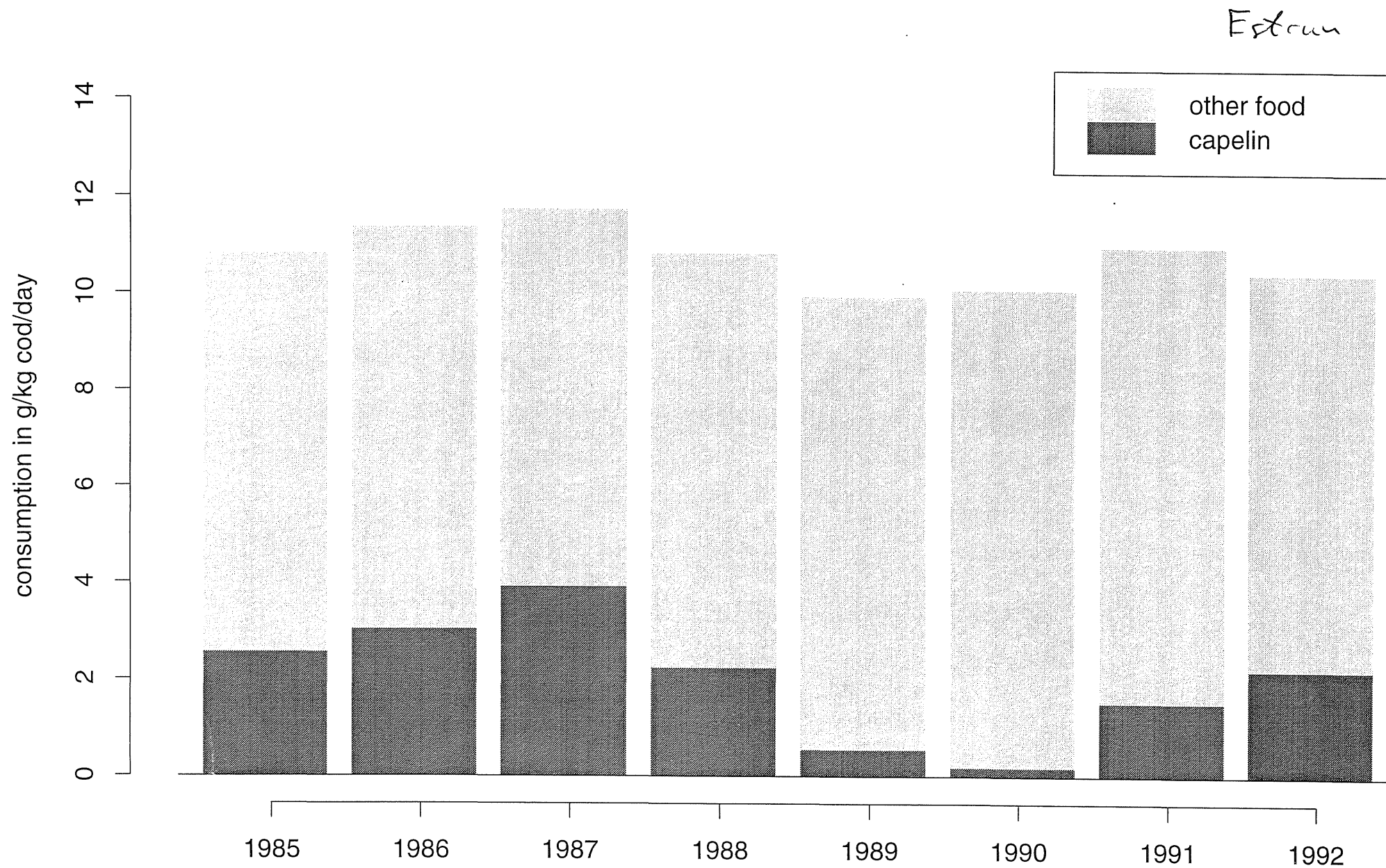


Fig. 2.3.12 BORMICON parameter estimation runs - BORMICON estimates of annual consumption of capelin (dark bars) and other food (light bars) by cod from 1985 to 1992.

Estim

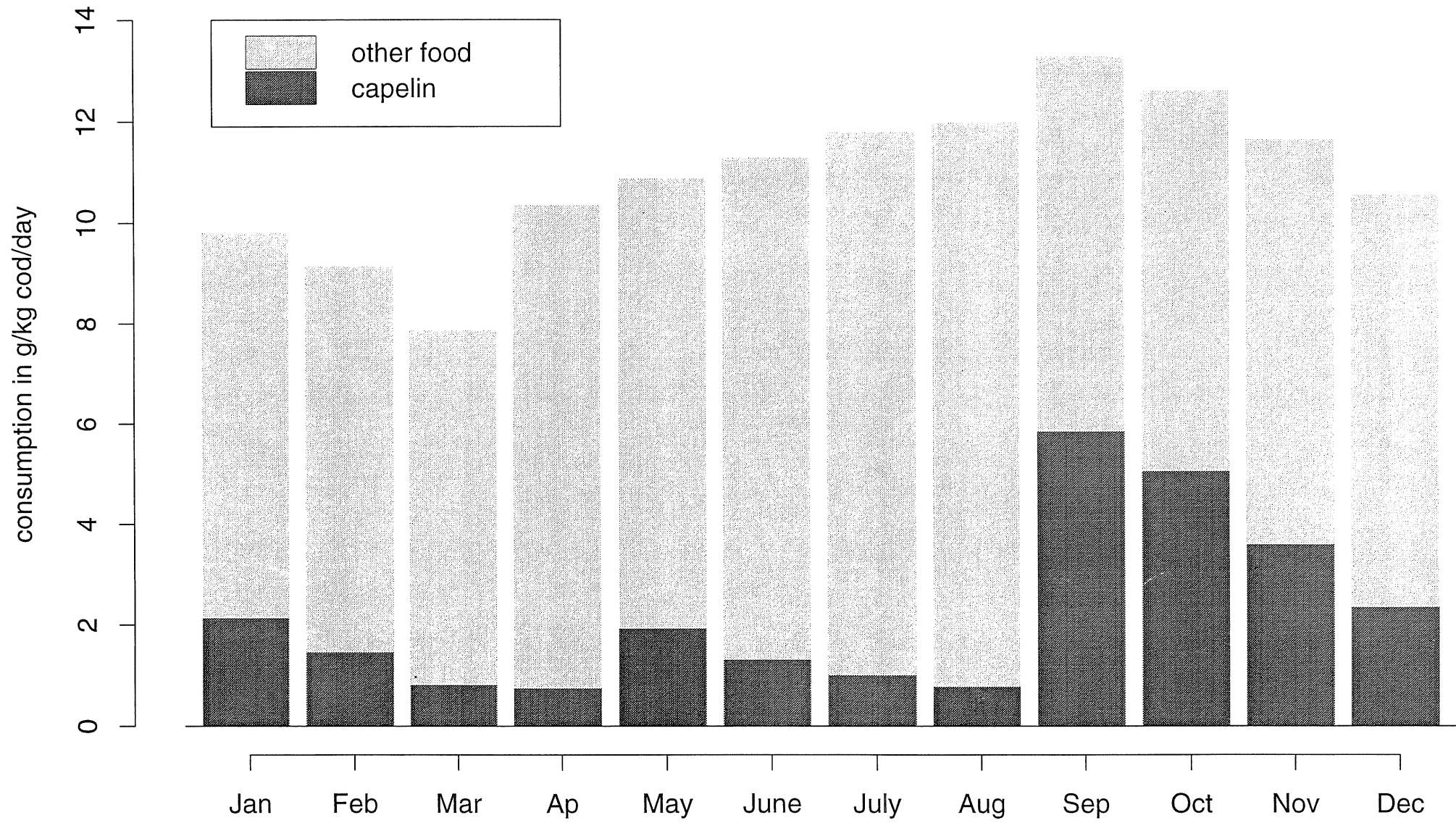


Fig. 2.3.13 BORMICON parameter estimation runs - BORMICON estimates of monthly consumption of capelin (dark bars) and other food (light bars) by cod averaged over 1985 to 1992.

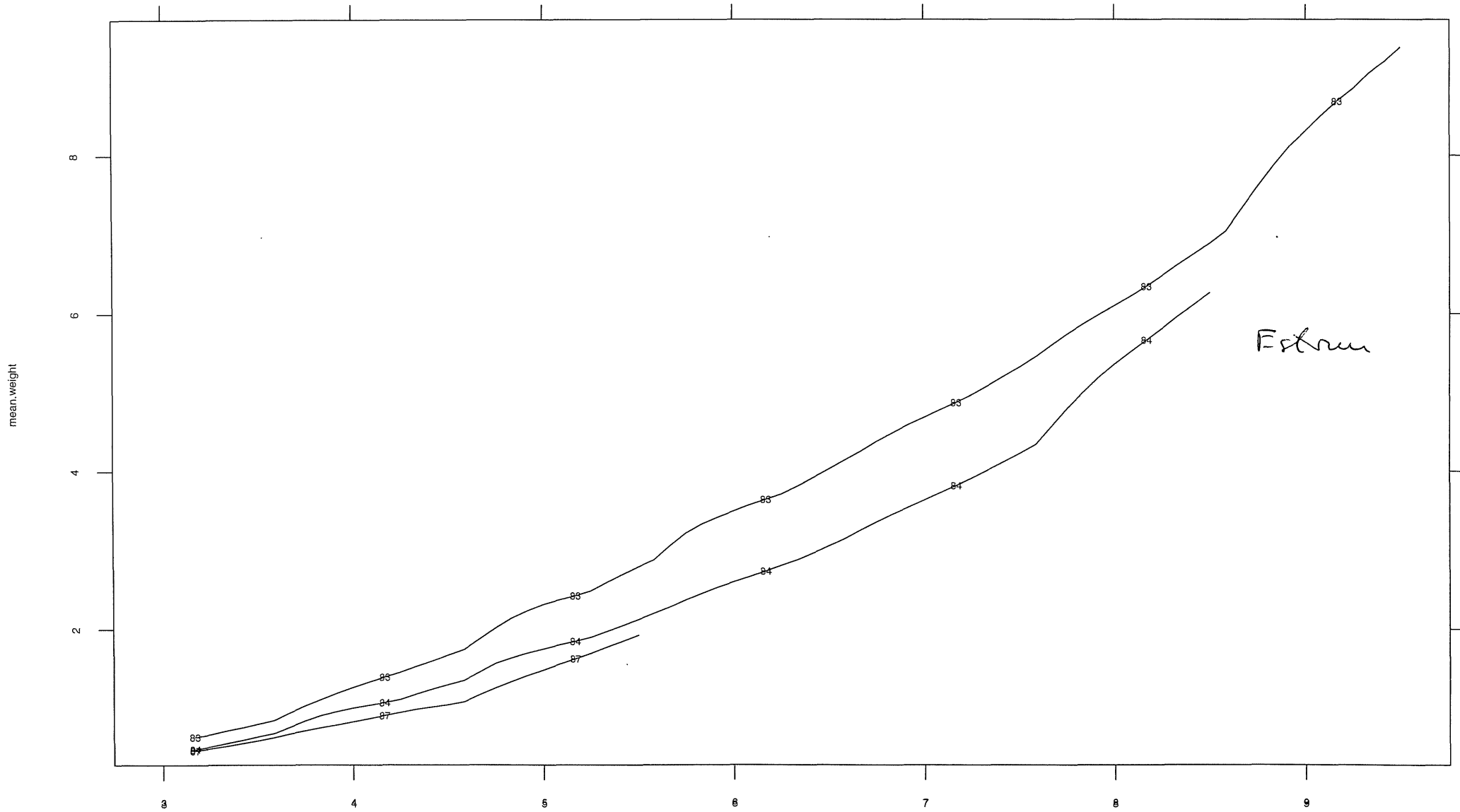


Fig. 2.3.14 BORMICON parameter estimation runs - Estimated mean weight at age of cod for the cohorts produced in 1983 (longest line - to upper right corner), 1984 (slightly shorter line - stops above and right of center of figure), and 1987 (shortest line - stops below and left of center)

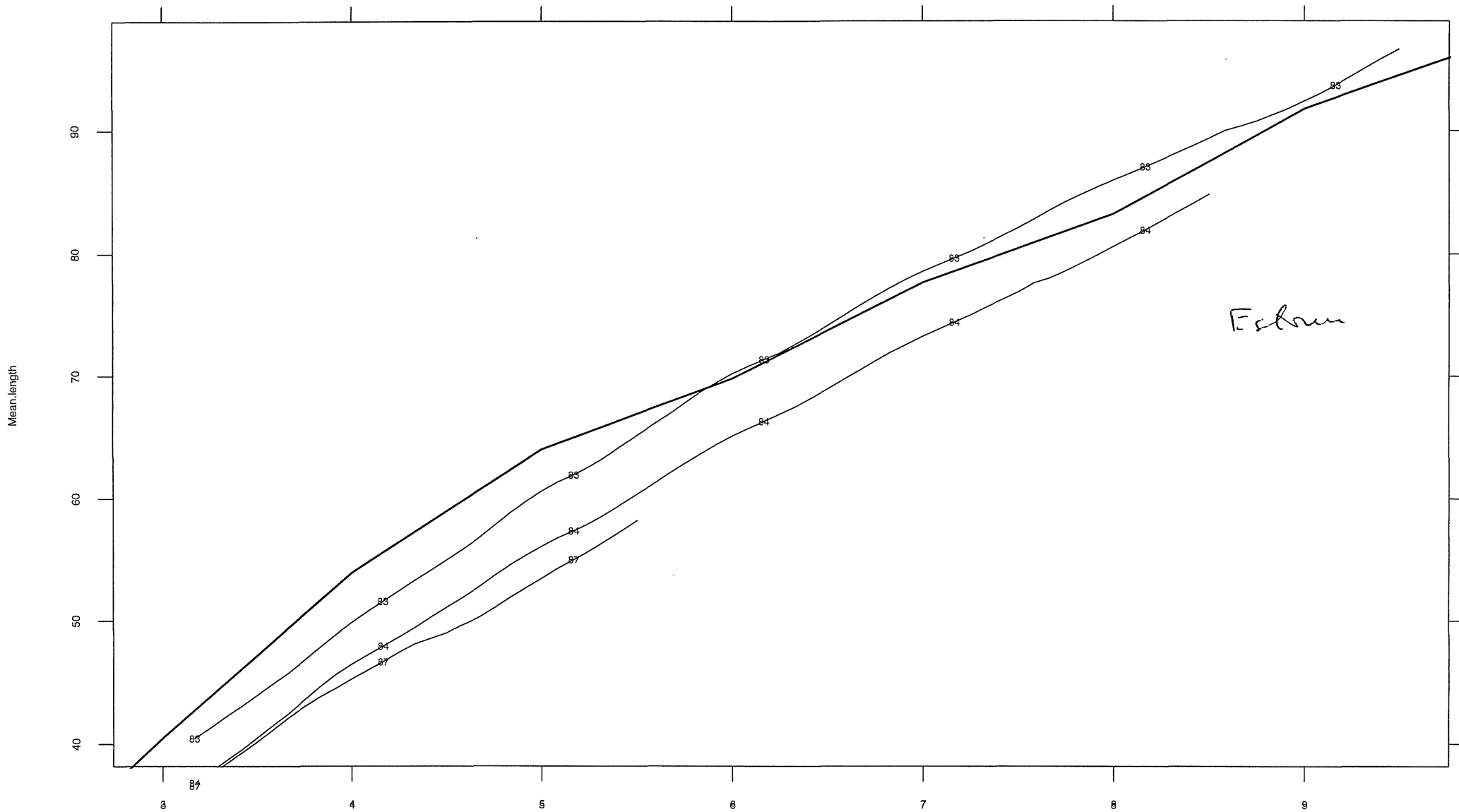


Fig. 2.3.15 BORMICON parameter estimation runs - Estimated mean length at age of cod for the cohorts produced in 1983 (longest line - to upper right corner), 1984 (slightly shorter line - stops above and right of center of figure), and 1987 (shortest line - stops below and left of center). Heavy dark line is reference values from single species assessment.

1985

1986

1987

1988

1989

1990

1991

1992

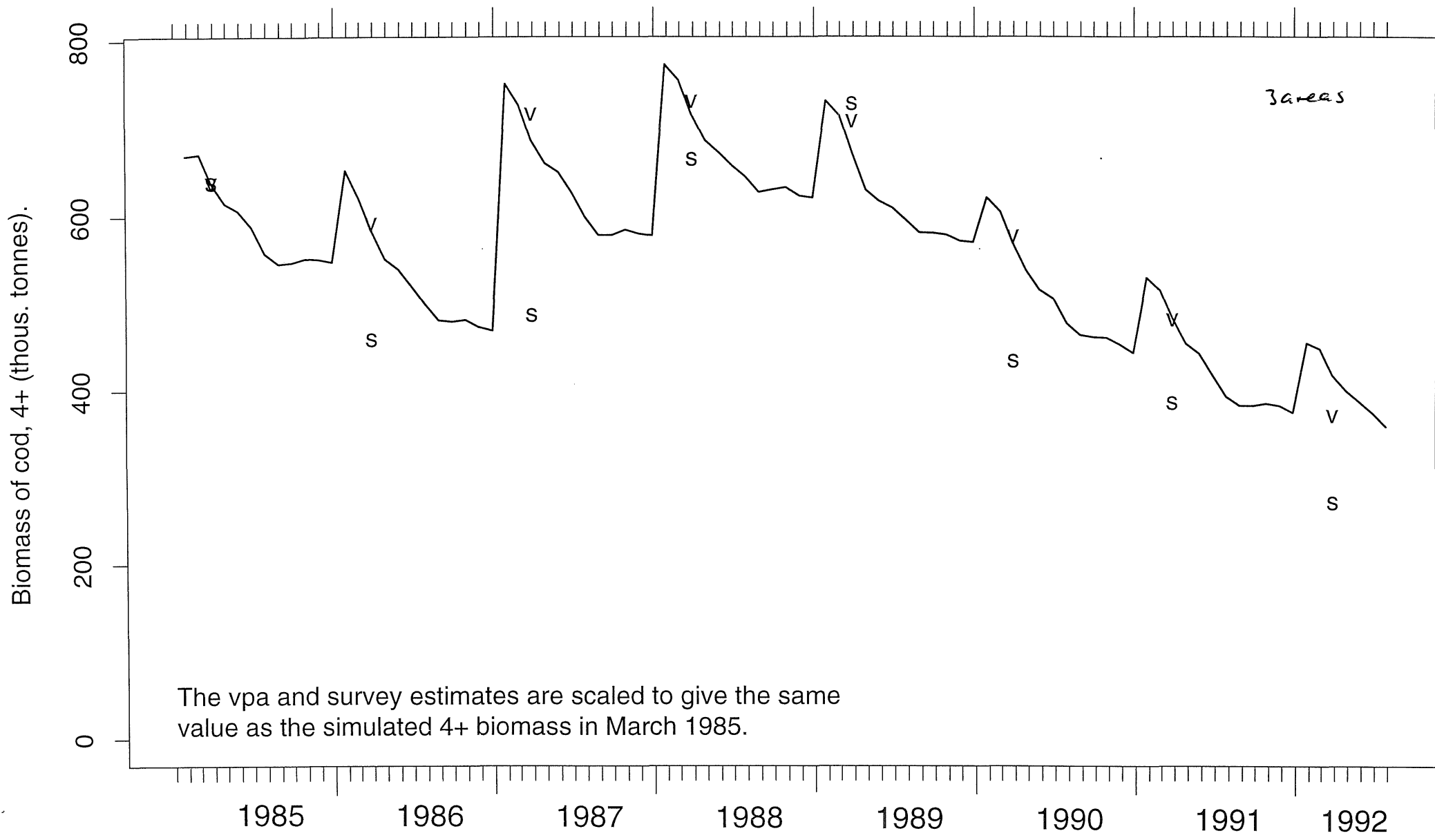


Fig 2.3.16 BORMICON 3 area run - biomass of 4+ cod from survey (s), single species VPA (v), and BORMICON (line), all scaled to produce same value in March 1985.

1985 1986 1987 1988 1989 1990 1991 1992

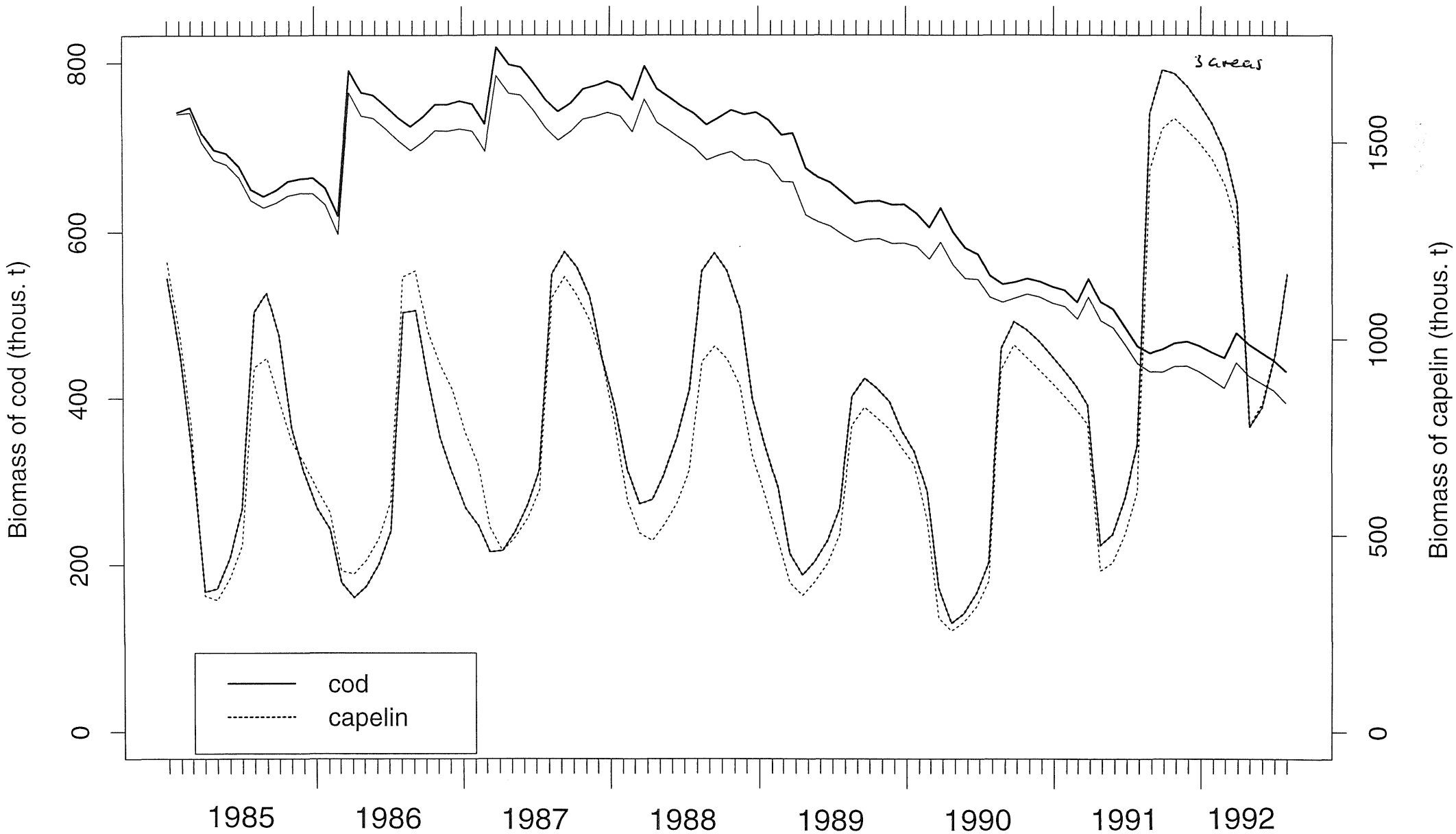


Fig. 2.3.18 BORMICON 3 area runs - BORMICON estimates of biomass of 4+ cod and capelin plotted together. Baseline runs for reference as lighter lines.

3 areas

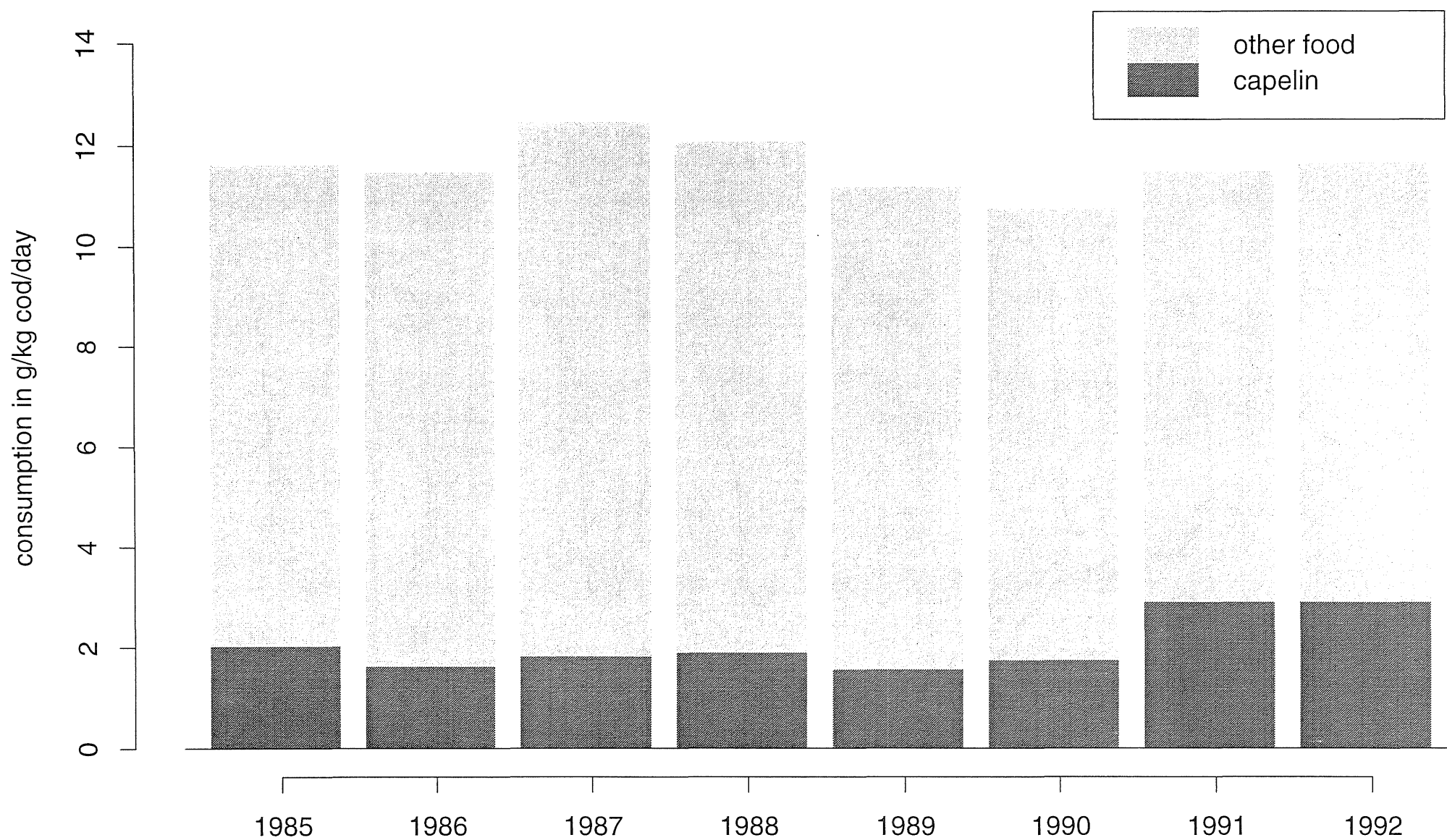


Fig. 2.3.19 BORMICON 3 area runs - BORMICON estimates of annual consumption of capelin (dark bars) and other food (light bars) by cod from 1985 to 1992.

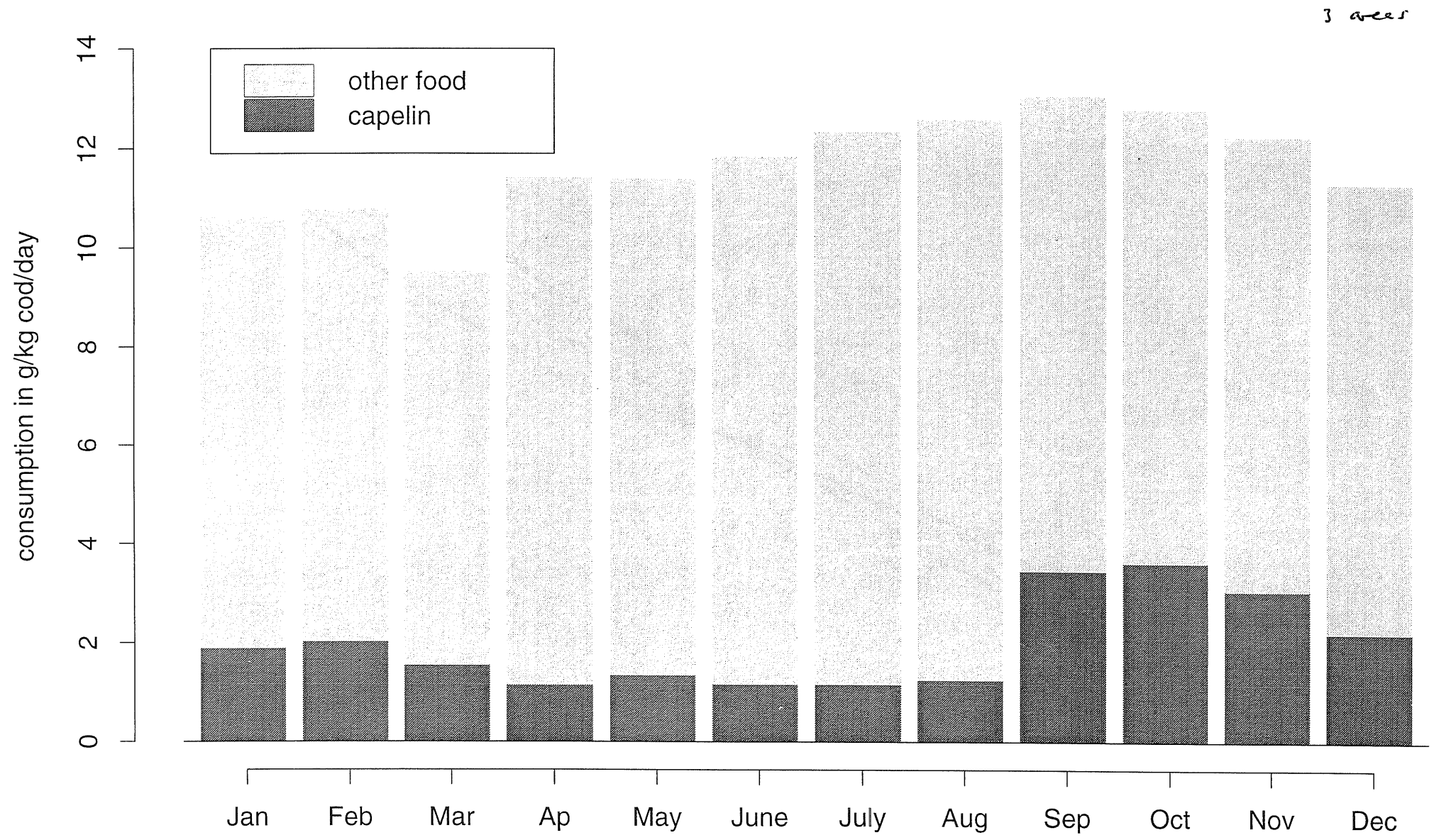


Fig. 2.3.20 BORMICON 3 area runs - BORMICON estimates of monthly consumption of capelin (dark bars) and other food (light bars) by cod averaged over 1985 to 1992.

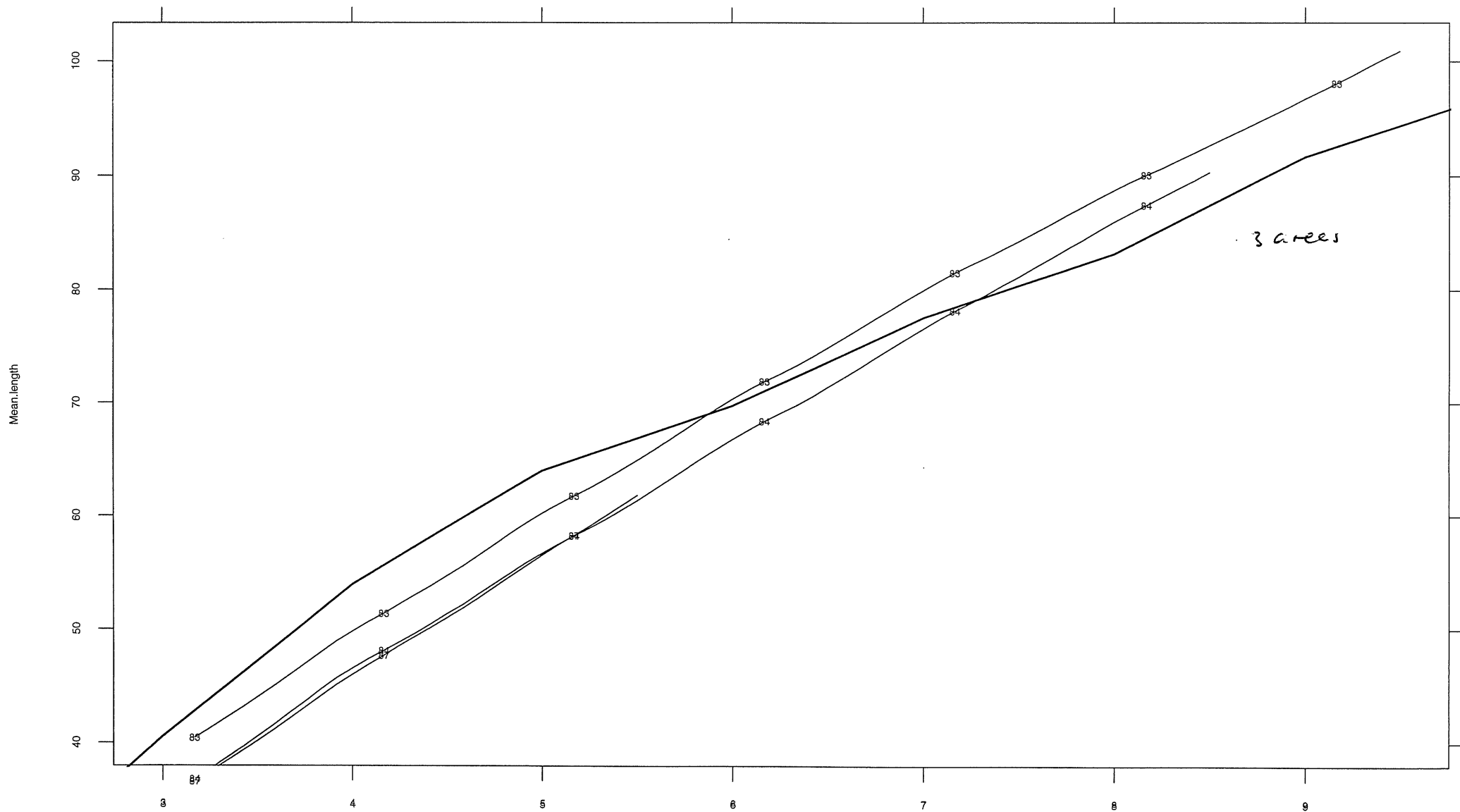


Fig. 2.3.21 BORMICON 3 area runs - Estimated mean length at age of cod for the cohorts produced in 1983 (longest line - to upper right corner), 1984 (slightly shorter line - stops above and right of center of figure), and 1987 (shortest line - stops below and left of center). Heavy dark line is reference values from single species assessment.

Figure 2.4.1

The MSVPA- estimates of cod total (1) and spawning (2) stock in comparison with single-species VPA estimates of its total (3) and spawning (4) stock (all - beginning from age 3).

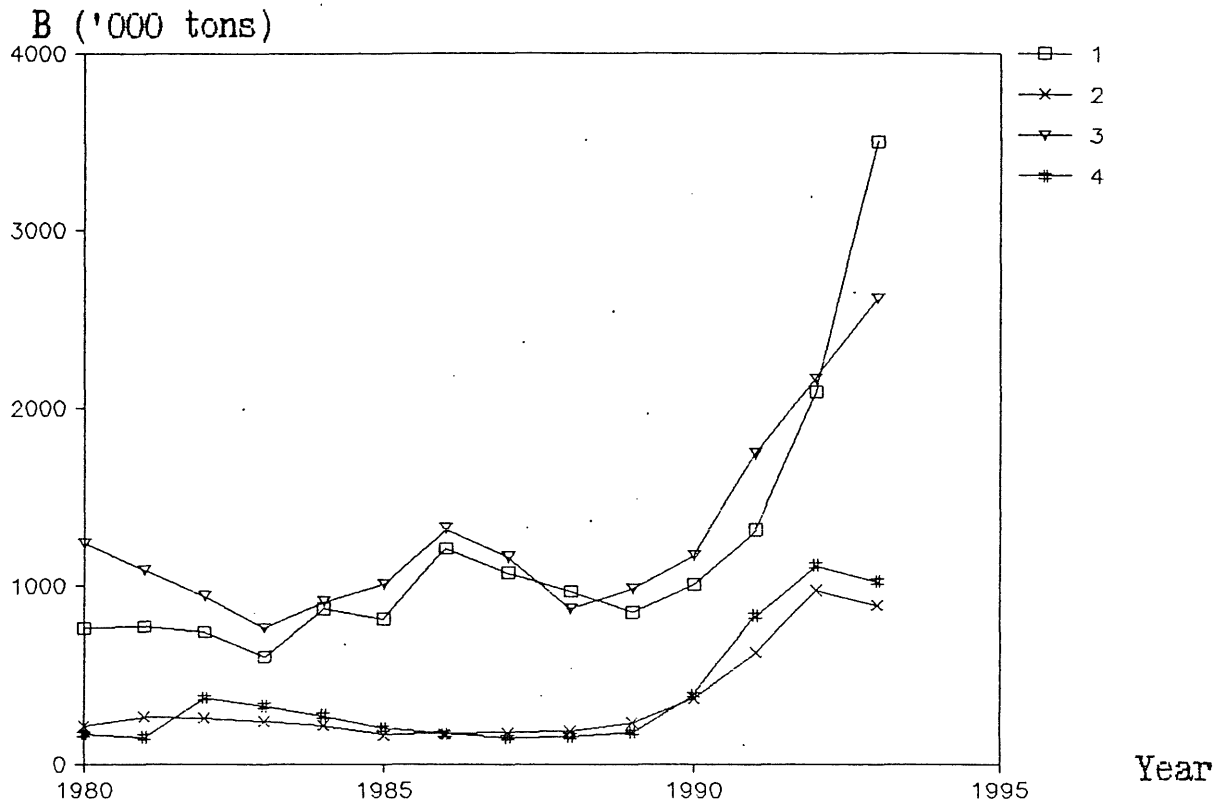


Figure 2.4.2

The MSVPA- estimates of capelin total (1) and spawning (2) stock for the beginning of quarter IV in comparison with the autumn survey estimates of its total (3) and spawning (4) stock (all - beginning from age 1).

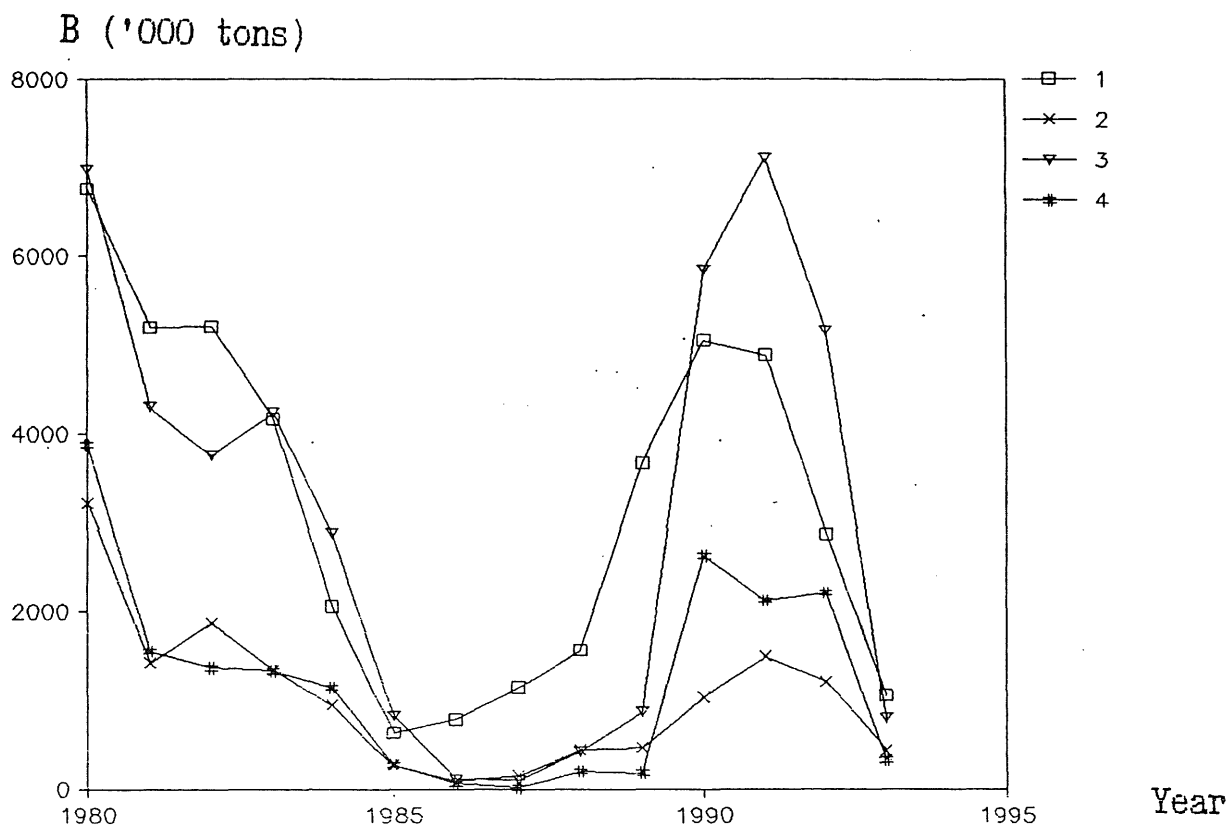


Figure 2.4.3

The MSVPA- estimates of shrimp total stock (1) in comparison with survey estimates (2) (all - beginning from age 2).

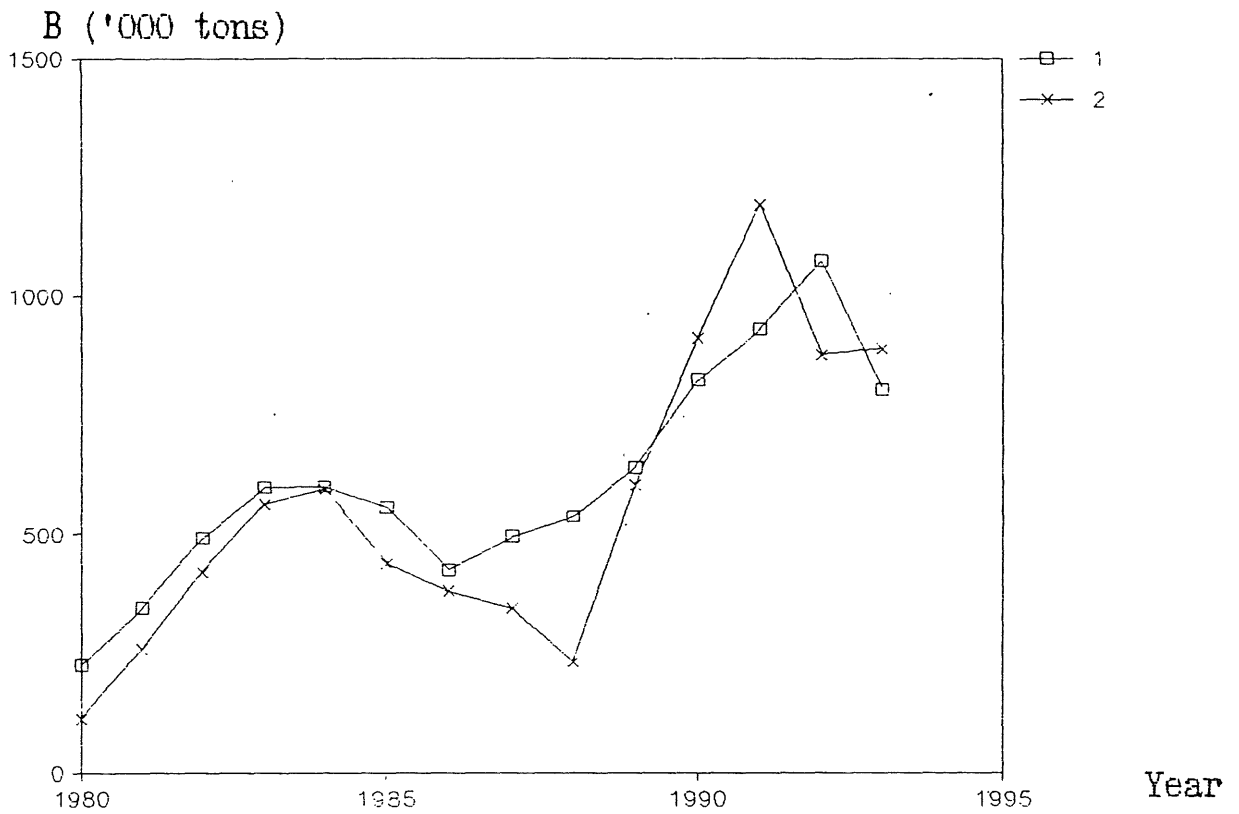


Figure 2.4.4

The MSVPA- estimates of herring total (1) and spawning (2) stock in comparison with sigle-species VPA estimates of its total (3) and spawning (4) stock (all - beginning from age 3).

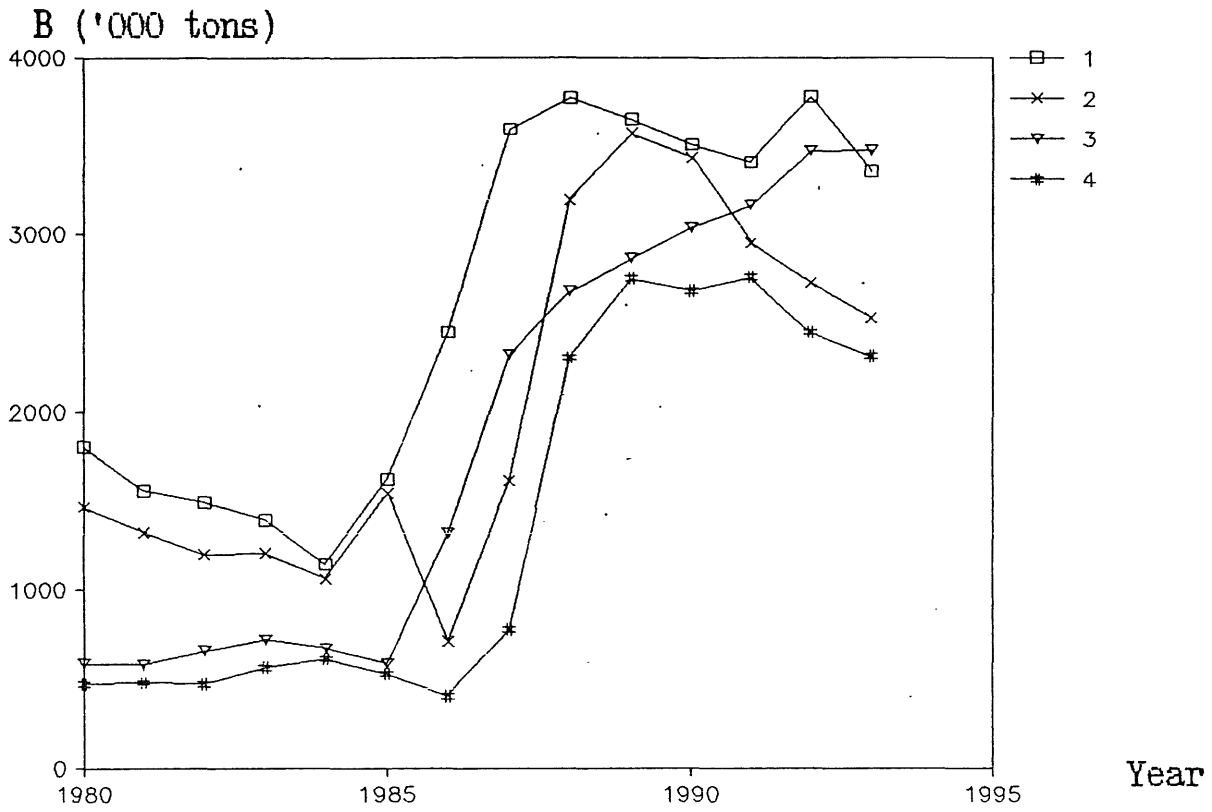


Figure 2.4.5

The estimates of biomass consumed by cod by species:
1 - cod; 2 - capelin; 3 - shrimp; 4 - herring

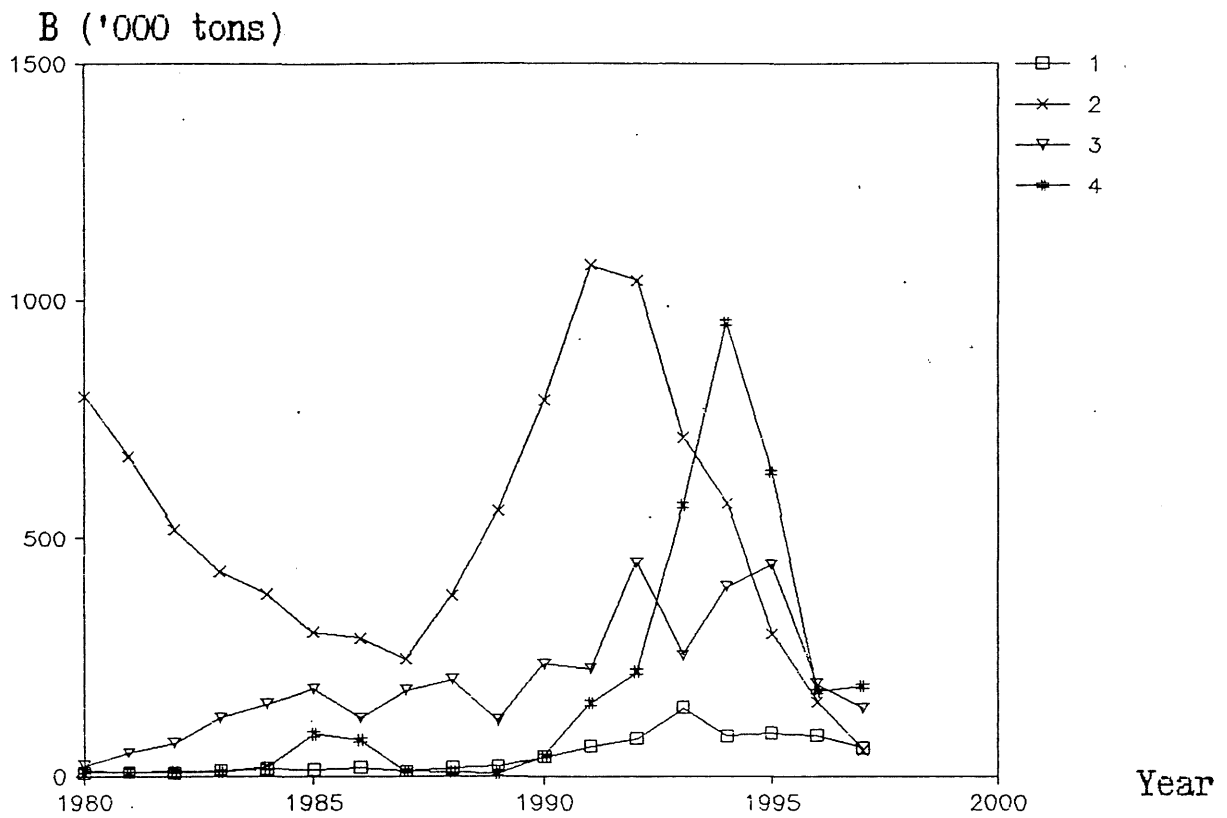


Figure 2.4.6

The proportion of cod consumed to total number at age. The curves 0-3 correspond to age groups 0-3.

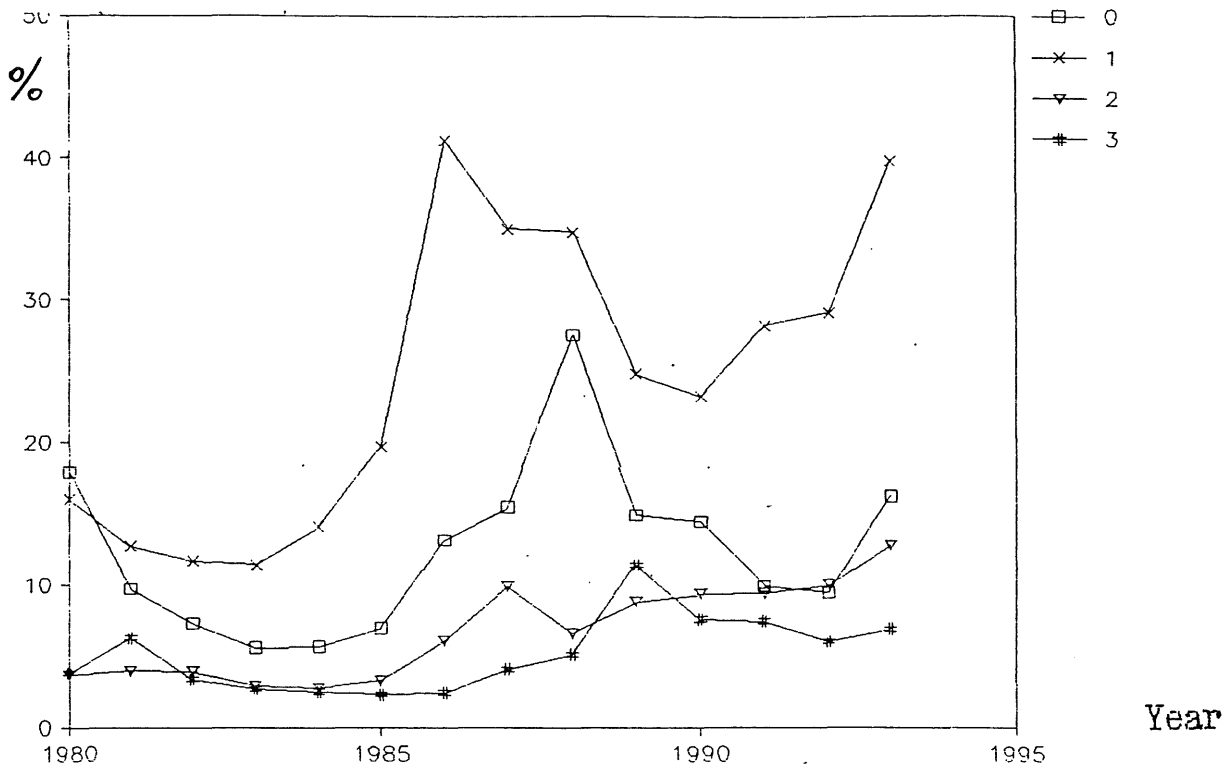
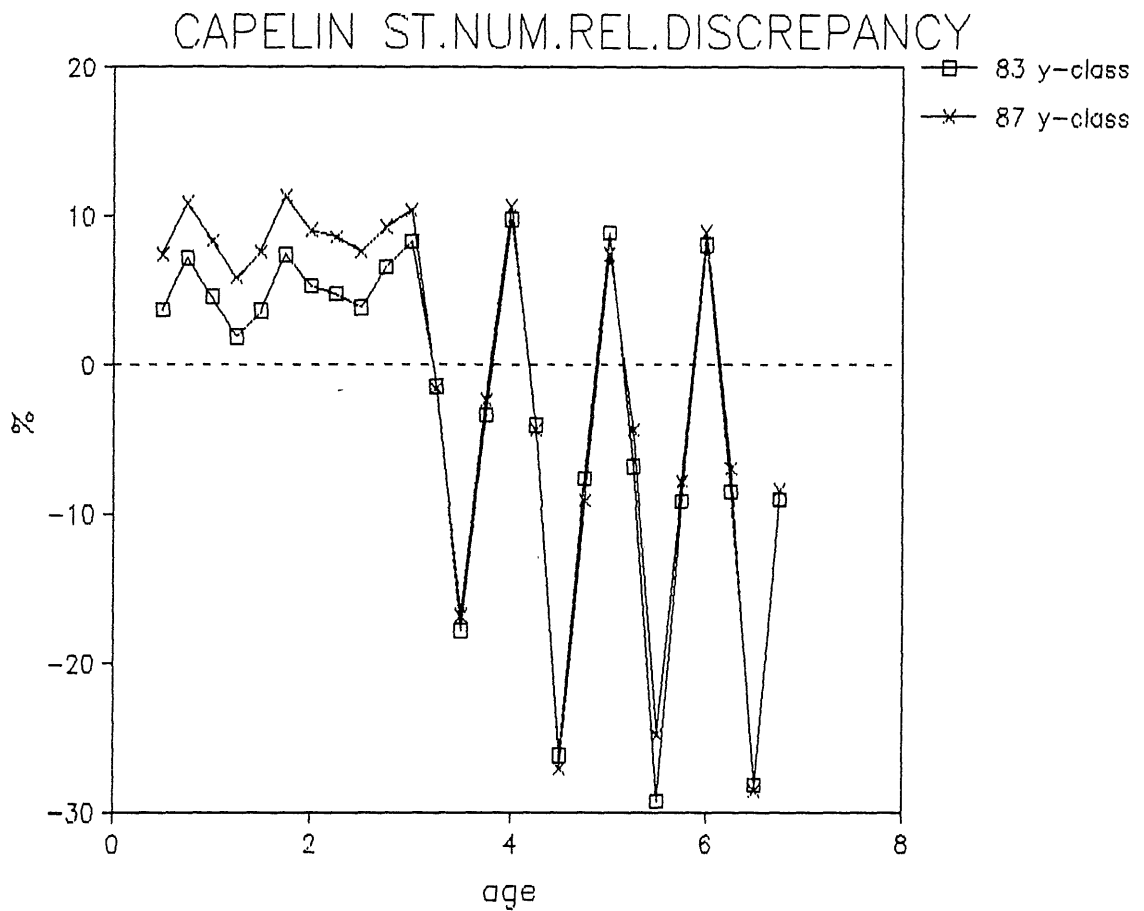


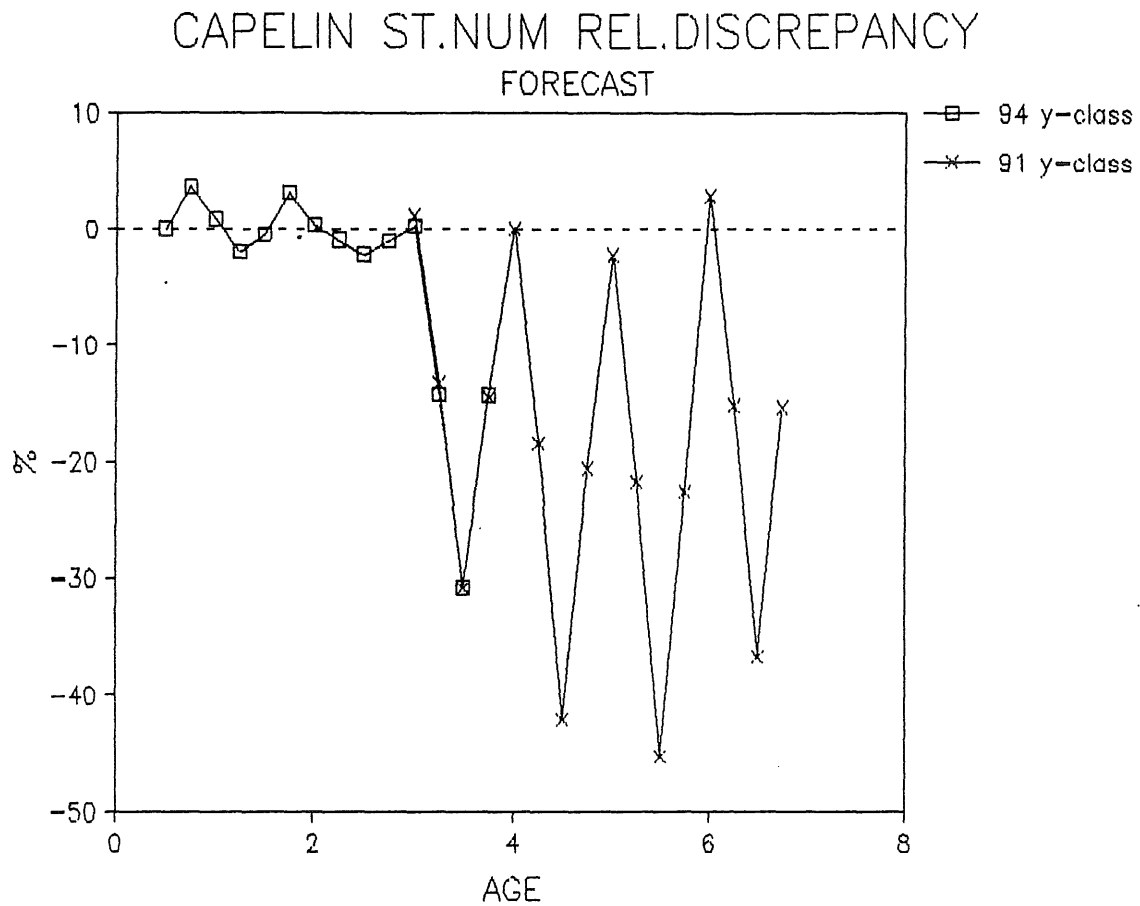
Figure 2.4.7



Relative discrepancy $\frac{N_{cap1}(a) - N_{cap2}(a)}{N_{cap1}(a)} \cdot 100$ (in %) for two year classes (1983 and 1987) of Barents Sea capelin.

$N_{cap1}(a)$ - the numbers of capelin age group a estimated by the version MSV in which $M1 = M1(a, Q)$ and $N_{cap2}(a)$ - the same estimated by the version MSVPA_W ($M1 = M1(a)$).

Figure 2.4.8



$$\text{Relative discrepancy} = \frac{N_{\text{cap1}}(a) - N_{\text{cap2}}(a)}{N_{\text{cap1}}(a)} \cdot 100(\text{in}\%)$$
 for forecast of two year classes (1994 and 1991) of Barents Sea capelin.

$N_{\text{cap1}}(a)$ - the numbers of capelin age group a estimated by the version MSFOR in which $M1 = M1(a, Q)$ and $N_{\text{cap2}}(a)$ - the same estimated by the old version ($M1 = M1(a)$).

Fig 2.4.9 Deviations in "Observed" and MSVPA estimated levels of capelin consumption, and index of Spatial Overlap

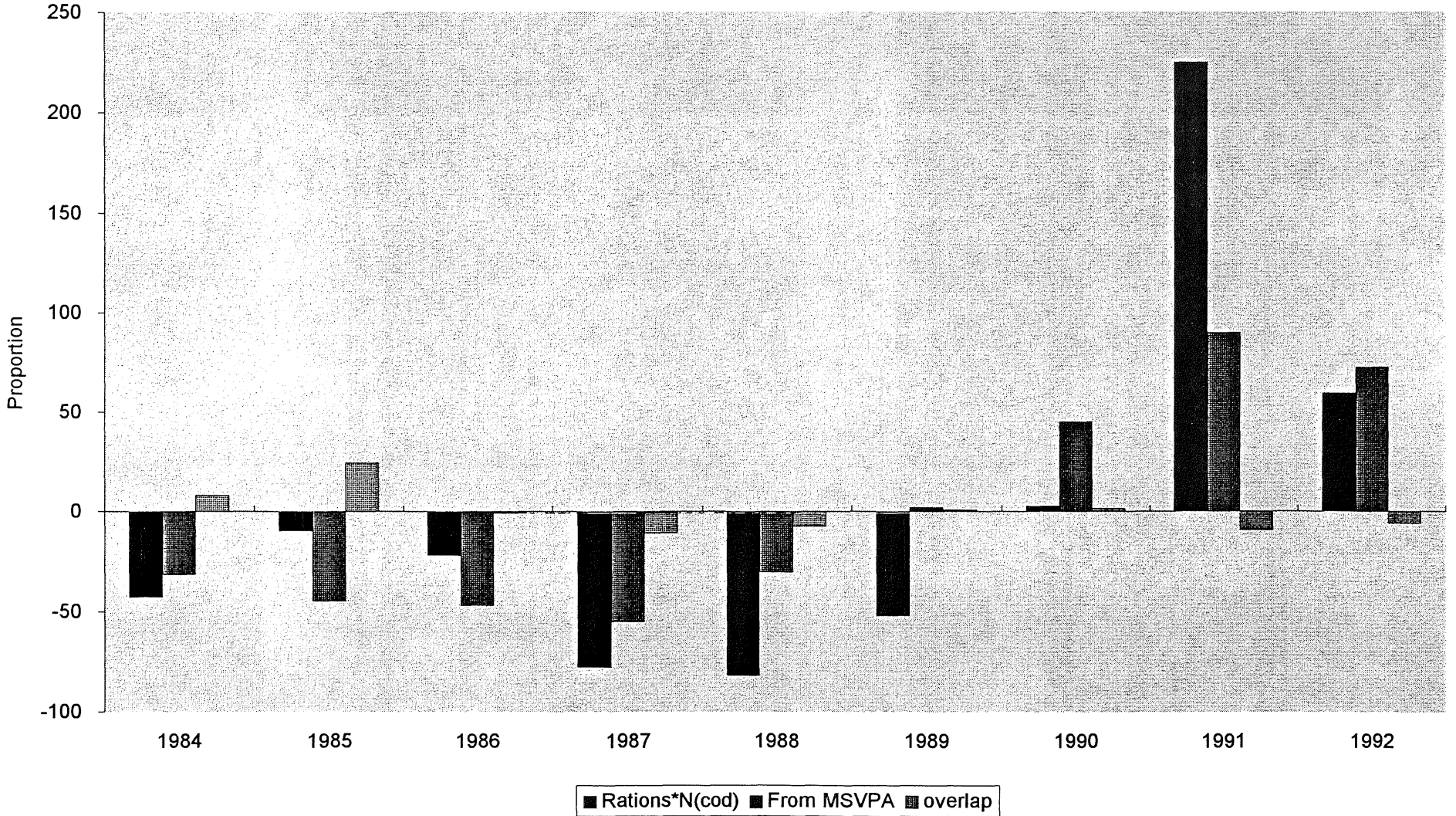


Fig 2.4.10 Same deviations as in 2.4.9, disaggregated by quarter.

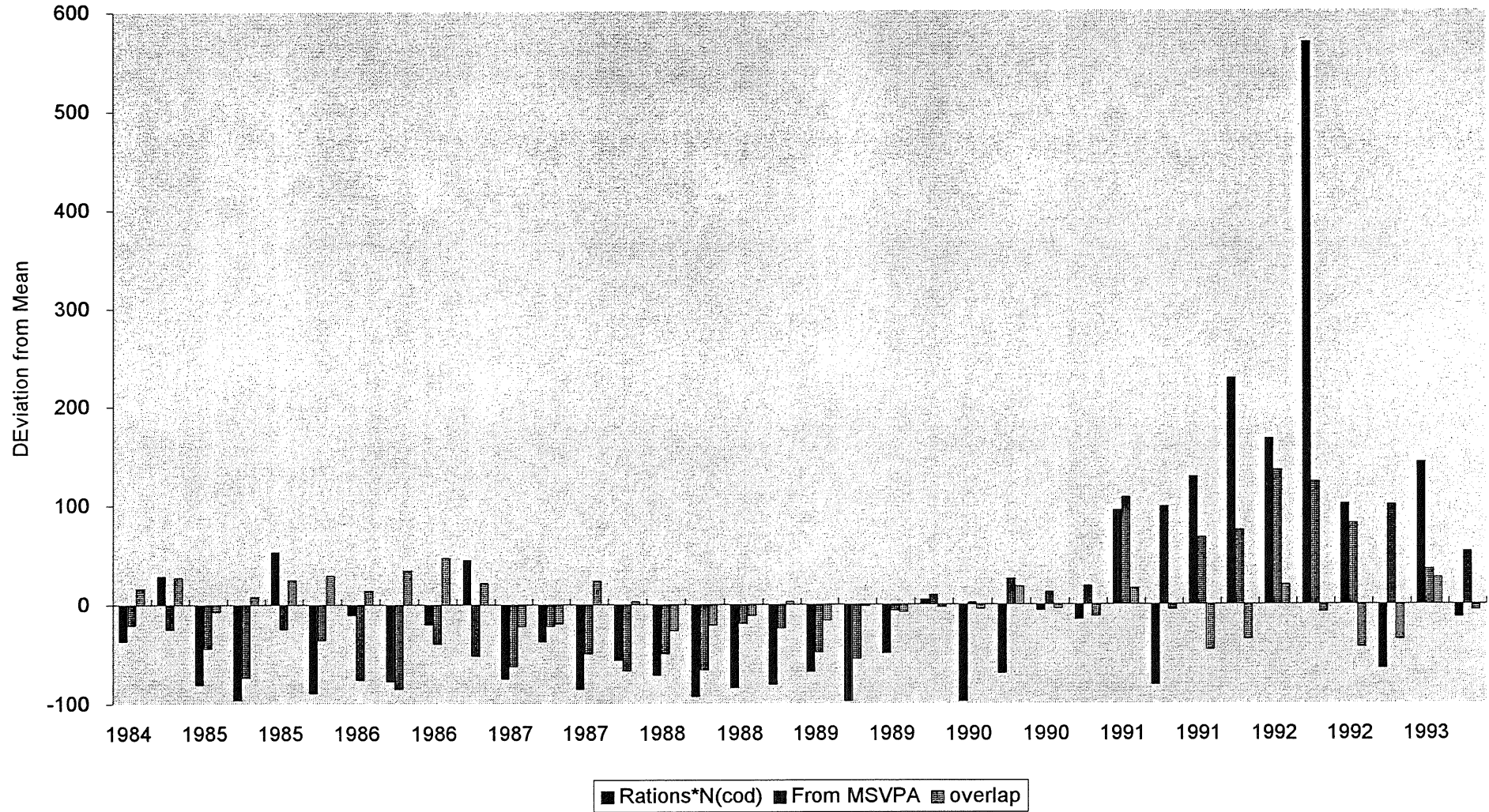


Fig 2.4.11 Deviations as in 2.4.10, in absolute amounts.

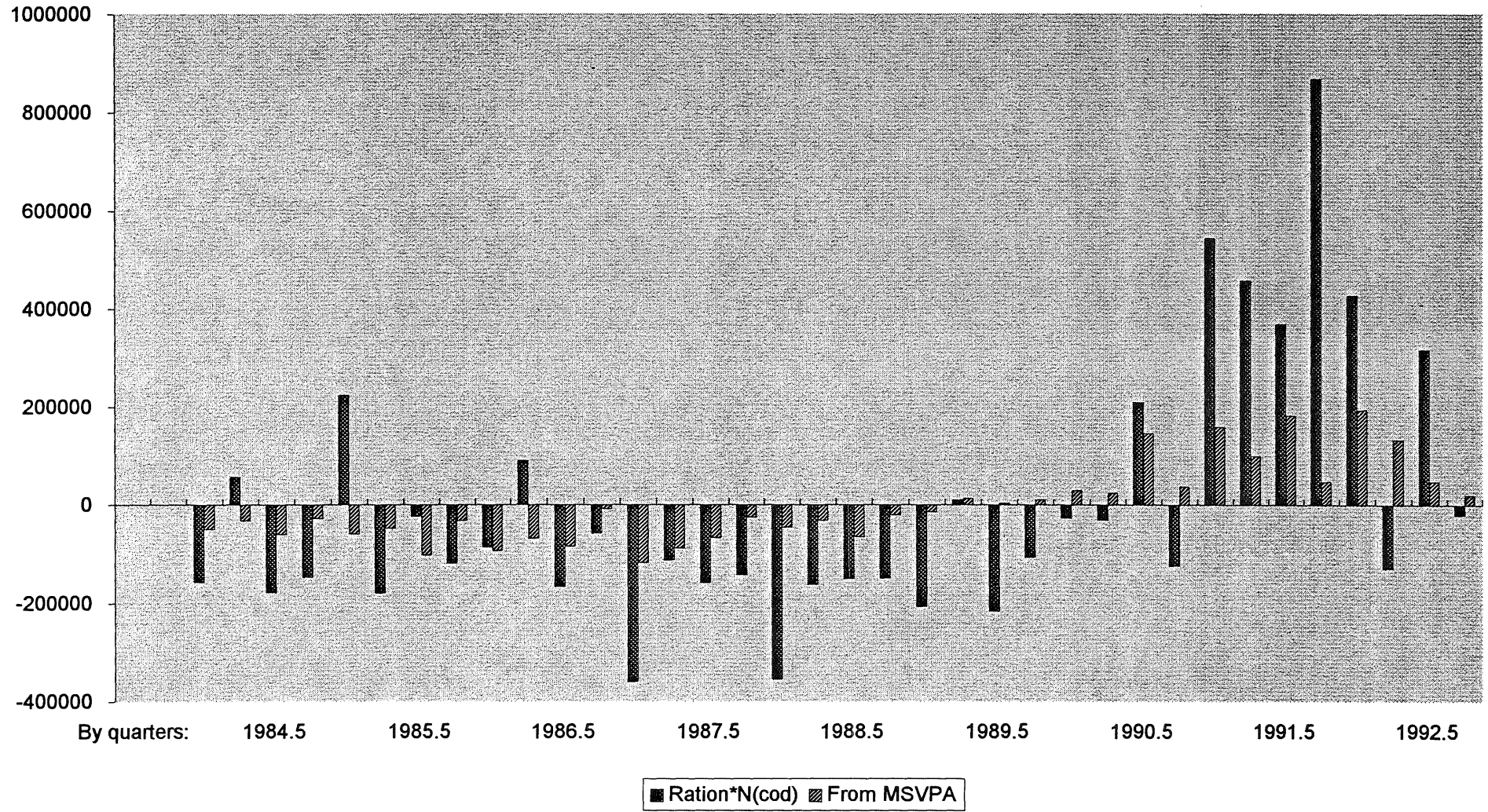
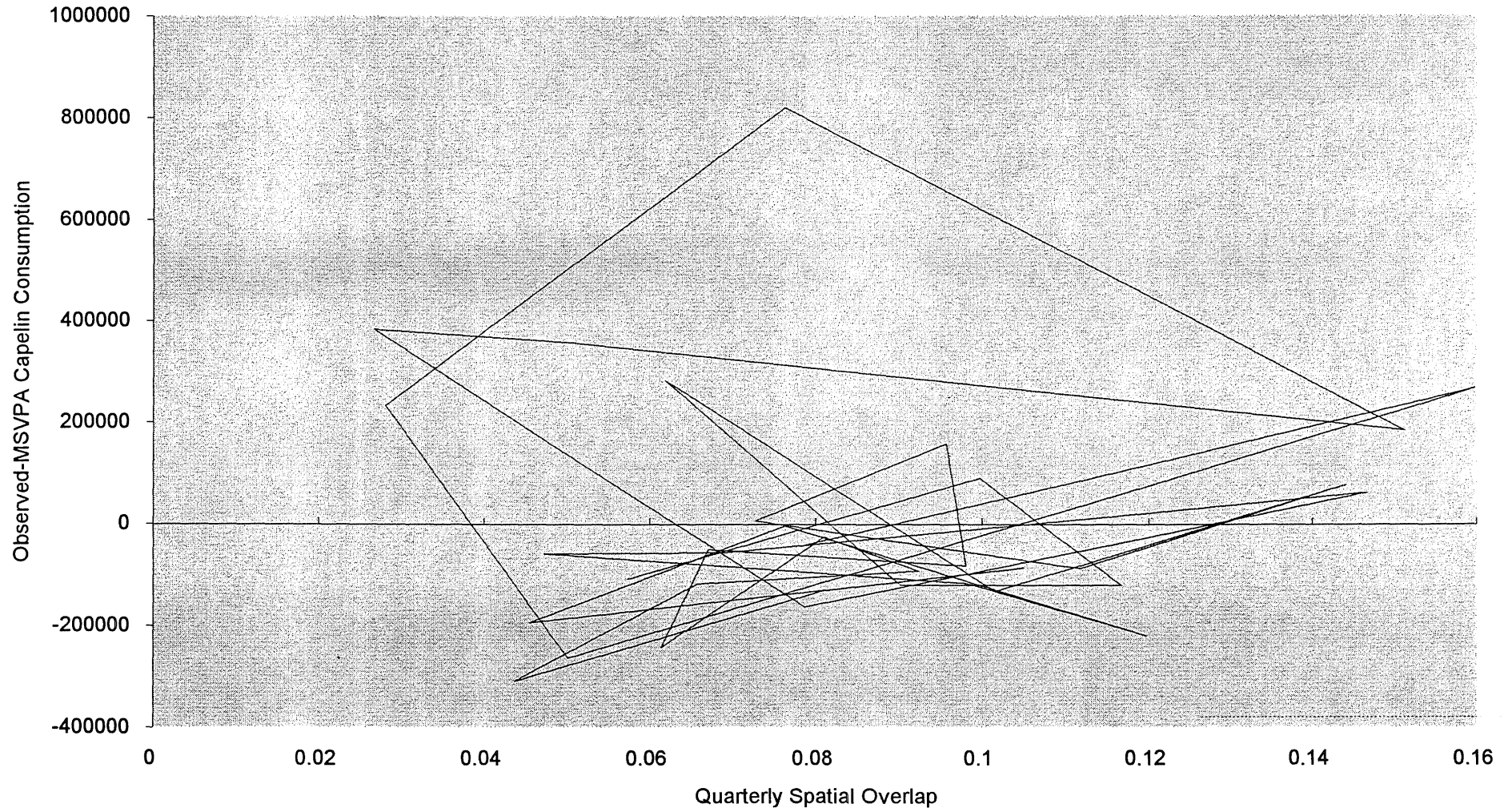


Fig 2-4-12 Differences in obs. and estim. consumption of capelin plotted against index of spatial overlap. Lines connect sequential points.



Survey vs Model

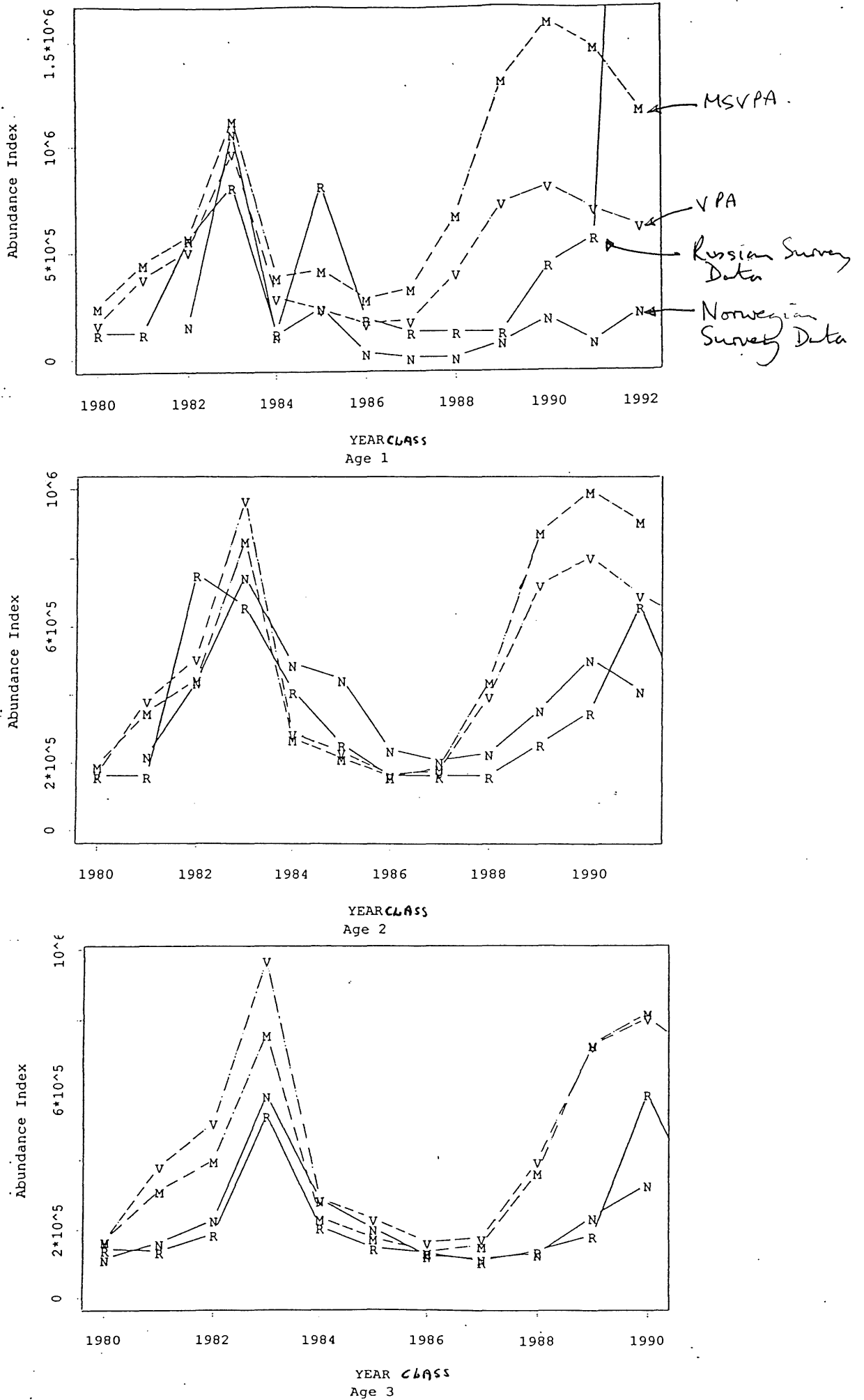
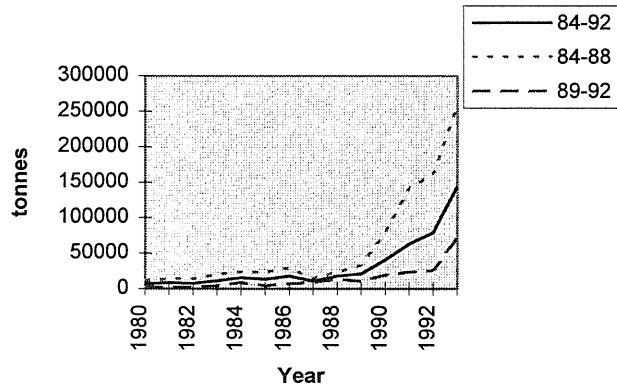
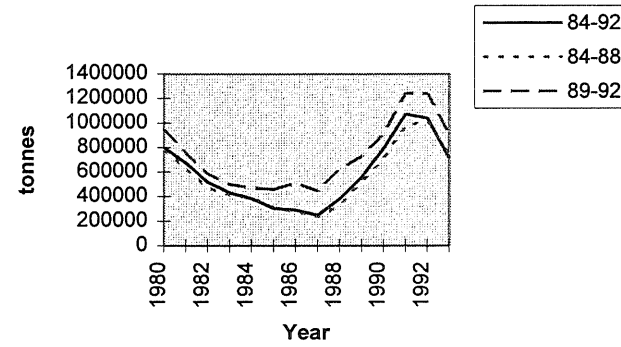


Fig. 2.4.13 Recruitment predictions from surveys by Russia (solid line with R) and Norway (Solid line with N), single

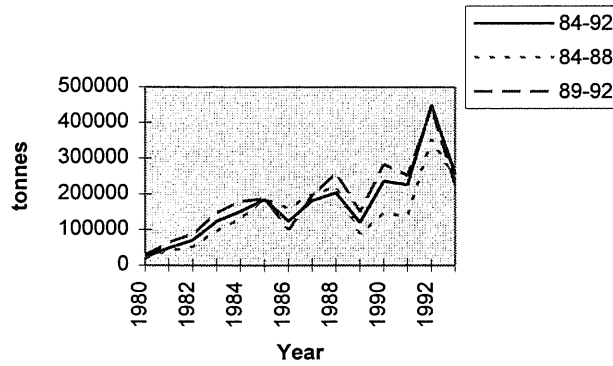
Fig 2.4.14a - Biomasses consumed by cod - cod as prey



Capelin as prey



Shrimp as prey



Herring as prey

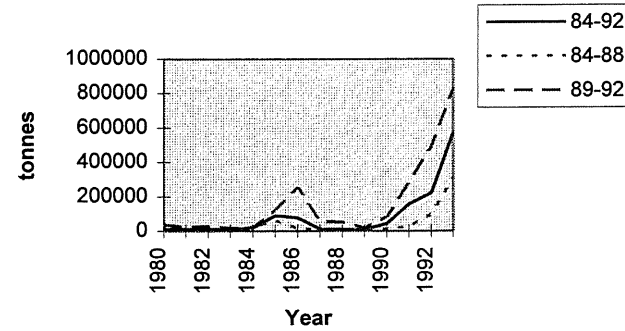
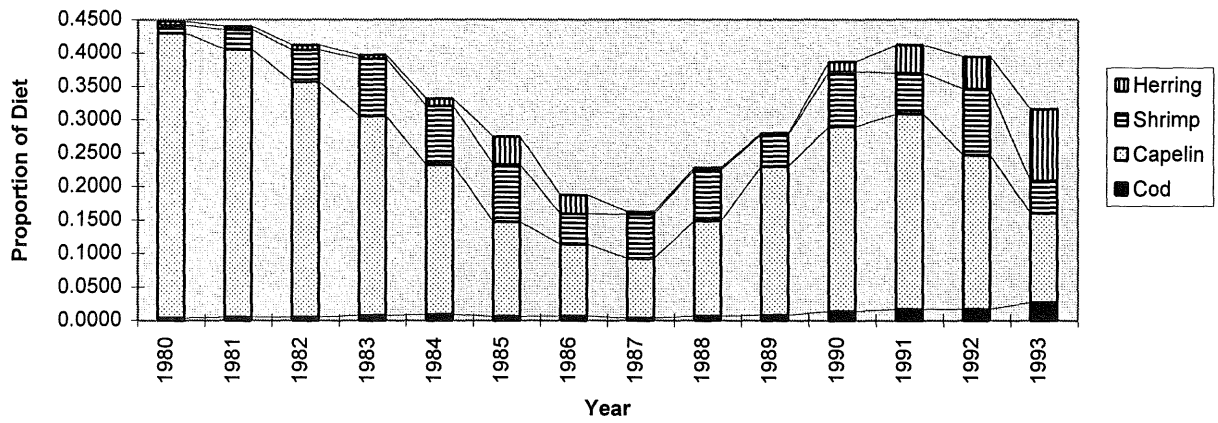
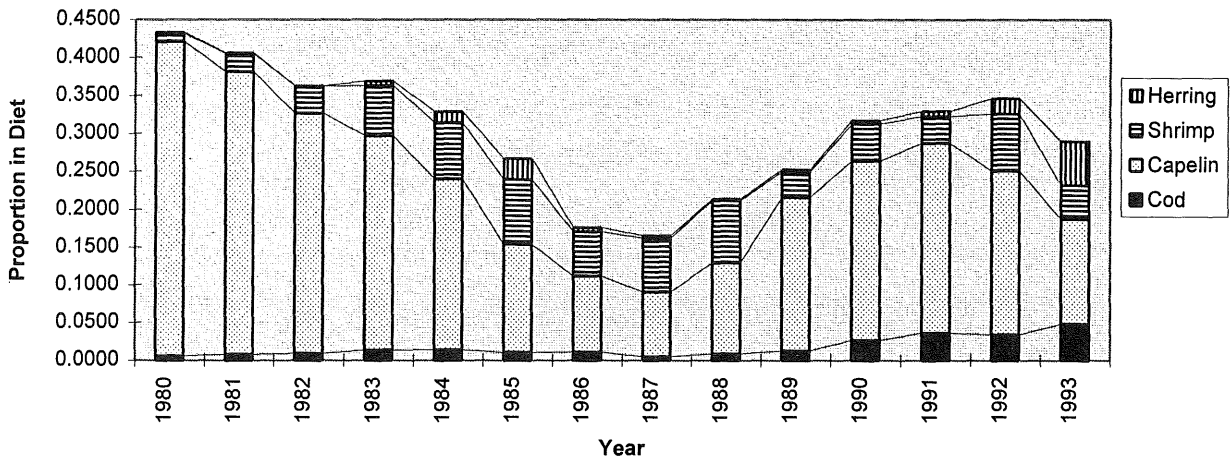


Fig 2.4.14b Cod diet based on different parts of stomach data - All data



Cod Diet based on 1984-88 Stomachs



Cod Diet based on 1989-92 Stomachs

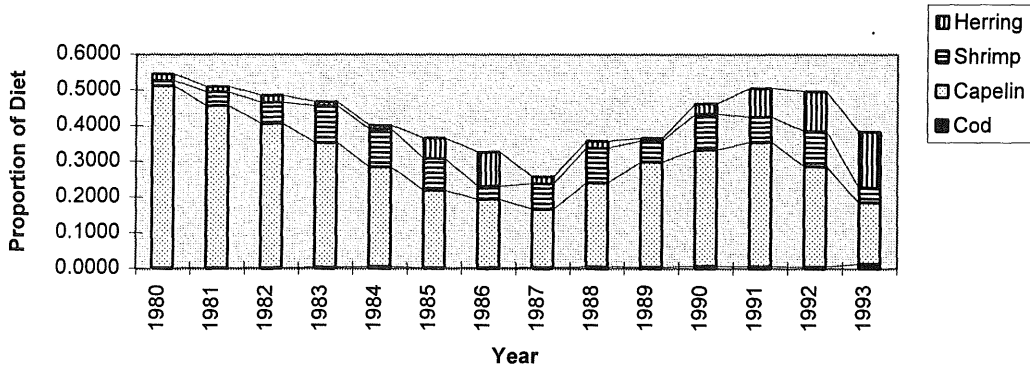


Fig 2.4.15 Predicted consumption of capelin by cod, using different portions of stomach data, and mean stomach data for each period.

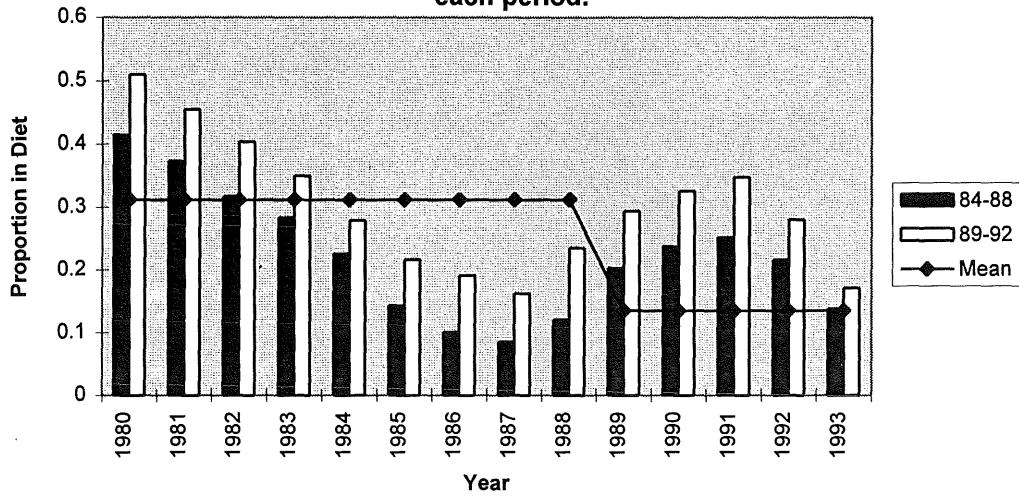


Fig 2.4.16 MSVPA predictions of total food consumed by Barents Sea cod from 1980 to 1992.

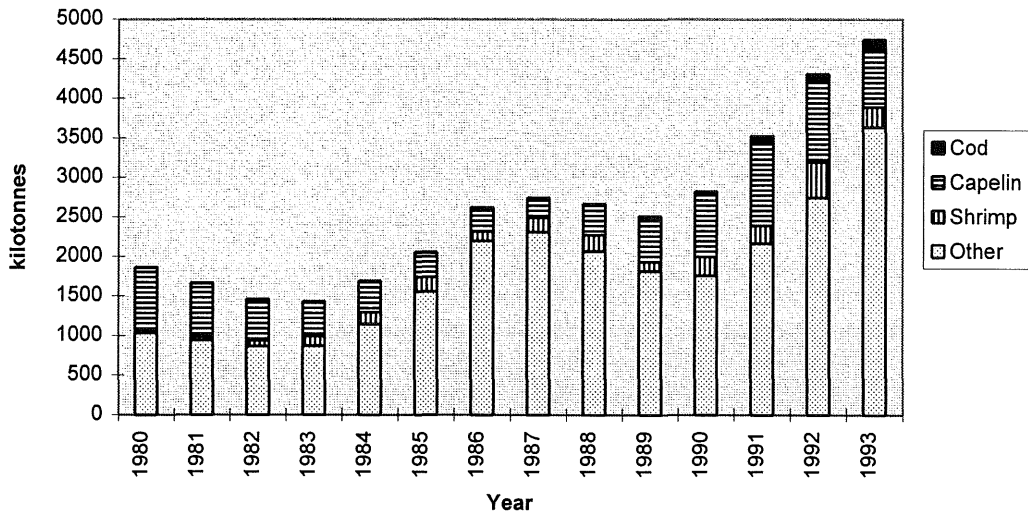


Fig. 2.7.1 Cod Eating Age 1 Cod : Observed and Eye-fitted UM2 Curves

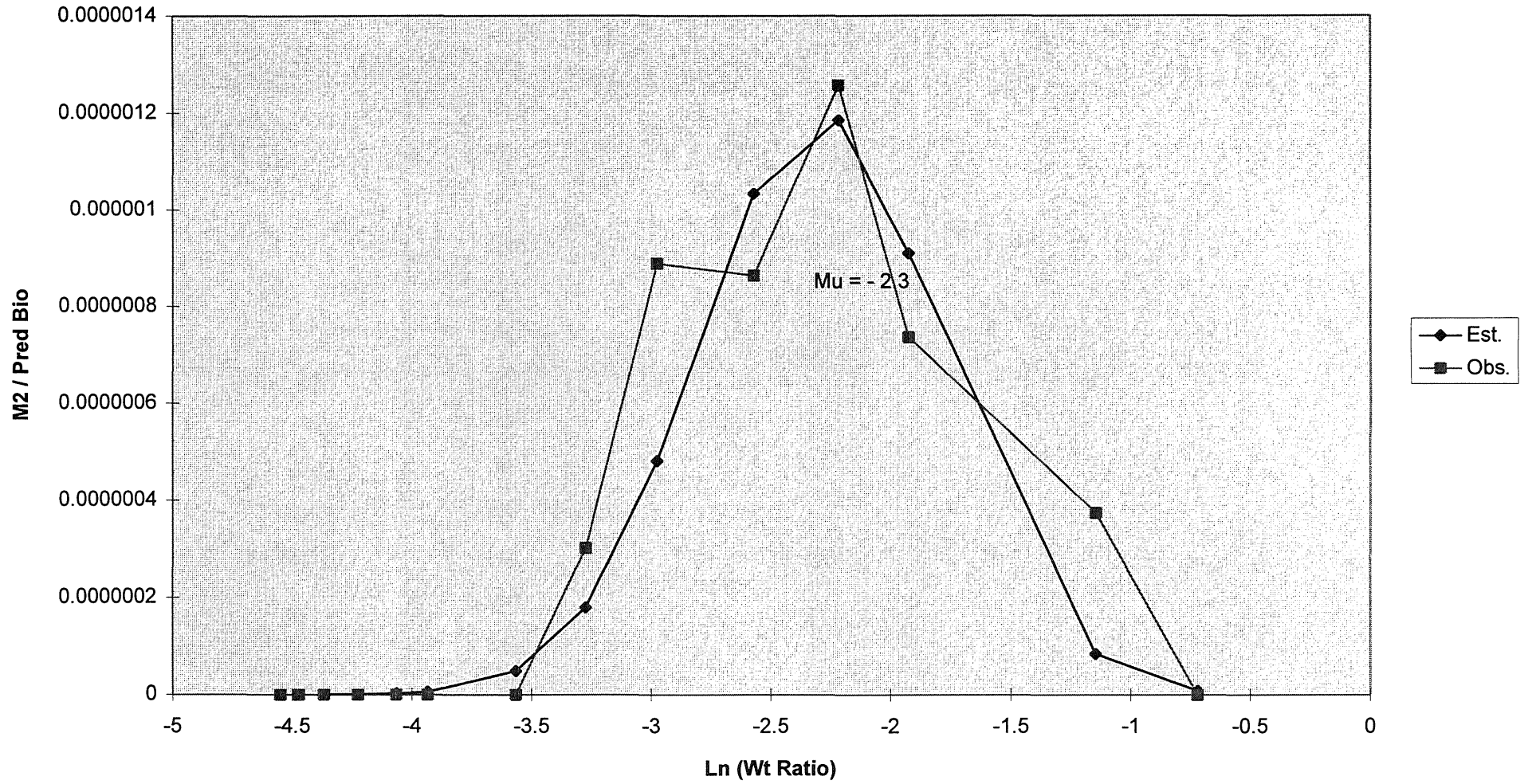


Fig. 2.7.2 Cod eating age 2 cod Observed and eye fitted UM2 curves

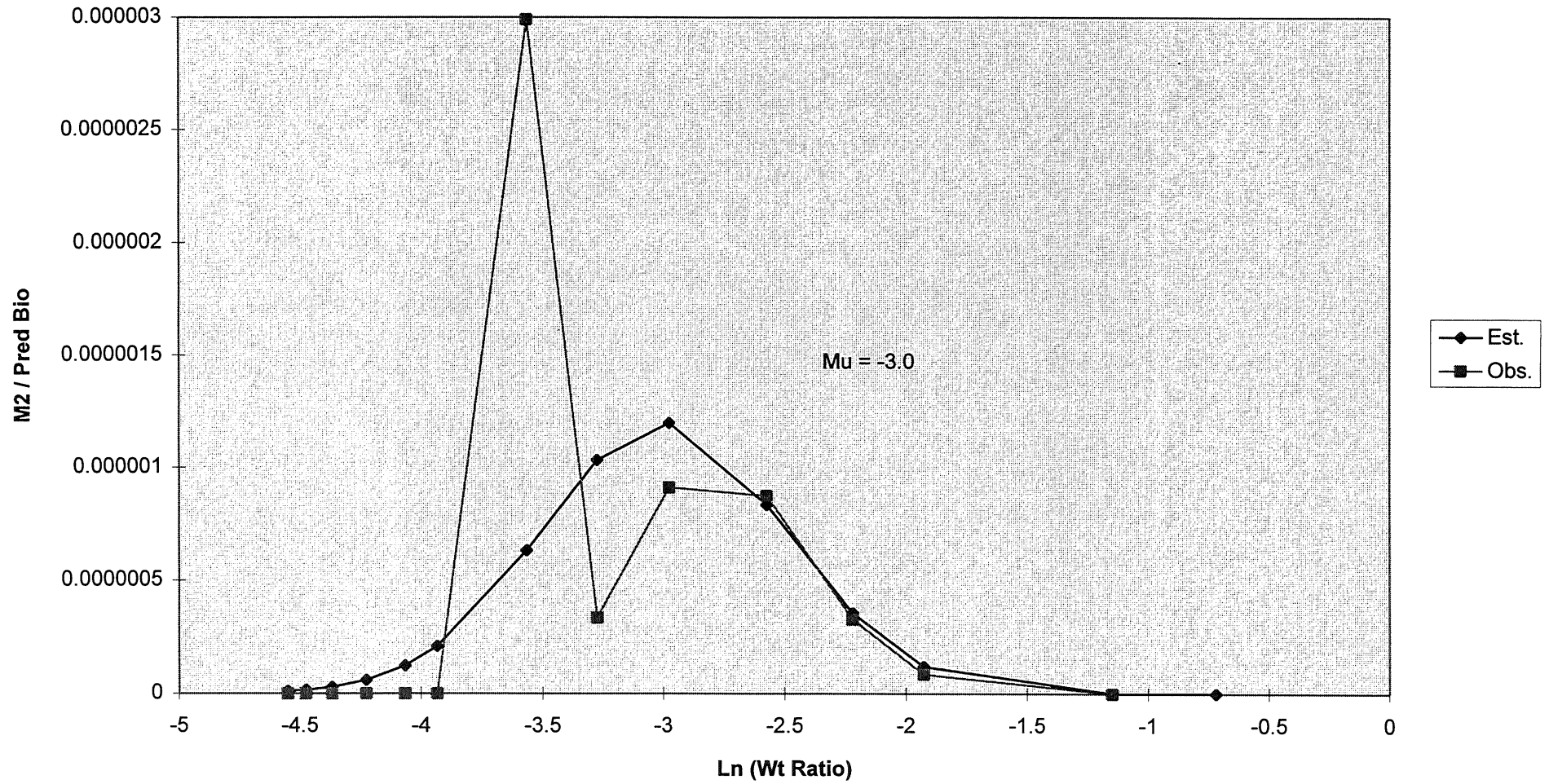


Fig 2.7.3 Cod eating age 3 cod - Observed and eye-fitted UM2 curves

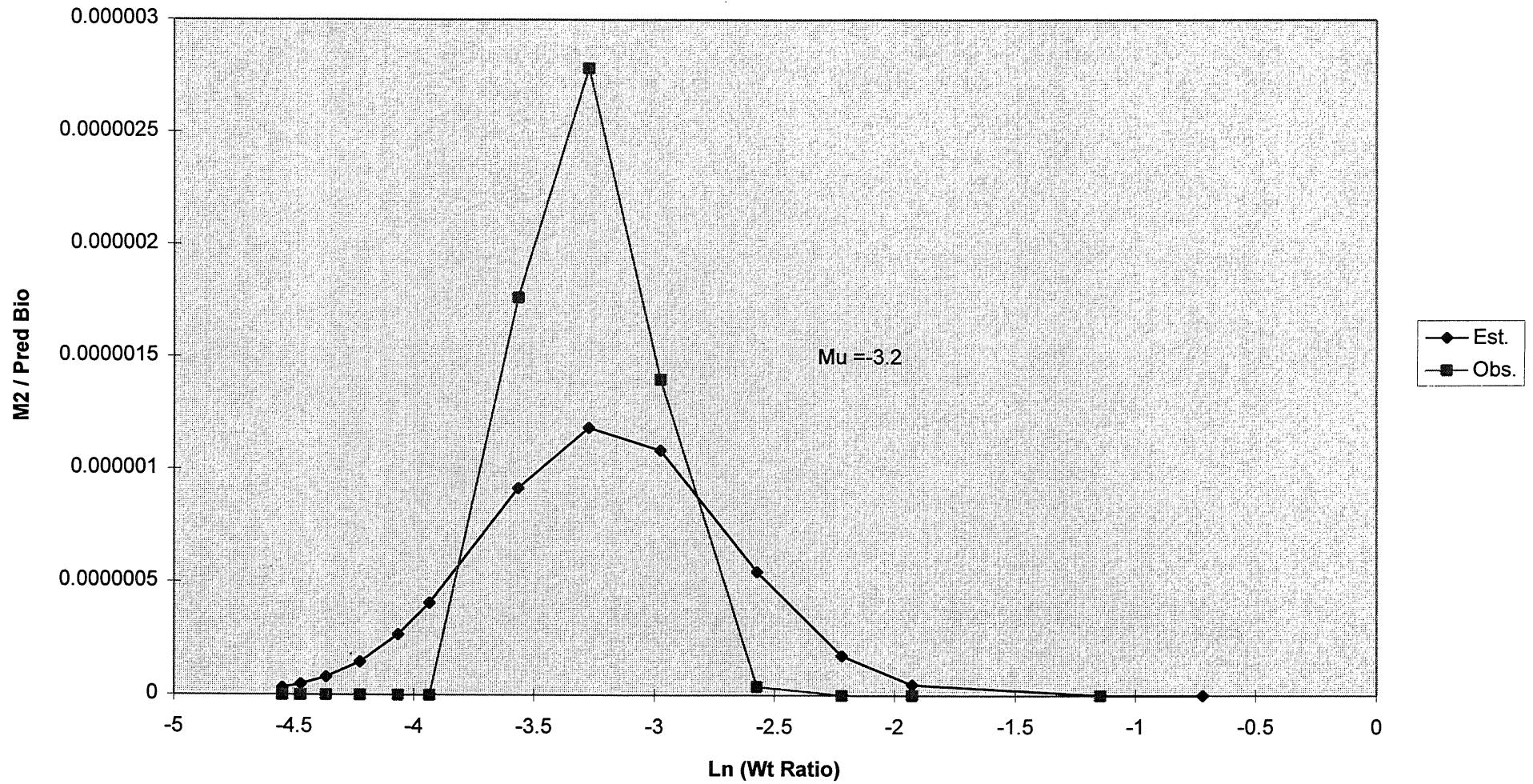


Fig. 2.7.4 - UM2 for various ages of cod as prey

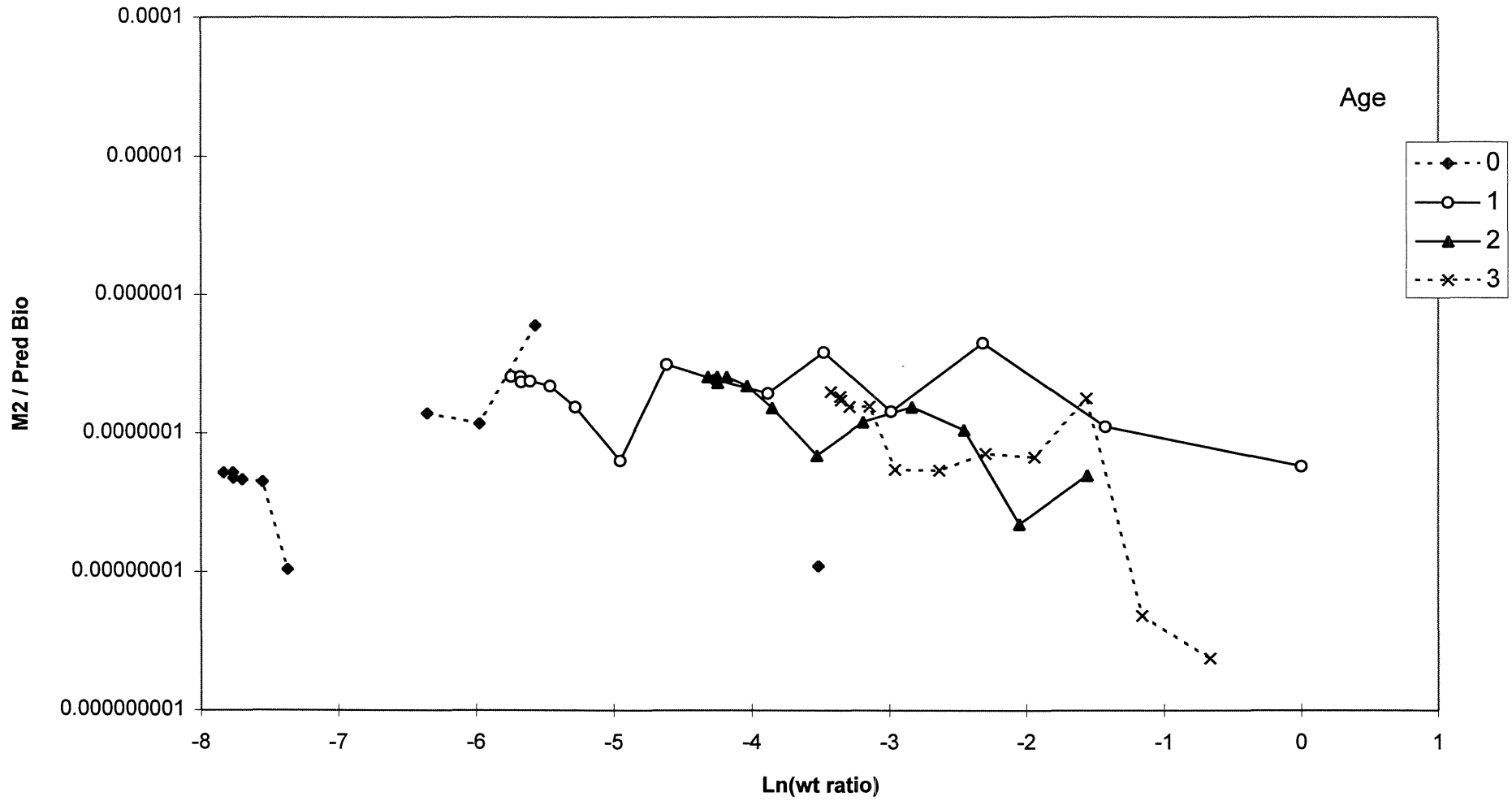


Fig 2.7.5 UM2's for Capelin as prey

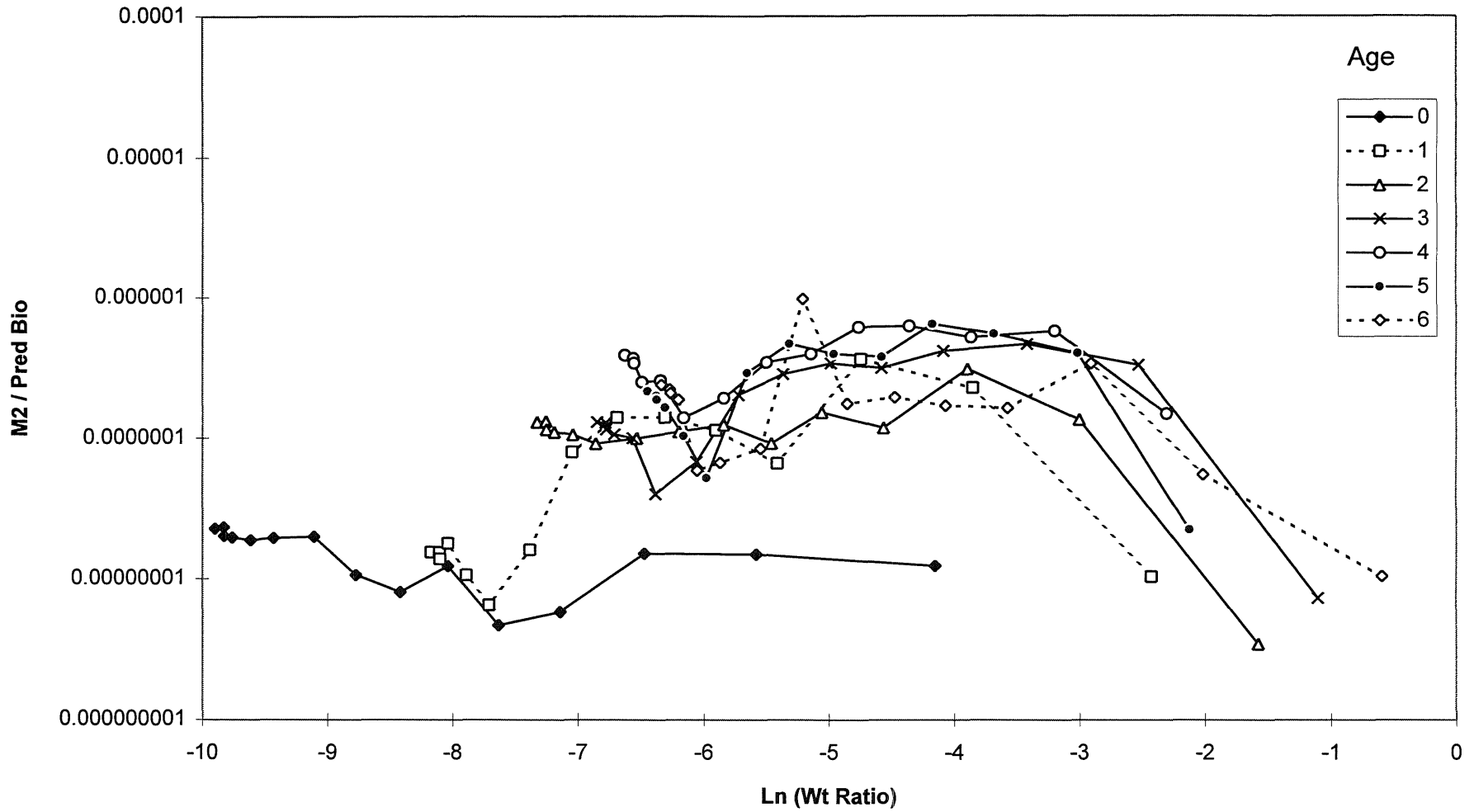


Fig 2.7.6 UM2's for Shrimp as prey

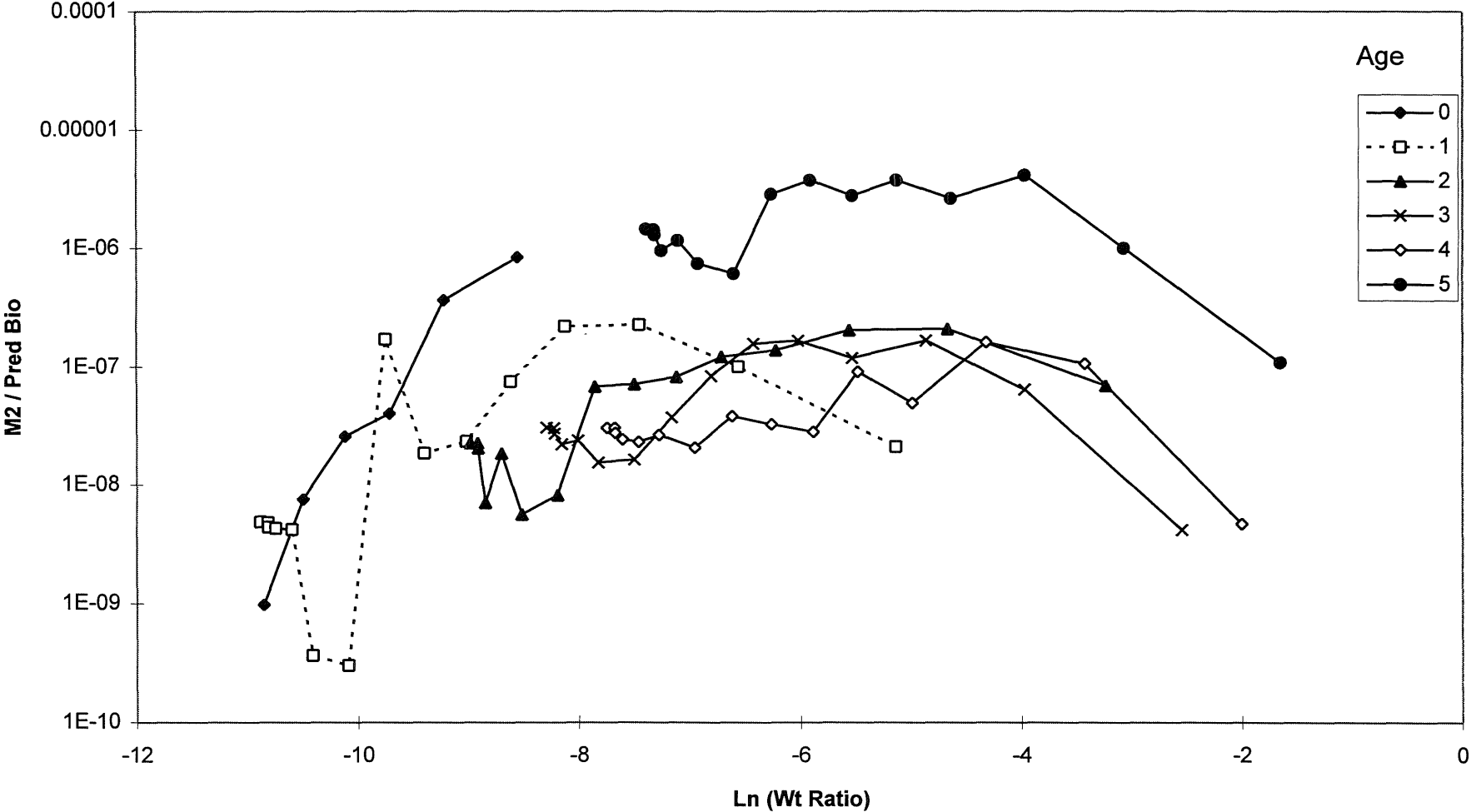


Fig 2.7.7 UM2's for Herring as prey

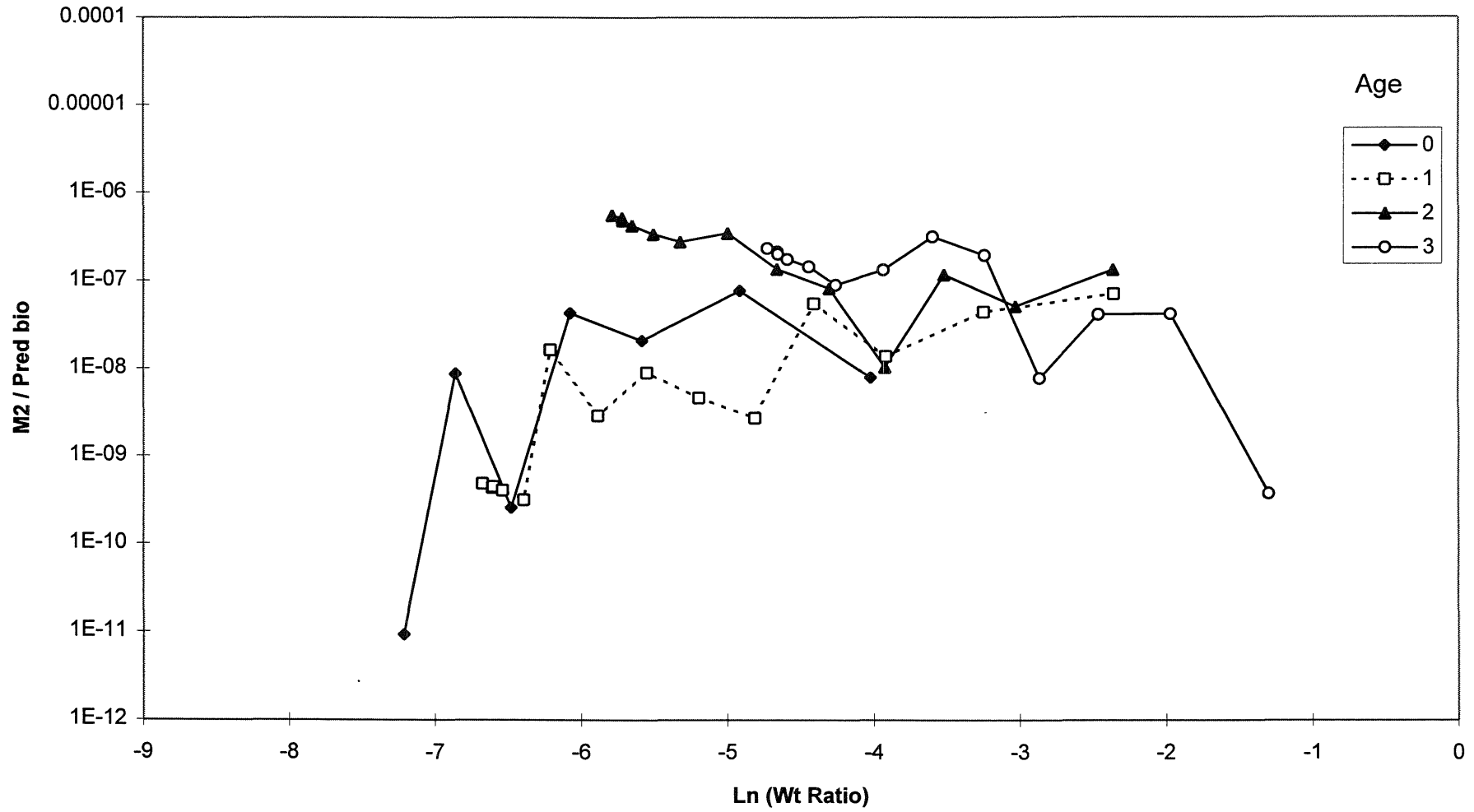


Figure 2.8.1 Mean lengths of 4 year old Icelandic cod from research survey samples (dark line) and estimated by BORMICON (lighter line).

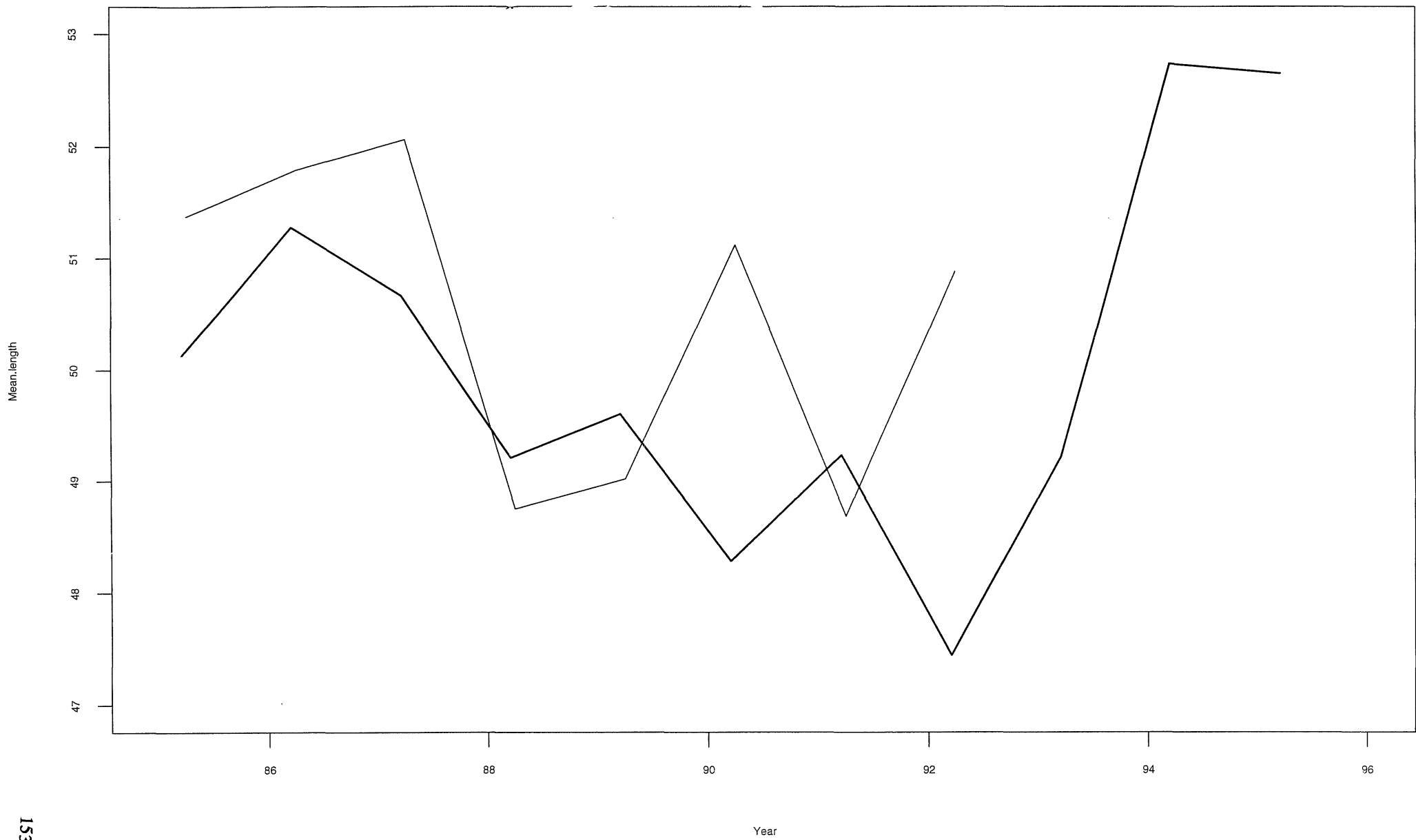


Figure 6.2.1a

Total Biomass (tons) consumed by predators 1 quarter										
Predator		Prey								Total
		Cod	Whiting	Haddock	Sprat	Herring	N.Pout	Sandeel	Other	
Cod	1991-New	367,91	9400,24	1278,95	2493,74	5051,75	4070,10	997,41	32860,12	56.520,22
	-Old	368,82	9386,84	1280,36	2434,09	5055,85	4042,60	956,26	32586,26	56.111,08
	1981	436,47	4907,85	2731,89	2356,81	6742,75	1739,52	4603,67	32533,02	56.051,98
Saithe	1991-New	-	-	-	-	31505,16	97791,61	855,85	104006,26	234.158,88
	-Old	-	-	-	43,64	31505,47	97791,70	855,85	103962,22	234.158,88
	1981	-	354,74	16873,85	888,5	4443,03	93195,71	17351,90	101051,2	234.158,88
Whiting	1991-New	-	3552,28	186,61	18596,11	2168,09	39894,71	17937,05	67029,57	149.364,42
	-Old	-	3638,68	301,96	26809,54	804,56	26147,31	18540,83	69786,72	146.029,60
	1981	63,98	1705,89	1853,86	18260,29	23233,93	11326,31	17594,36	61958,60	135.997,22
Haddock	1991-New	-	-	-	-	237,93	909,03	2192,41	44125,64	47.465,01
	-Old	-	-	-	-	232,71	898,87	2172,48	43842,63	47.146,69
	1981	-	-	-	162,72	13,58	3603,67	585,54	69853,90	74.219,41
Mackerel	1991-New	-	-	-	-	-	-	39145,09	77636,57	116.781,66
	-Old	-	-	-	-	-	-	21924,02	94857,65	116.781,67
	1981	-	-	-	-	51,19	-	11539,05	105191,4	116.781,66

Total Biomass (%) consumed by predators 1 quarter										
Predator		Prey								Total
		Cod	Whiting	Haddock	Sprat	Herring	N.Pout	Sandeel	Other	
Cod	1991-New	0,7	16,6	2,3	4,4	8,9	7,2	1,8	58,1	100,0
	-Old	0,7	16,7	2,3	4,3	9,0	7,2	1,7	58,1	100,0
	1981	0,8	8,8	4,9	4,2	12,0	3,1	8,2	58,0	100,0
Saithe	1991-New	-	-	-	-	13,5	41,8	0,4	44,4	100,0
	-Old	-	-	-	0,0	13,5	41,8	0,4	44,4	100,0
	1981	-	0,2	7,2	0,4	1,9	39,8	7,4	43,2	100,0
Whiting	1991-New	-	2,4	0,1	12,5	1,5	26,7	12,0	44,9	100,0
	-Old	-	2,5	0,2	18,4	0,6	17,9	12,7	47,8	100,0
	1981	-	1,3	1,4	13,4	17,1	8,3	12,9	45,6	100,0
Haddock	1991-New	-	-	-	-	0,5	1,9	4,6	93,0	100,0
	-Old	-	-	-	-	0,5	1,9	4,6	93,0	100,0
	1981	-	-	-	0,2	0,0	4,9	0,8	94,1	100,0
Mackerel	1991-New	-	-	-	-	-	-	33,5	66,5	100,0
	-Old	-	-	-	-	-	-	18,8	81,2	100,0
	1981	-	-	-	-	0,0	-	9,9	90,1	100,0

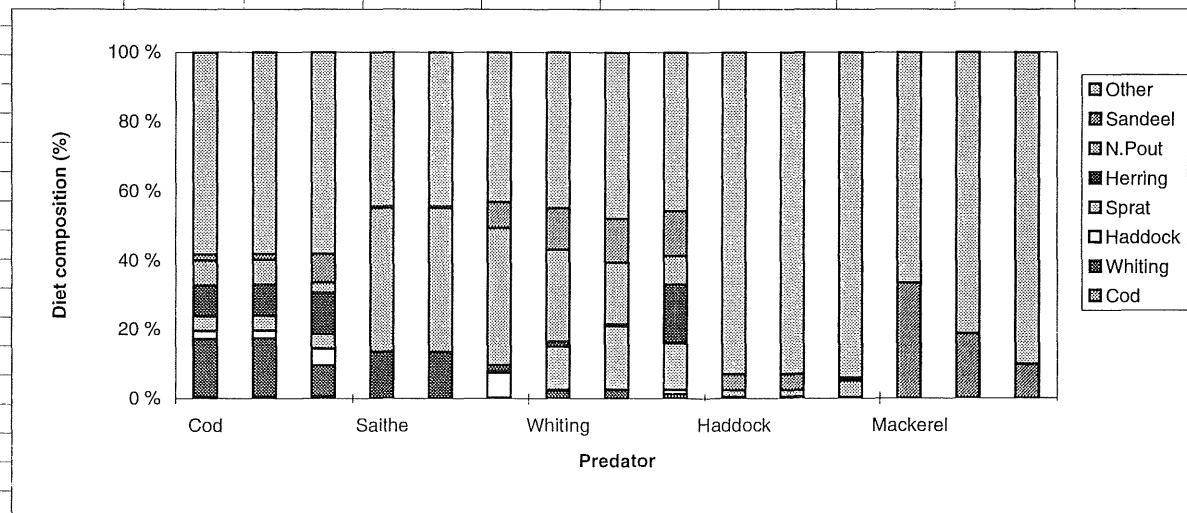


Figure 6.2.1b

Total Biomass (tons) consumed by predators 2 quarter										
Predator		Prey								
		Cod	Whiting	Haddock	Sprat	Herring	N.Pout	Sandeel	Other	Total
Cod	1991-New	668,97	3725,86	1763,26	225,9	6336,74	5938,84	5201,65	42161,88	66.023,10
	-Old	1467,14	3794,34	1247,17	324,08	5543,81	3317,36	3222,51	46200,67	65.117,08
	1981	556,63	1691,85	1318,25	844,55	3038,27	952,92	9826,49	46779,33	65.008,29
Saithe	1991-New	-	503,57	284,09	-	6173,94	31481,24	1554,19	183086,9	223.083,95
	-Old	-	503,57	284,08	-	6173,97	31480,61	1554,21	183087,5	223.083,95
	1981	-	549,06	4186,02	-	750,56	54986,46	2305,77	160306,1	223.083,93
Whiting	1991-New	-	854,51	-	11076,66	666,51	3598,75	31187,77	121571,4	168.955,62
	-Old	-	882,99	-	9178,86	92,48	4833,76	45008,8	103929,85	163.926,74
	1981	-	1381,76	828,35	1703,58	1796,99	10247,51	63624,97	78239,73	157.822,89
Haddock	1991-New	-	7,55	-	-	-	8,47	2364,77	95324,13	97.704,92
	-Old	-	-	-	6,44	-	20,29	1819,58	95050,47	96.896,78
	1981	-	576,62	-	-	-	-	988,17	113765,1	115.329,84
Mackerel	1991-New	-	-	-	4074,87	449,68	92,04	19908,04	196114,5	220.639,12
	-Old	-	-	-	3896,31	447,42	92,63	19928,27	196274,5	220.639,12
	1981	-	-	-	1569,18	1068,34	-	138271	79730,63	220.639,13

Total Biomass (%) consumed by predators 2 quarter										
Predator		Prey								
		Cod	Whiting	Haddock	Sprat	Herring	N.Pout	Sandeel	Other	Total
Cod	1991-New	1,0	5,6	2,7	0,3	9,6	9,0	7,9	63,9	100,0
	-Old	2,3	5,8	1,9	0,5	8,5	5,1	4,9	71,0	100,0
	1981	0,9	2,6	2,0	1,3	4,7	1,5	15,1	72,0	100,0
Saithe	1991-New	-	0,2	0,1	-	2,8	14,1	0,7	82,1	100,0
	-Old	-	0,2	0,1	-	2,8	14,1	0,7	82,1	100,0
	1981	-	0,2	1,9	-	0,3	24,6	1,0	71,9	100,0
Whiting	1991-New	-	0,5	-	6,6	0,4	2,1	18,5	72,0	100,0
	-Old	-	0,5	-	5,6	0,1	2,9	27,5	63,4	100,0
	1981	-	0,9	0,5	1,1	1,1	6,5	40,3	49,6	100,0
Haddock	1991-New	-	0,0	-	-	-	0,0	2,4	97,6	100,0
	-Old	-	-	-	0,0	-	0,0	1,9	98,1	100,0
	1981	-	0,5	-	-	-	-	0,9	98,6	100,0
Mackerel	1991-New	-	-	-	1,8	0,2	0,0	9,0	88,9	100,0
	-Old	-	-	-	1,8	0,2	0,0	9,0	89,0	100,0
	1981	-	-	-	0,7	0,5	-	62,7	36,1	100,0

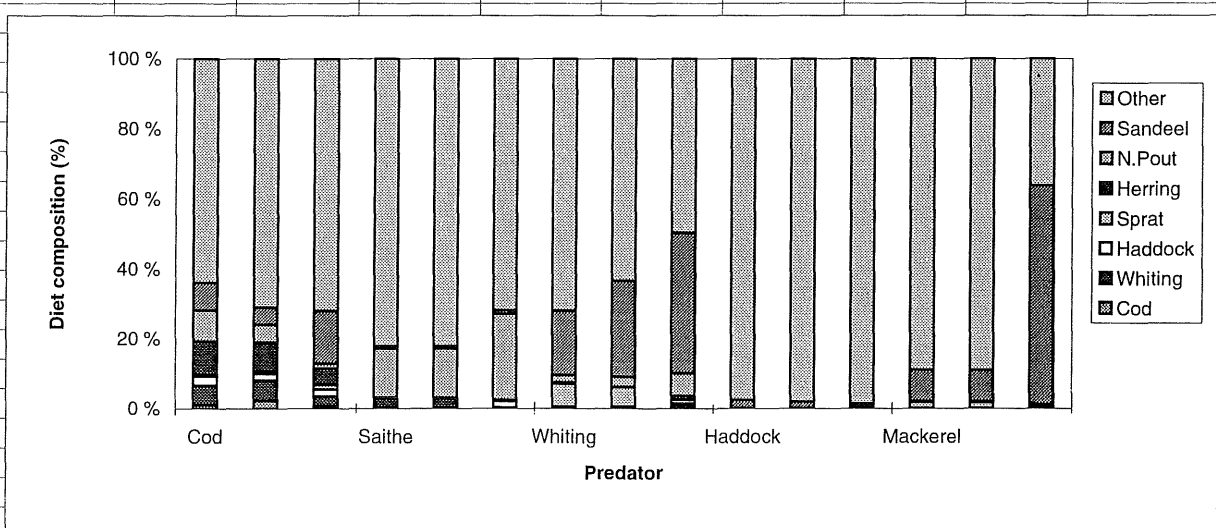


Figure 6.2.1c

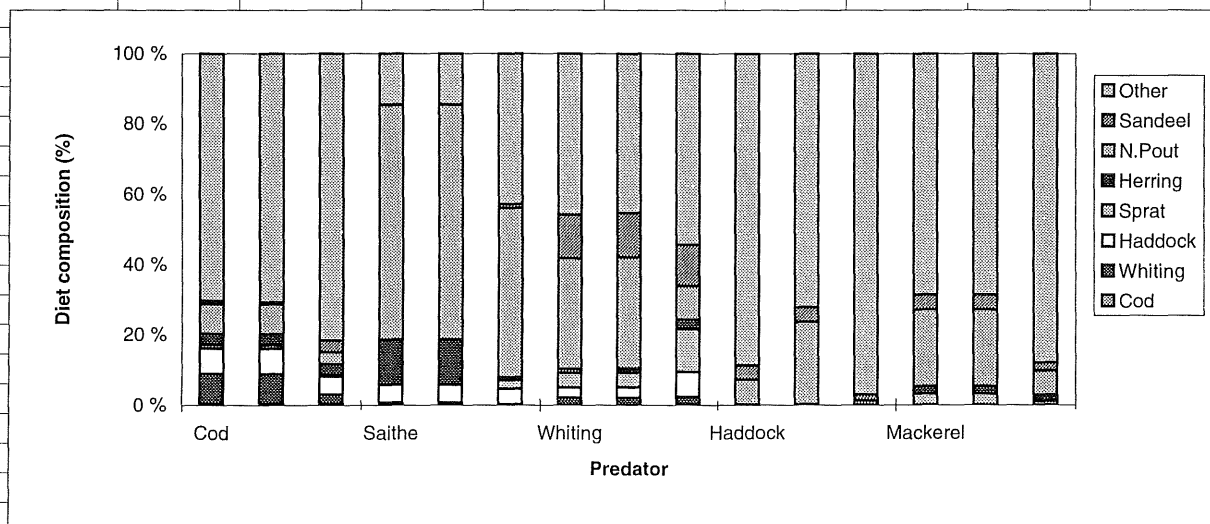
Total Biomass (tons) consumed by predators 3 quarter										
Predator		Prey								
		Cod	Whiting	Haddock	Sprat	Herring	N.Pout	Sandeel	Other	Total
Cod	1991-New	2223,05	5363,55	3491,26	1770,86	15914,37	15692,90	13024,91	78380,71	135.861,61
	-Old	2259,25	3273,43	2783,79	5445,01	15910,06	14852,84	6083,60	87381,70	137.989,68
	1981	1750,96	5187,11	4485,33	1979,70	17964,90	6705,75	2241,11	92528,78	132.843,64
Saithe	1991-New	-	11069,79	20926,49	350,57	19304,92	130690,4	3956,13	52350,64	238.648,96
	-Old	-	11070,37	20928,67	350,58	19265,83	130699,69	3956,81	52377,02	238.648,97
	1981	510,86	578,31	19290,17	281,70	488,41	48315,27	11888,82	157295,4	238.648,97
Whiting	1991-New	451,05	7547,16	4302,70	29950,14	14616,03	46325,12	81692,83	195011,6	379.896,60
	-Old	1446,68	6667,69	12327,92	30447,62	23622,57	42353,51	103499,54	148047,00	368.412,53
	1981	-	13646,79	25413,19	28342,50	25957,86	12555,28	43363,42	197688,83	346.967,87
Haddock	1991-New	2,57	-	907,95	-	-	4585,27	83395,25	273066,6	361.957,61
	-Old	0,65	-	251,72	-	-	1209,83	73219,19	297971,82	372.653,21
	1981	-	1,21	70,07	152,41	-	2543,15	35264,47	571143,19	609.174,50
Mackerel	1991-New	74,89	16,10	-	290,75	544,48	5983,40	16105,50	168126,4	191.141,49
	-Old	75,01	16,16	-	291,50	631,86	5979,31	15786,48	168361,16	191.141,48
	1981	105,03	-	-	4893,43	15509,98	3729,56	31257,59	135645,90	191.141,49
Total Biomass (%) consumed by predators 3 quarter										
Predator		Prey								
		Cod	Whiting	Haddock	Sprat	Herring	N.Pout	Sandeel	Other	Total
Cod	1991-New	1,6	3,9	2,6	1,3	11,7	11,6	9,6	57,7	100,0
	-Old	1,6	2,4	2,0	3,9	11,5	10,8	4,4	63,3	100,0
	1981	1,3	3,9	3,4	1,5	13,5	5,0	1,7	69,7	100,0
Saithe	1991-New	-	4,6	8,8	0,1	8,1	54,8	1,7	21,9	100,0
	-Old	-	4,6	8,8	0,1	8,1	54,8	1,7	21,9	100,0
	1981	0,2	0,2	8,1	0,1	0,2	20,2	5,0	65,9	100,0
Whiting	1991-New	0,1	2,0	1,1	7,9	3,8	12,2	21,5	51,3	100,0
	-Old	0,4	1,8	3,3	8,3	6,4	11,5	28,1	40,2	100,0
	1981	-	3,9	7,3	8,2	7,5	3,6	12,5	57,0	100,0
Haddock	1991-New	0,0	-	0,3	-	-	1,3	23,0	75,4	100,0
	-Old	0,0	-	0,1	-	-	0,3	19,6	80,0	100,0
	1981	-	0,0	0,0	0,0	-	0,4	5,8	93,8	100,0
Mackerel	1991-New	0,0	0,0	-	0,2	0,3	3,1	8,4	88,0	100,0
	-Old	0,0	0,0	-	0,2	0,3	3,1	8,3	88,1	100,0
	1981	0,1	-	-	2,6	8,1	2,0	16,4	71,0	100,0

Detailed description of the stacked bar chart: The chart displays the percentage composition of various prey items in the diet of five predator species. For each predator, there are three bars representing different time periods: 1991-New, -Old, and 1981. The prey items are stacked from bottom to top in the following order: Cod, Whiting, Haddock, Sprat, Herring, N.Pout, Sandeel, and Other. Cod is the most significant prey item for all predators, typically making up 50-90% of the diet. Other prey items like Herring and N.Pout are also present in smaller proportions.

Figure 6.2.1d

Total Biomass (tons) consvumed by predators 4 quarter										
Predator		Prey								
		Cod	Whiting	Haddock	Sprat	Herring	N.Pout	Sandeel	Other	Total
Cod	1991-New	305,62	7247,14	6154,88	849,02	2699,31	7259,29	813,00	60003,26	85.331,52
	-Old	304,57	7205,61	6119,64	839,51	2699,23	7230,38	485,79	60334,66	85.219,39
	1981	406,83	2176,76	4477,66	279,89	2692,40	2940,77	2886,25	70652,85	86.513,41
Saithe	1991-New	-	1381,62	9760,29	-	24582,35	127746,4	37,61	28076,12	191.584,38
	-Old	-	1381,62	9760,32	-	24582,33	127746,3	37,61	28076,17	191.584,38
	1981	-	336,93	8597,49	4593,23	1575,24	92230,21	2088,92	82162,38	191.584,40
Whiting	1991-New	95,33	4241,26	6119,83	8671,89	2292,57	65820,47	25902,01	96032,5	209.175,86
	-Old	94,98	4216,45	5906,39	8555,75	2268,83	64153,09	25270,89	91751,44	202.217,82
	1981	259,29	4161,99	13175,93	22523,06	5041,94	17922,37	21618,38	101011,69	185.714,65
Haddock	1991-New	-	-	250,60	-	180,45	14260,89	8459,74	180218,93	203.370,61
	-Old	-	-	250,94	-	179,81	47802,35	8395,05	146852,45	203.480,60
	1981	-	19,01	45,25	-	6,92	3945,95	5369,18	307592,76	316.979,07
Mackerel	1991-New	-	-	-	3169,38	2234,10	21877,24	4339,6	68671,07	100.291,39
	-Old	-	-	-	3175,70	2236,51	21903,21	4309,64	68666,33	100.291,39
	1981	-	-	-	1101,96	1831,27	6870,19	2273,93	88214,04	100.291,39

Total Biomass (%) consvumed by predators 4 quarter										
Predator		Prey								
		Cod	Whiting	Haddock	Sprat	Herring	N.Pout	Sandeel	Other	Total
Cod	1991-New	0,4	8,5	7,2	1,0	3,2	8,5	1,0	70,3	100,0
	-Old	0,4	8,5	7,2	1,0	3,2	8,5	0,6	70,8	100,0
	1981	0,5	2,5	5,2	0,3	3,1	3,4	3,3	81,7	100,0
Saithe	1991-New	-	0,7	5,1	-	12,8	66,7	0,0	14,7	100,0
	-Old	-	0,7	5,1	-	12,8	66,7	0,0	14,7	100,0
	1981	-	0,2	4,5	2,4	0,8	48,1	1,1	42,9	100,0
Whiting	1991-New	0,0	2,0	2,9	4,1	1,1	31,5	12,4	45,9	100,0
	-Old	0,0	2,1	2,9	4,2	1,1	31,7	12,5	45,4	100,0
	1981	0,1	2,2	7,1	12,1	2,7	9,7	11,6	54,4	100,0
Haddock	1991-New	-	-	0,1	-	0,1	7,0	4,2	88,6	100,0
	-Old	-	-	0,1	-	0,1	23,5	4,1	72,2	100,0
	1981	-	0,0	0,0	-	0,0	1,2	1,7	97,0	100,0
Mackerel	1991-New	-	-	-	3,2	2,2	21,8	4,3	68,5	100,0
	-Old	-	-	-	3,2	2,2	21,8	4,3	68,5	100,0
	1981	-	-	-	1,1	1,8	6,9	2,3	88,0	100,0



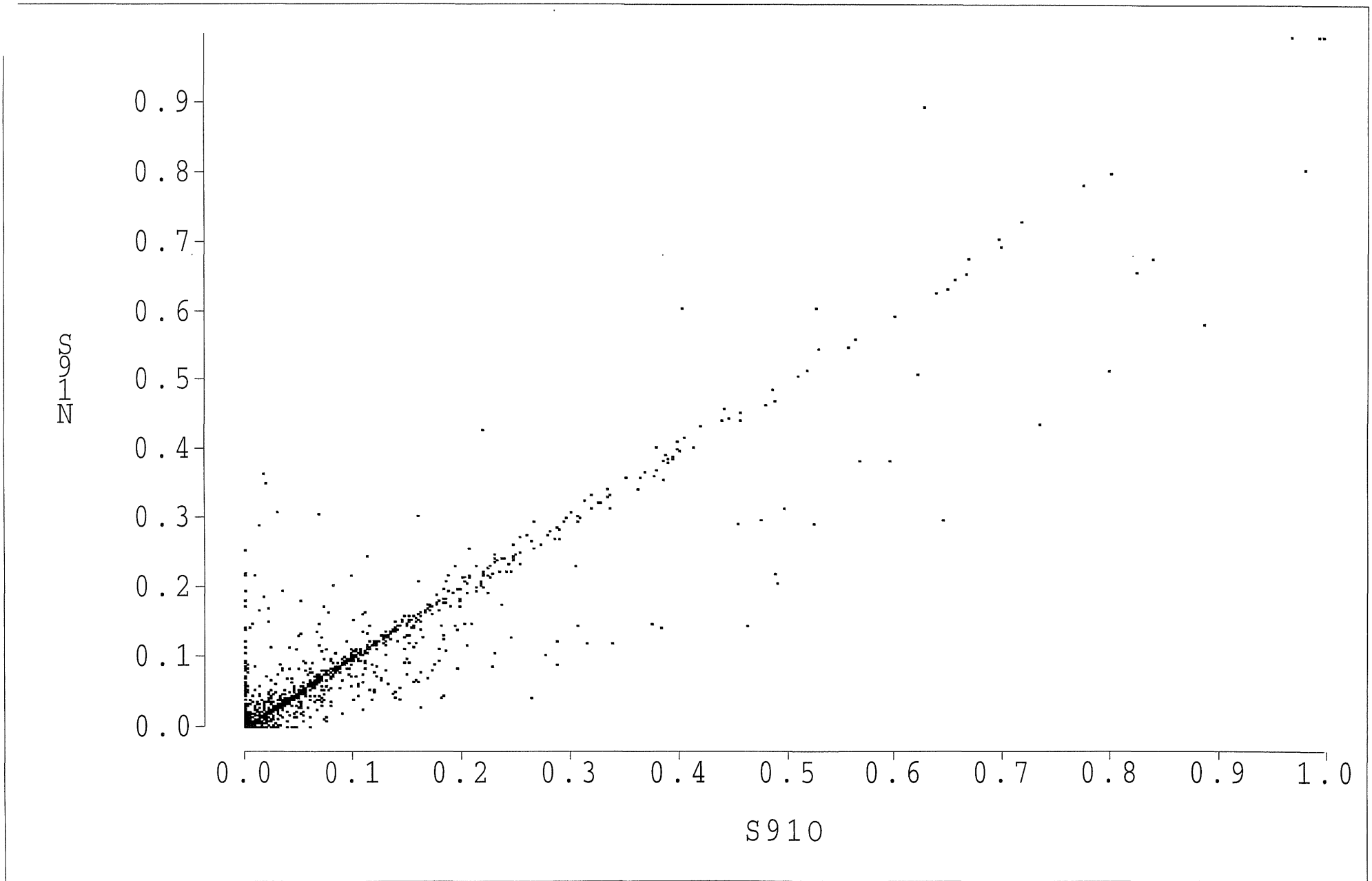


Fig. 6.2.2 Scatterplot of suitabilities in North Sea MSVPA estimated with "old" 1991 data (x-axis) and "new" 1991 data (y-axis).

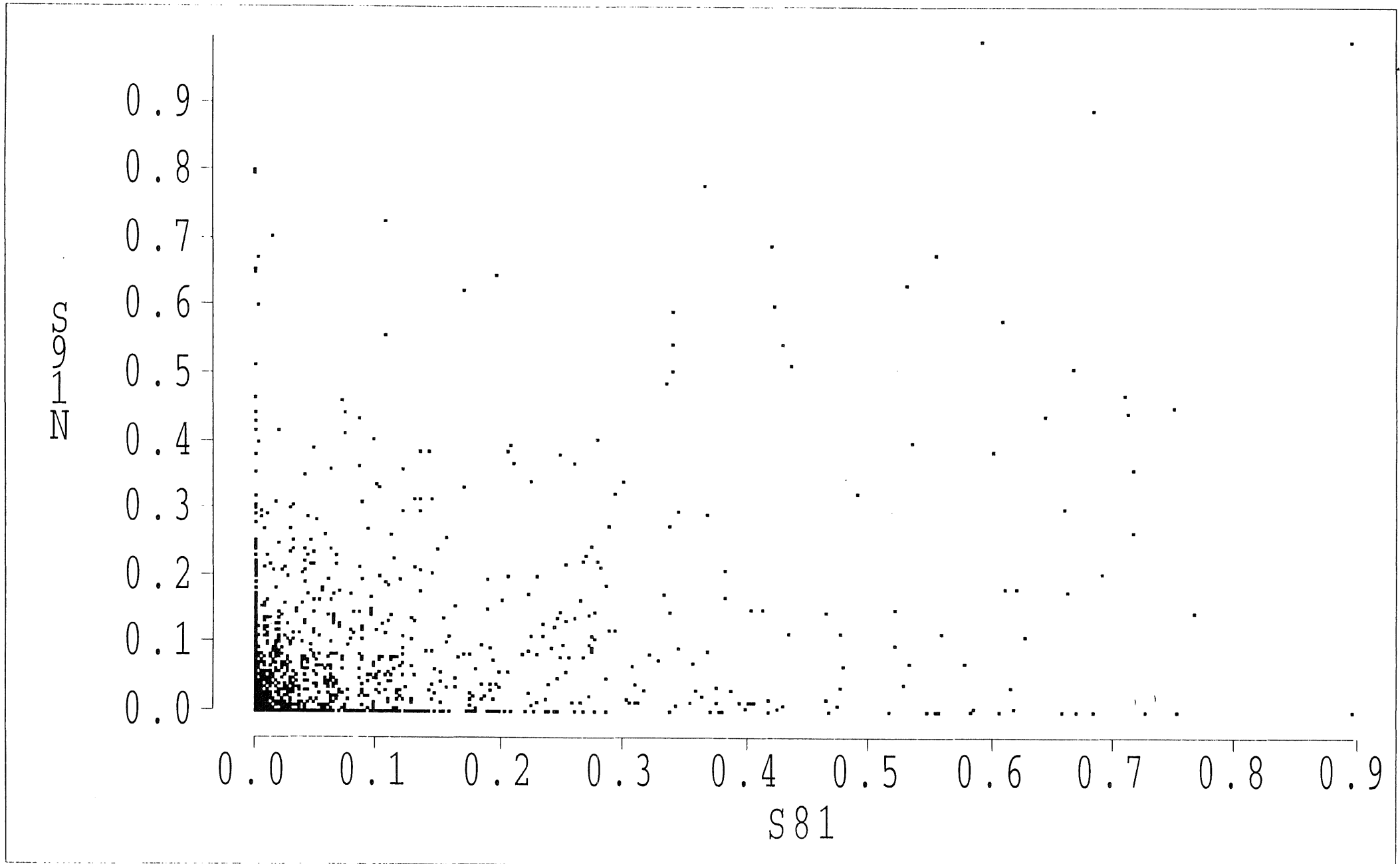


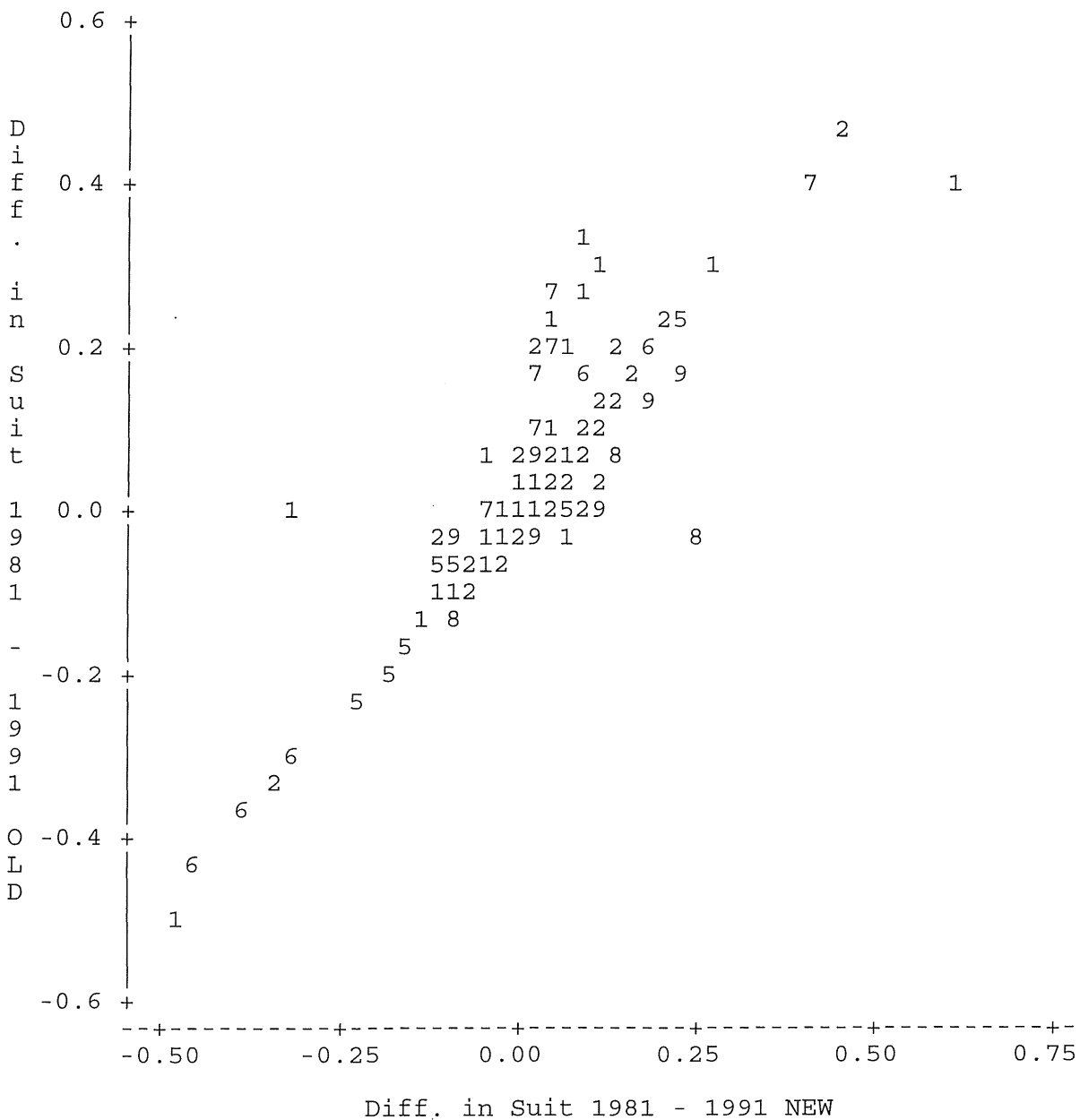
Fig 6.2.3 Scatterplot of suitabilities in North Sea MSVPA estimated with 1981 data (x-axis) and with the new 1991 data (y-axis).

Figure 6.2.4a Scatterplots of the differences between the SUITABILITIES estimated with only the 1981 data and the SUITABILITIES estimated with the new (x-axis) and old (y-axis) 1991 data. Cod as predator. Numbers correspond to prey codes (1=cod, 2=whiting, 5=haddock, 6=herring, 7=sprat, 8=norway pout, 9=sandeels), however, SAS overwrite practice means other prey points could also be present but completely masked.

Change in suit 81-91old vs change 81-91new 13348
 12:30 Monday, June 26, 1995

----- PD=1 -----

Plot of DS890*DS89N. Symbol is value of PY.



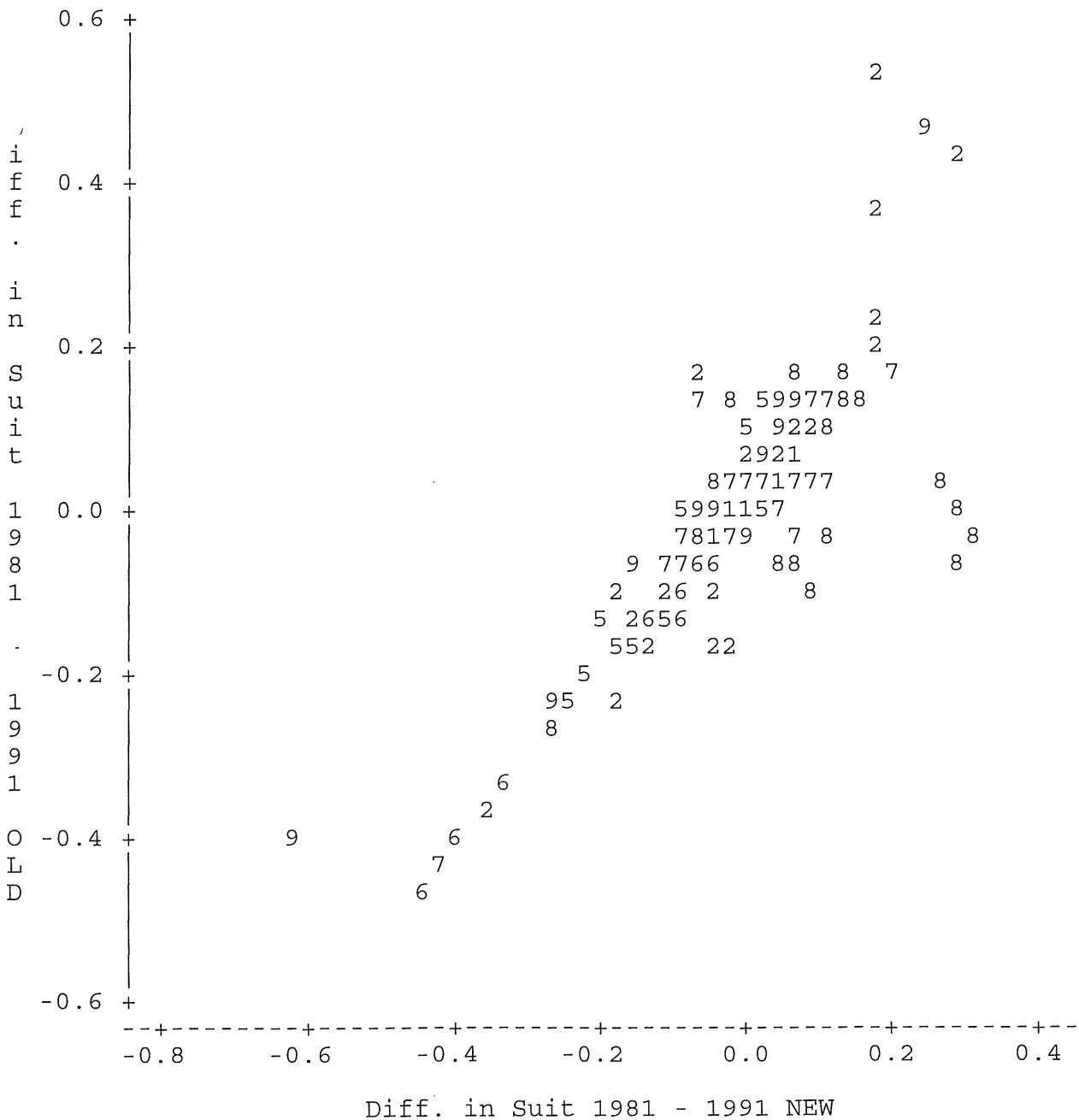
NOTE: 530 obs had missing values. 732 obs hidden.

Figure 6.2.4b Scatterplots of the differences between the SUITABILITIES estimated with only the 1981 data and the SUITABILITIES estimated with the new (x-axis) and old (y-axis) 1991 data. Whiting as predator. Numbers correspond to prey codes (1=cod, 2=whiting, 5=haddock, 6=herring, 7=sprat, 8=norway pout, 9=sandeels), however, SAS overwrite practice means other prey points could also be present but completely masked.

Change in suit 81-91old vs change 81-91new 13349
 12:30 Monday, June 26, 1995

----- PD=2 -----

Plot of DS89O*DS89N. Symbol is value of PY.



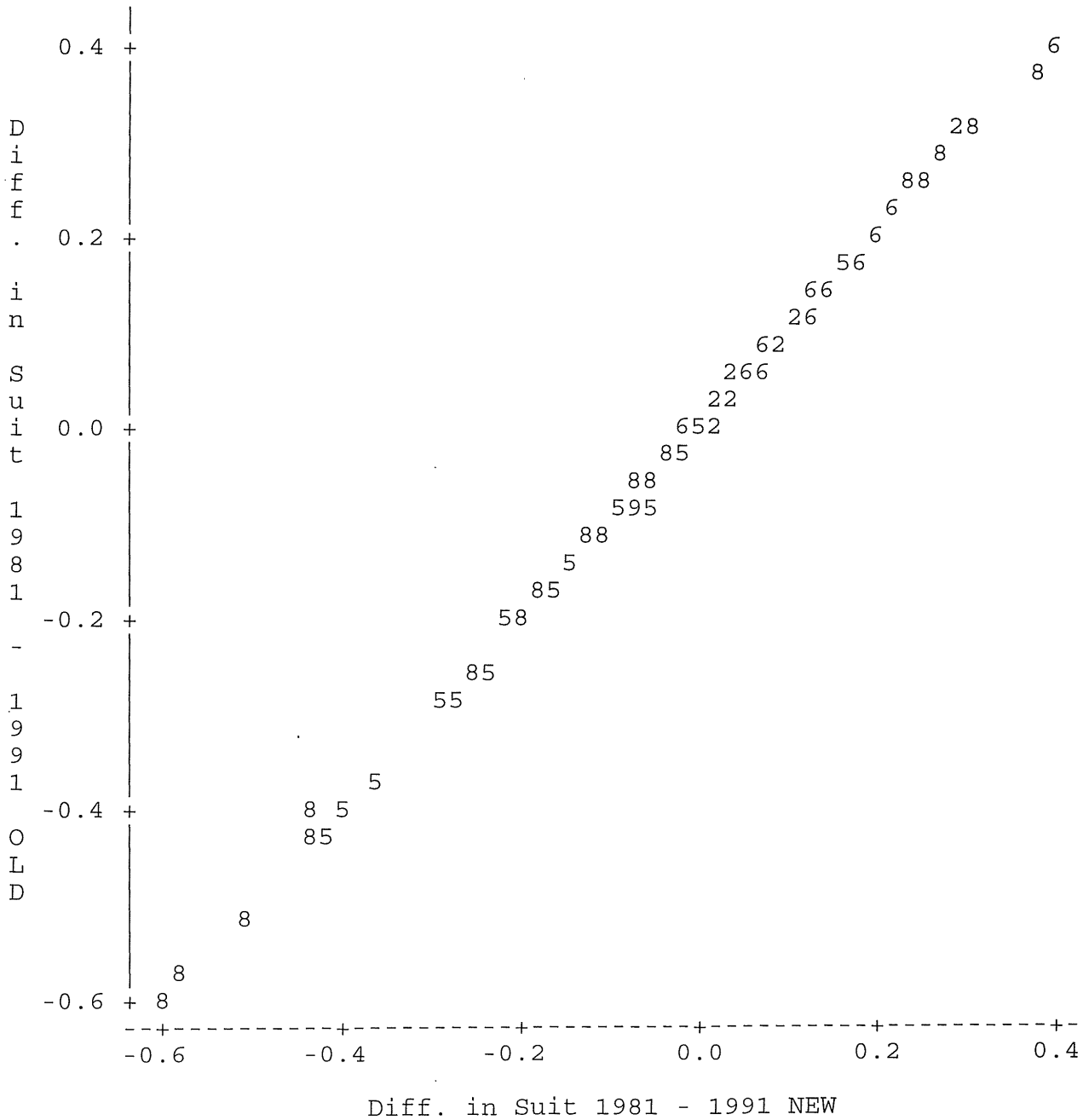
NOTE: 331 obs had missing values. 371 obs hidden.

Figure 6.2.4c Scatterplots of the differences between the SUITABILITIES estimated with only the 1981 data and the SUITABILITIES estimated with the new (x-axis) and old (y-axis) 1991 data. Mackerel as predator. Numbers correspond to prey codes (1=cod, 2=whiting, 5=haddock, 6=herring, 7=sprat, 8=norway pout, 9=sandeels), however, SAS overwrite practice means other prey points could also be present but completely masked.

Change in suit 81-91old vs change 81-91new 13350
 12:30 Monday, June 26, 1995

----- PD=3 -----

Plot of DS890*DS89N. Symbol is value of PY.



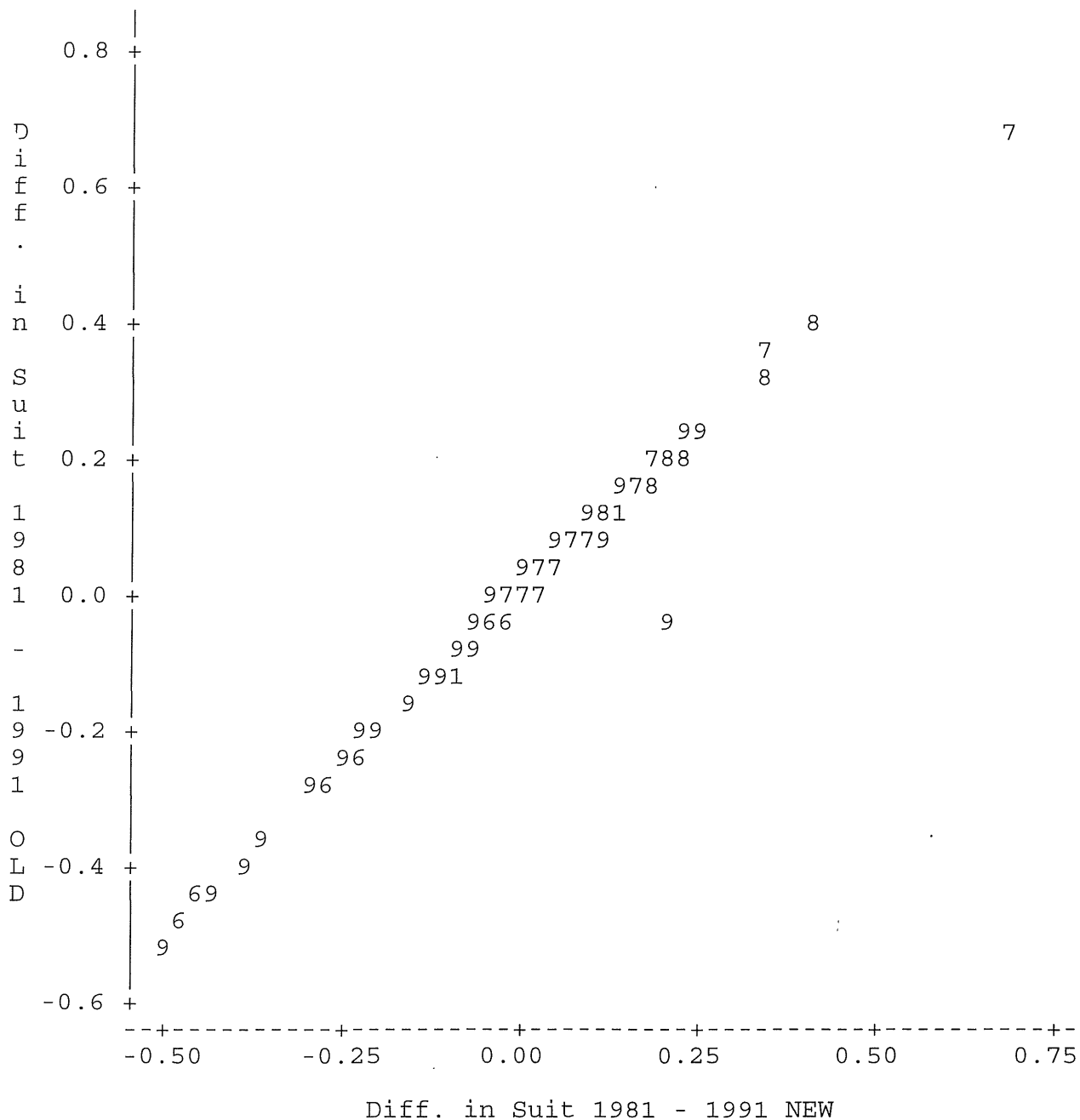
NOTE: 680 obs had missing values. 389 obs hidden.

Figure 6.2.4d Scatterplots of the differences between the SUITABILITIES estimated with only the 1981 data and the SUITABILITIES estimated with the new (x-axis) and old (y-axis) 1991 data. Saithe as predator. Numbers correspond to prey codes (1=cod, 2=whiting, 5=haddock, 6=herring, 7=sprat, 8=norway pout, 9=sandeels), however, SAS overwrite practice means other prey points could also be present but completely masked.

Change in suit 81-91old vs change 81-91new 13351
 12:30 Monday, June 26, 1995

----- PD=4 -----

Plot of DS890*DS89N. Symbol is value of PY.



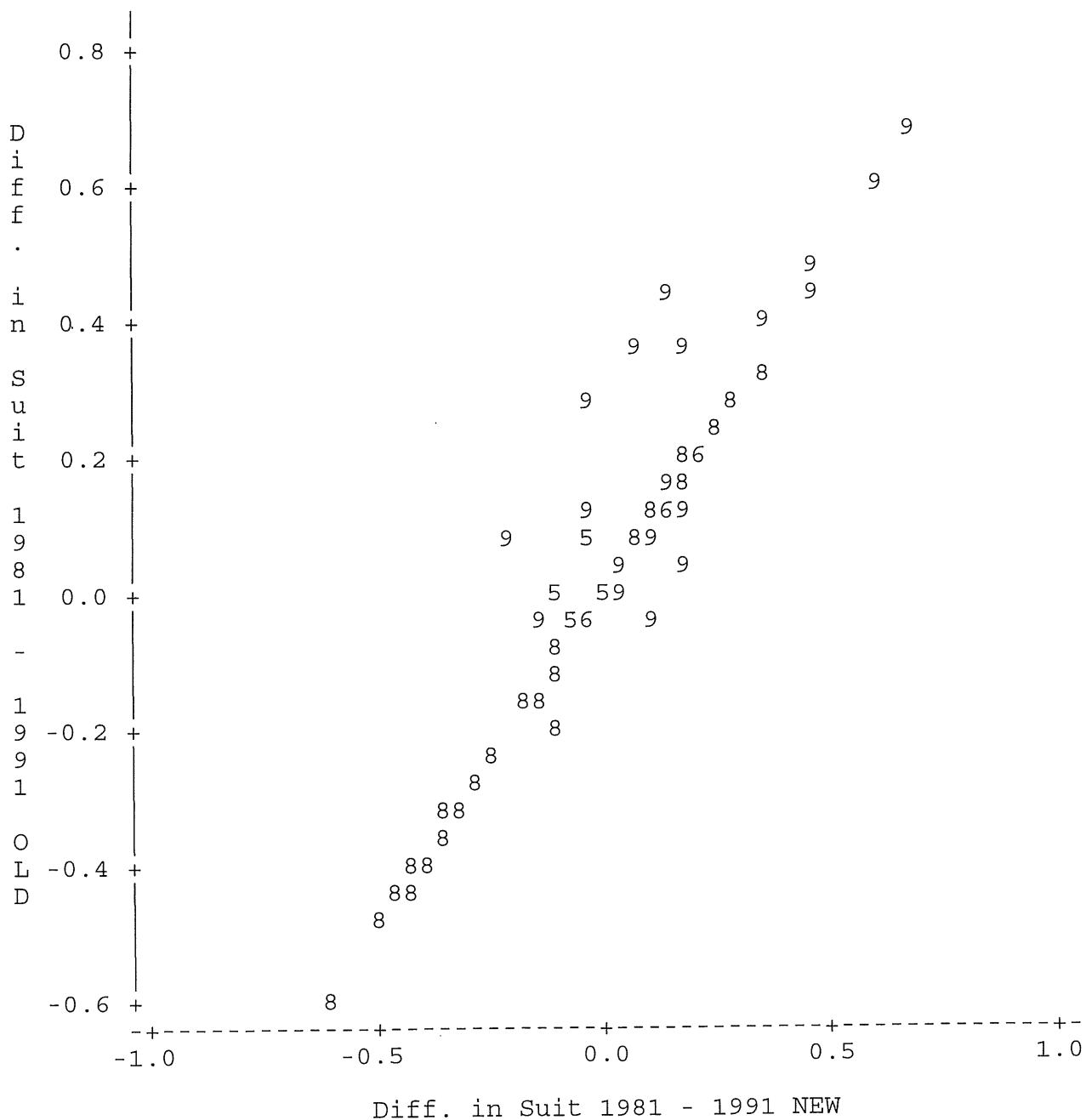
NOTE: 247 obs had missing values. 297 obs hidden.

Figure 6.2.4e Scatterplots of the differences between the SUITABILITIES estimated with only the 1981 data and the SUITABILITIES estimated with the new (x-axis) and old (y-axis) 1991 data. Haddock as predator. Numbers correspond to prey codes (1=cod, 2=whiting, 5=haddock, 6=herring, 7=sprat, 8=norway pout, 9=sandeels), however, SAS overwrite practice means other prey points could also be present but completely masked.

Change in suit 81-91old vs change 81-91new 13352
 12:30 Monday, June 26, 1995

----- PD=5 -----

Plot of DS89O*DS89N. Symbol is value of PY.



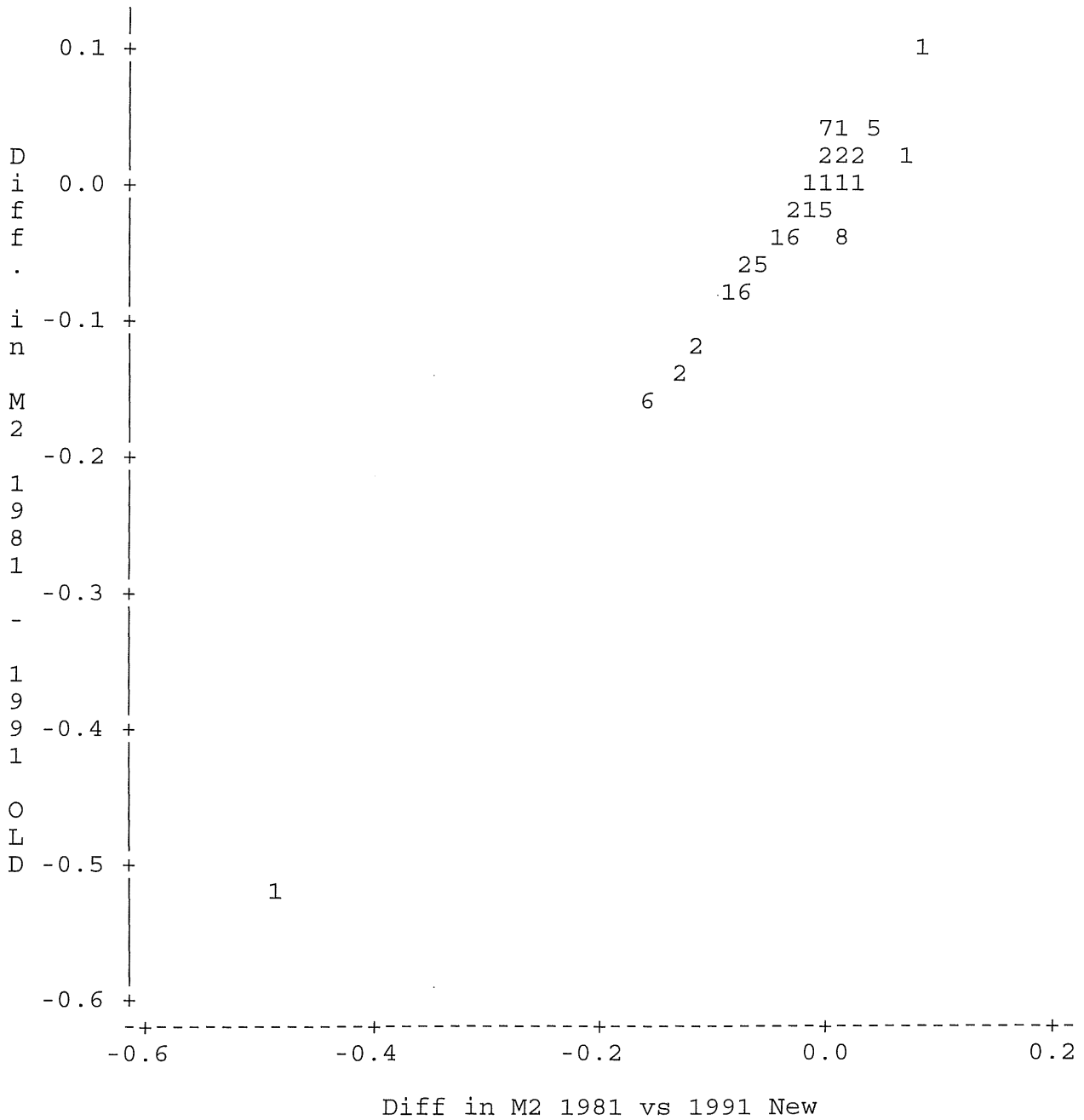
NOTE: 236 obs had missing values. 86 obs hidden.

Figure 6.2.5a Scatterplots of the differences between the PREDATION MORTALITIES (UM2's) estimated with only the 1981 data and the UM2's estimated with the new (x-axis) and old (y-axis) 1991 data. Cod as predator. Codes as in Figure 6.2.4.

Change in M2 81-91old vs change 81-91new 13353
 12:30 Monday, June 26, 1995

----- PD=1 -----

Plot of DM890*DM89N. Symbol is value of PY.



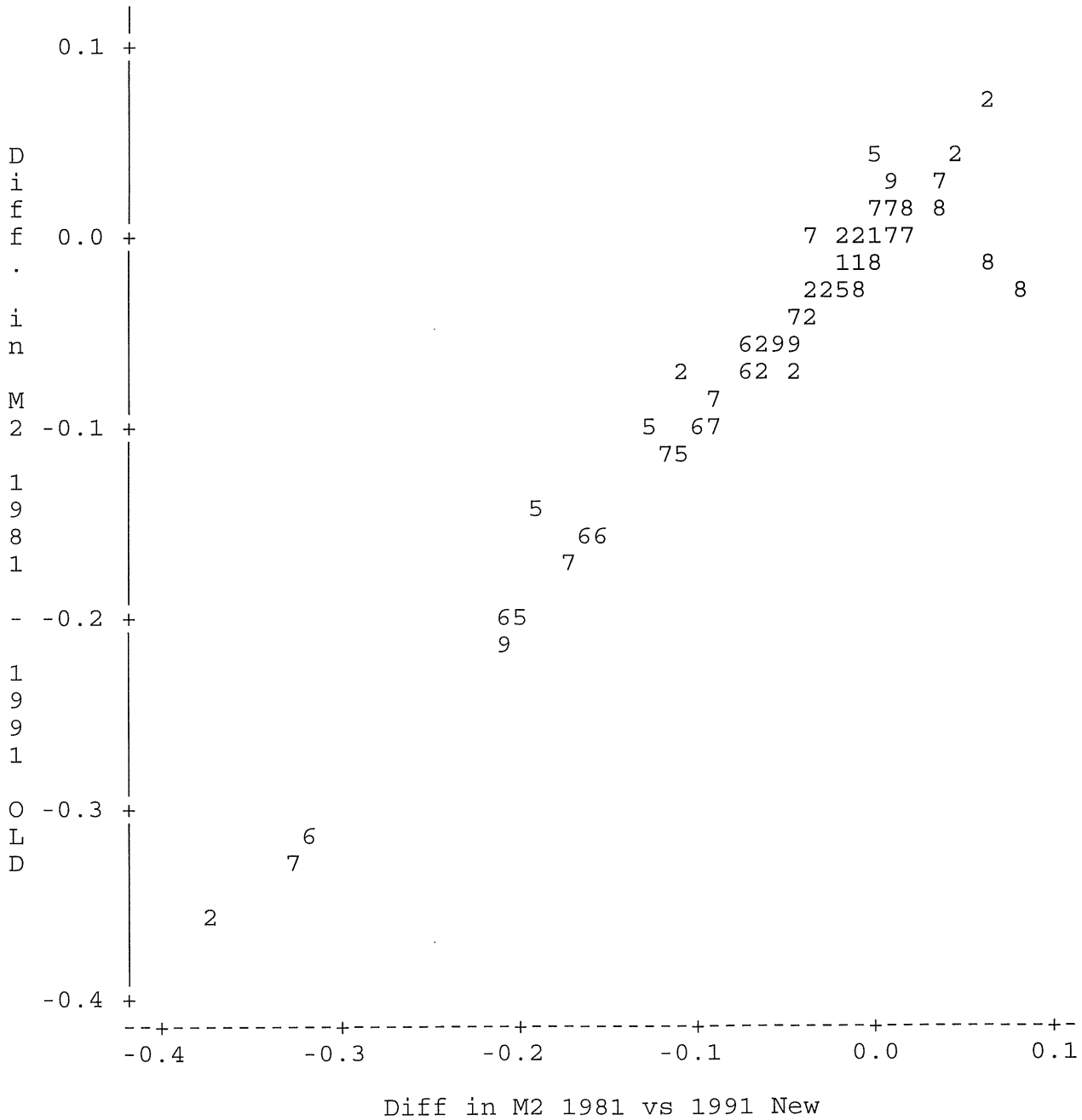
NOTE: 530 obs had missing values. 780 obs hidden.

Figure 6.2.5b Scatterplots of the differences between the PREDATION MORTALITIES (UM2's) estimated with only the 1981 data and the UM2's estimated with the new (x-axis) and old (y-axis) 1991 data. Whiting as predator. Codes as in Figure 6.2.4.

Change in M2 81-91old vs change 81-91new 13354
 12:30 Monday, June 26, 1995

----- PD=2 -----

Plot of DM890*DM89N. Symbol is value of PY.

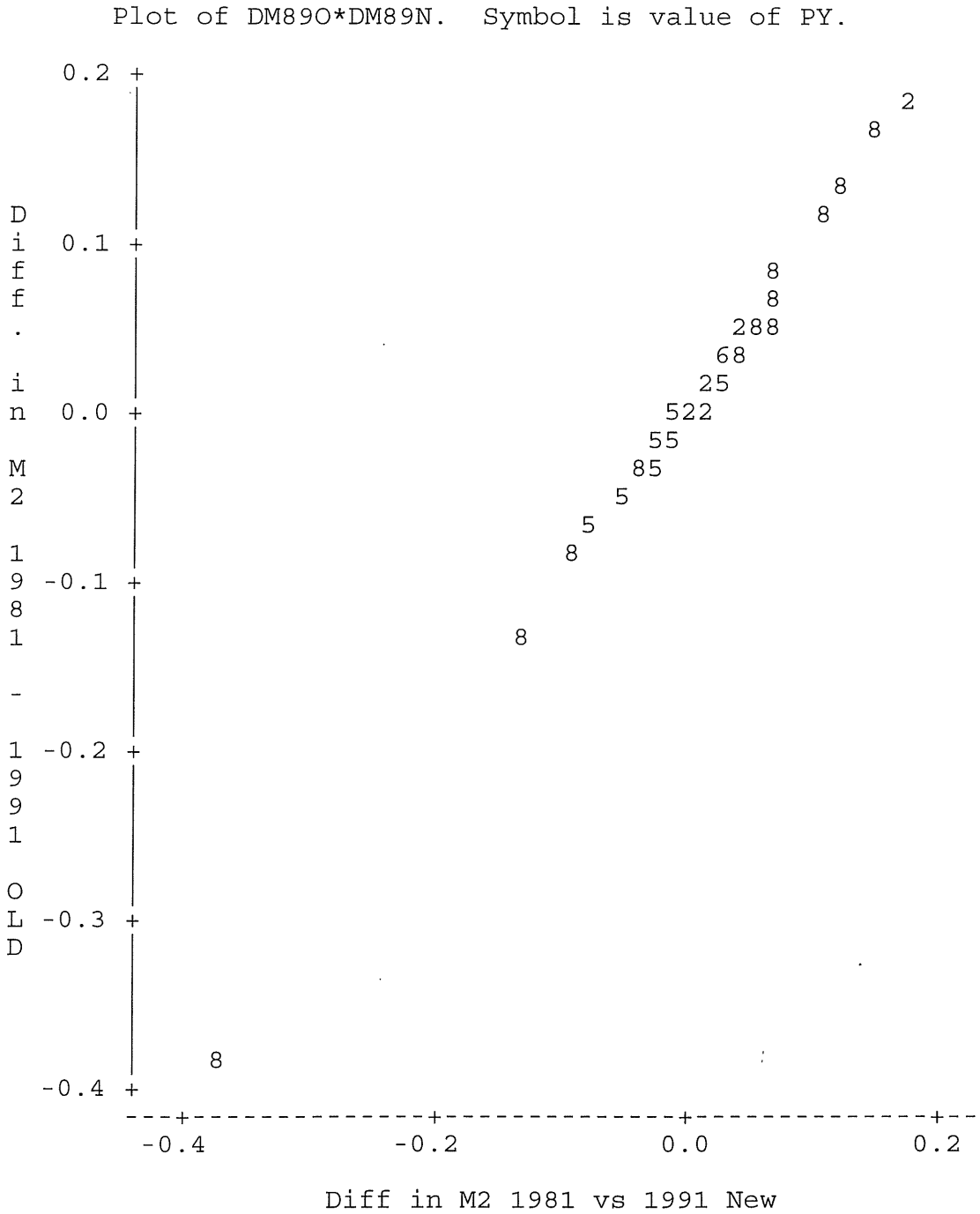


NOTE: 331 obs had missing values. 408 obs hidden.

Figure 6.2.5c Scatterplots of the differences between the PREDATION MORTALITIES (UM2's) estimated with only the 1981 data and the UM2's estimated with the new (x-axis) and old (y-axis) 1991 data. Mackerel as predator. Codes as in Figure 6.2.4.

Change in M2 81-91old vs change 81-91new 13355
 12:30 Monday, June 26, 1995

----- PD=3 -----



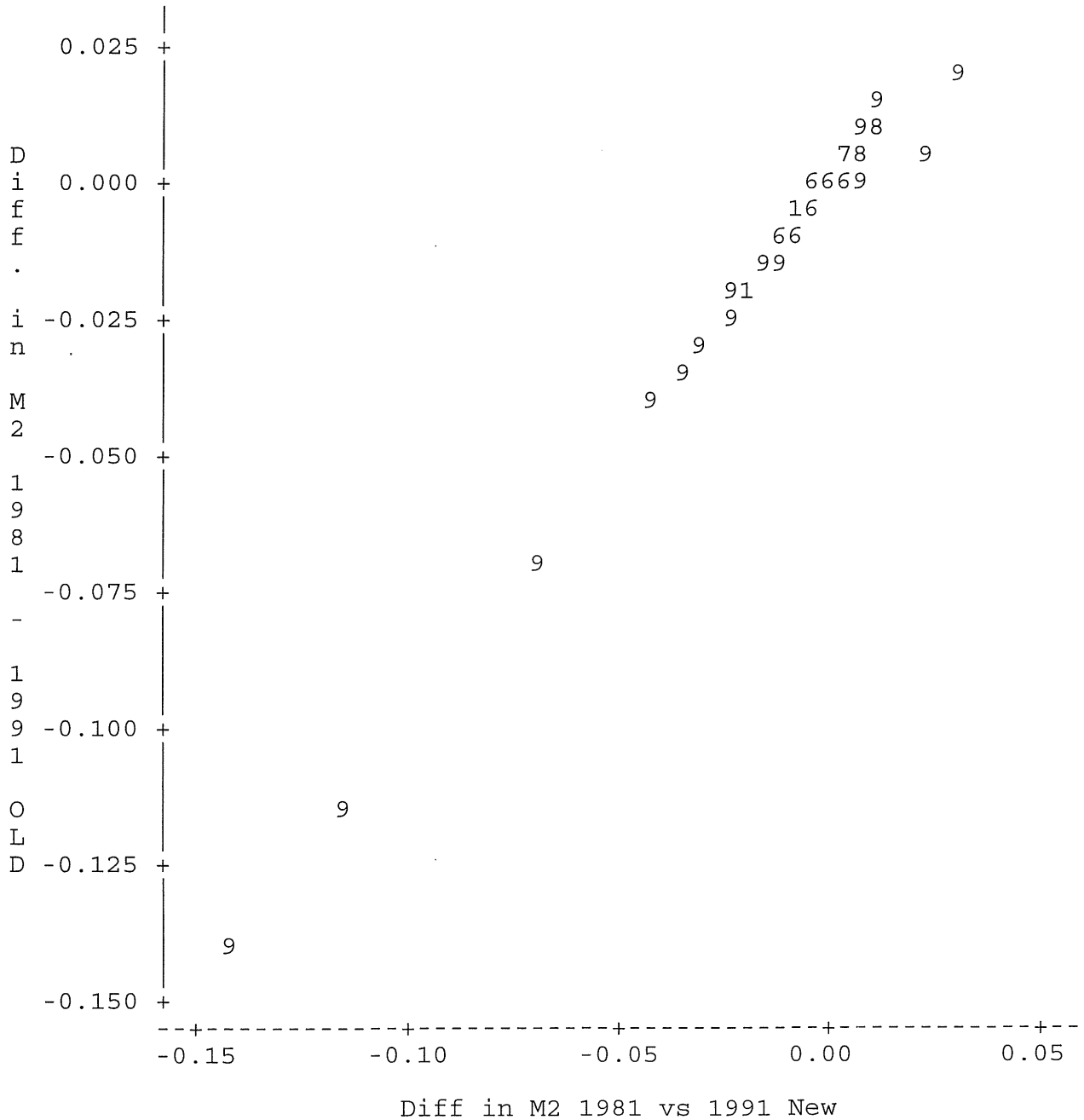
NOTE: 680 obs had missing values. 415 obs hidden.

Figure 6.2.5d Scatterplots of the differences between the PREDATION MORTALITIES (UM2's) estimated with only the 1981 data and the UM2's estimated with the new (x-axis) and old (y-axis) 1991 data. Saithe as predator. Codes as in Figure 6.2.4.

Change in M2 81-91old vs change 81-91new 13356
 12:30 Monday, June 26, 1995

----- PD=4 -----

Plot of DM89O*DM89N. Symbol is value of PY.



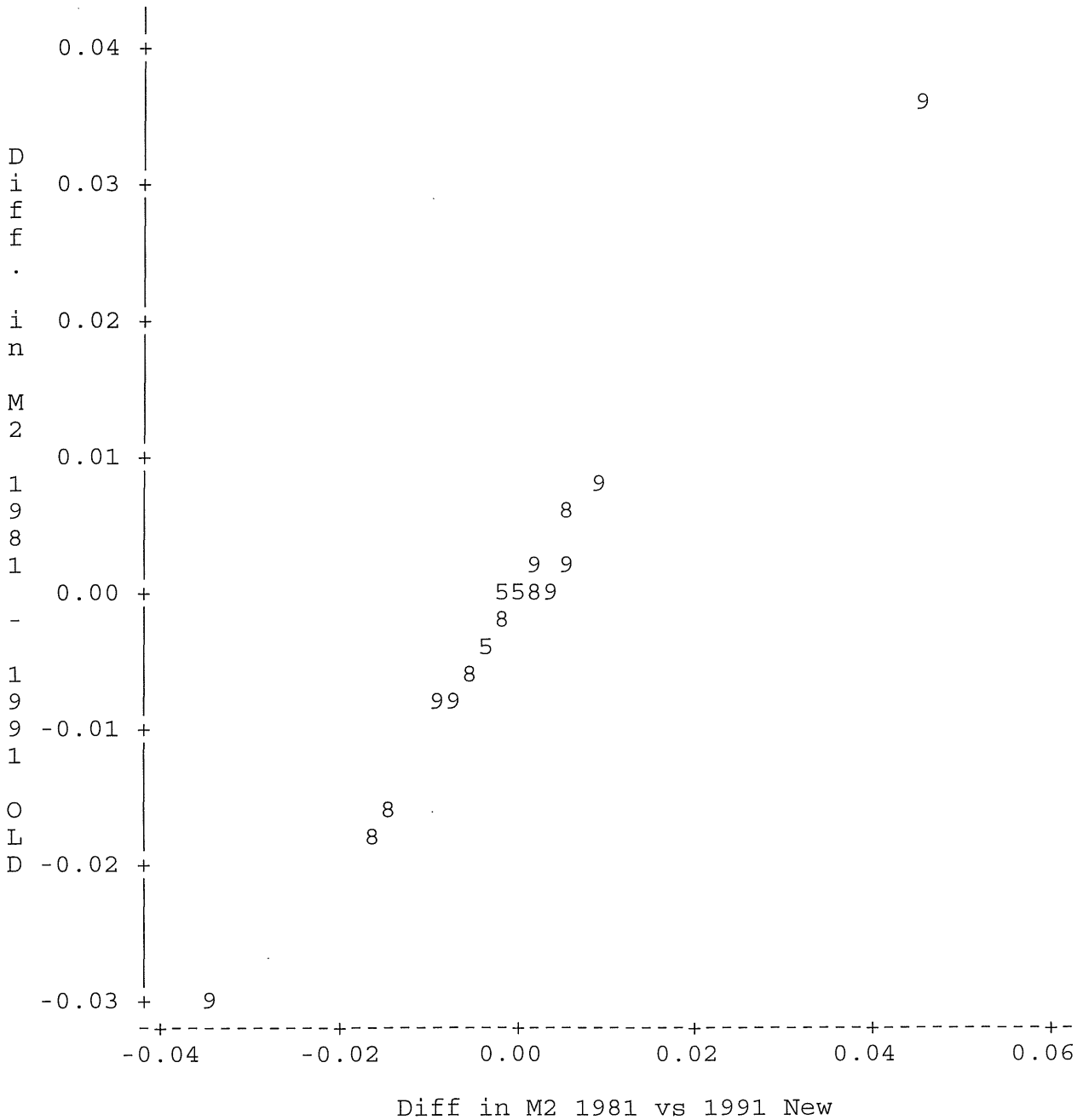
NOTE: 247 obs had missing values. 319 obs hidden.

Figure 6.2.5e Scatterplots of the differences between the PREDATION MORTALITIES (UM2's) estimated with only the 1981 data and the UM2's estimated with the new (x-axis) and old (y-axis) 1991 data. Haddock as predator. Codes as in Figure 6.2.4.

Change in M2 81-91old vs change 81-91new 13357
 12:30 Monday, June 26, 1995

----- PD=5 -----

Plot of DM890*DM89N. Symbol is value of PY.



NOTE: 236 obs had missing values. 118 obs hidden.

Figure 6.2.6a Frequency histograms of differences plotted in Figure 6.2.4, for each predator pooled across all prey. Series 1 uses old 1991 data; series 2 uses new 1991 data.

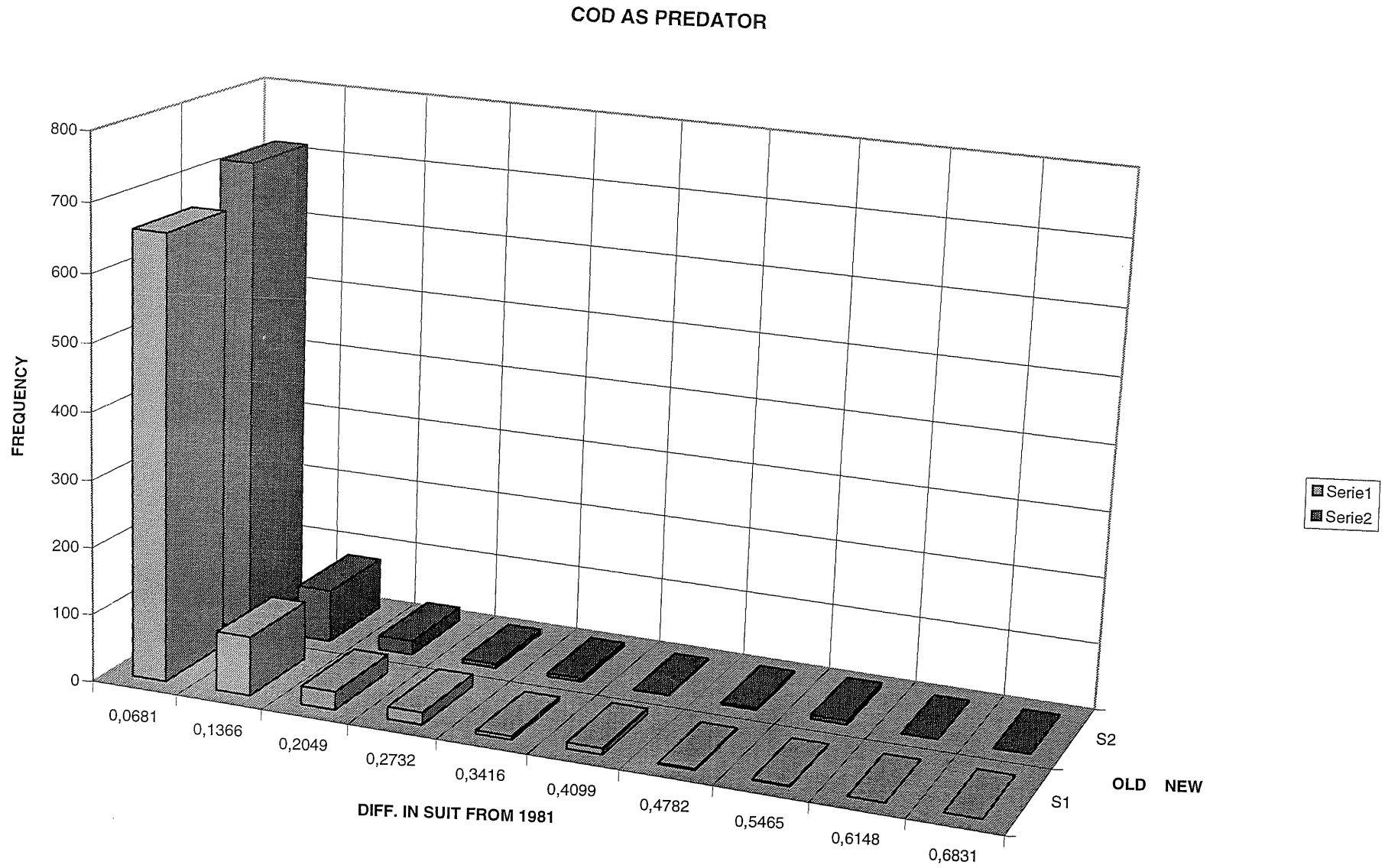


Figure 6.2.6b Frequency histograms of differences plotted in Figure 6.2.4, for each predator pooled across all prey.
 Series 1 uses old 1991 data; series 2 uses new 1991 data.

WHITING AS PREDATOR

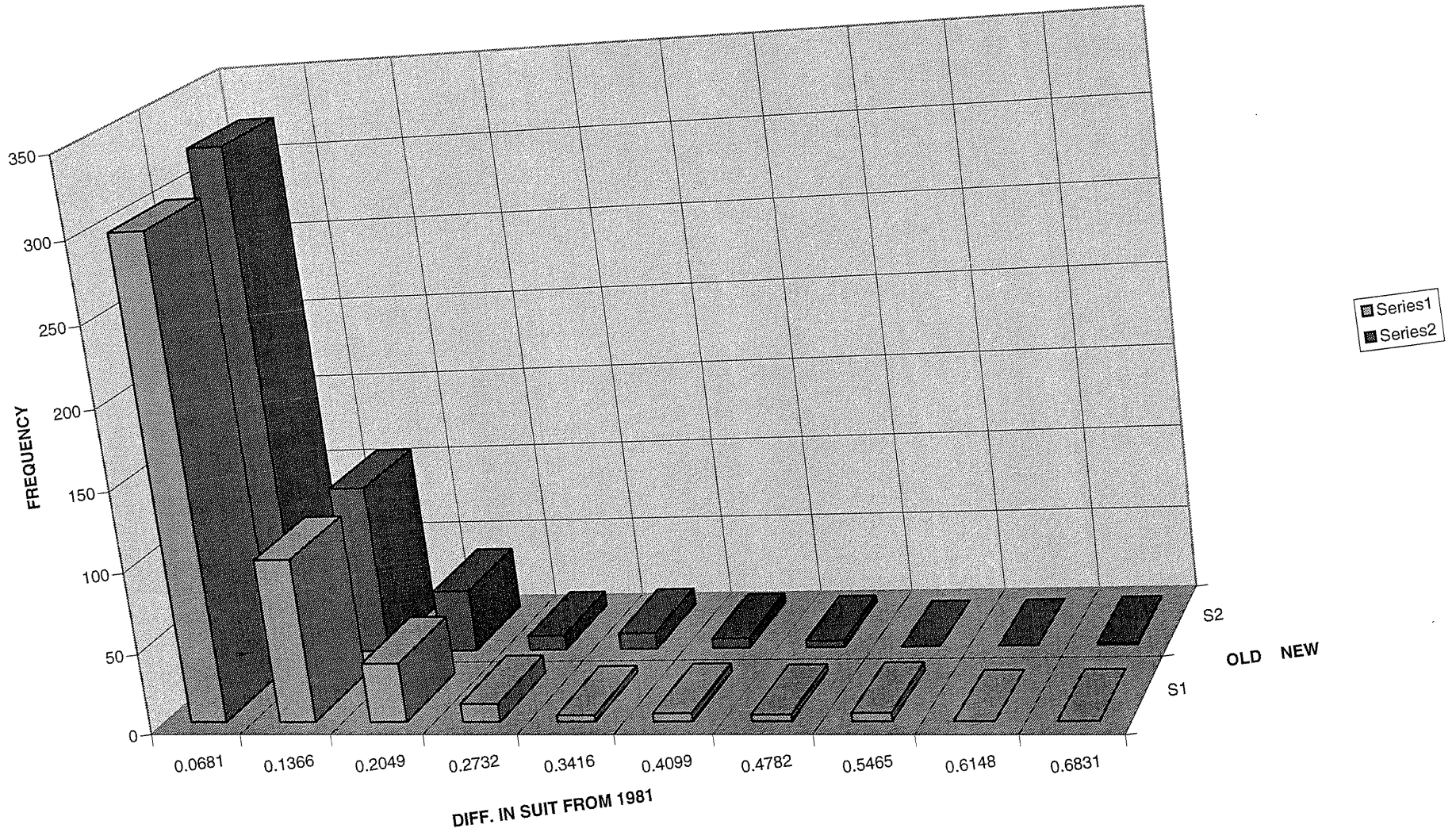


Figure 6.2.6c Frequency histograms of differences plotted in Figure 6.2.4, for each predator pooled across all prey. Series 1 uses old 1991 data; series 2 uses new 1991 data.

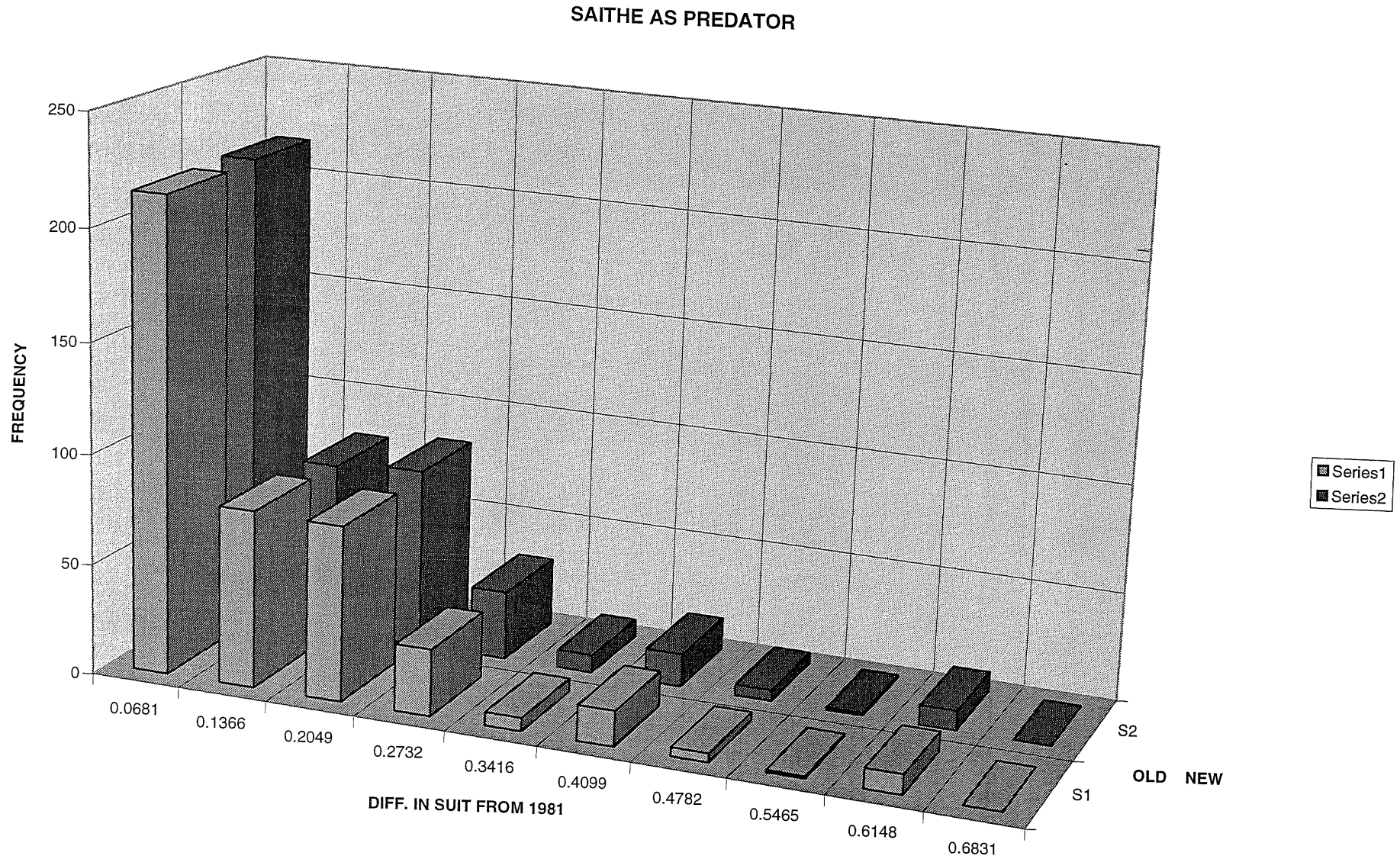


Figure 6.2.6d Frequency histograms of differences plotted in Figure 6.2.4, for each predator pooled across all prey. Series 1 uses old 1991 data; series 2 uses new 1991 data.

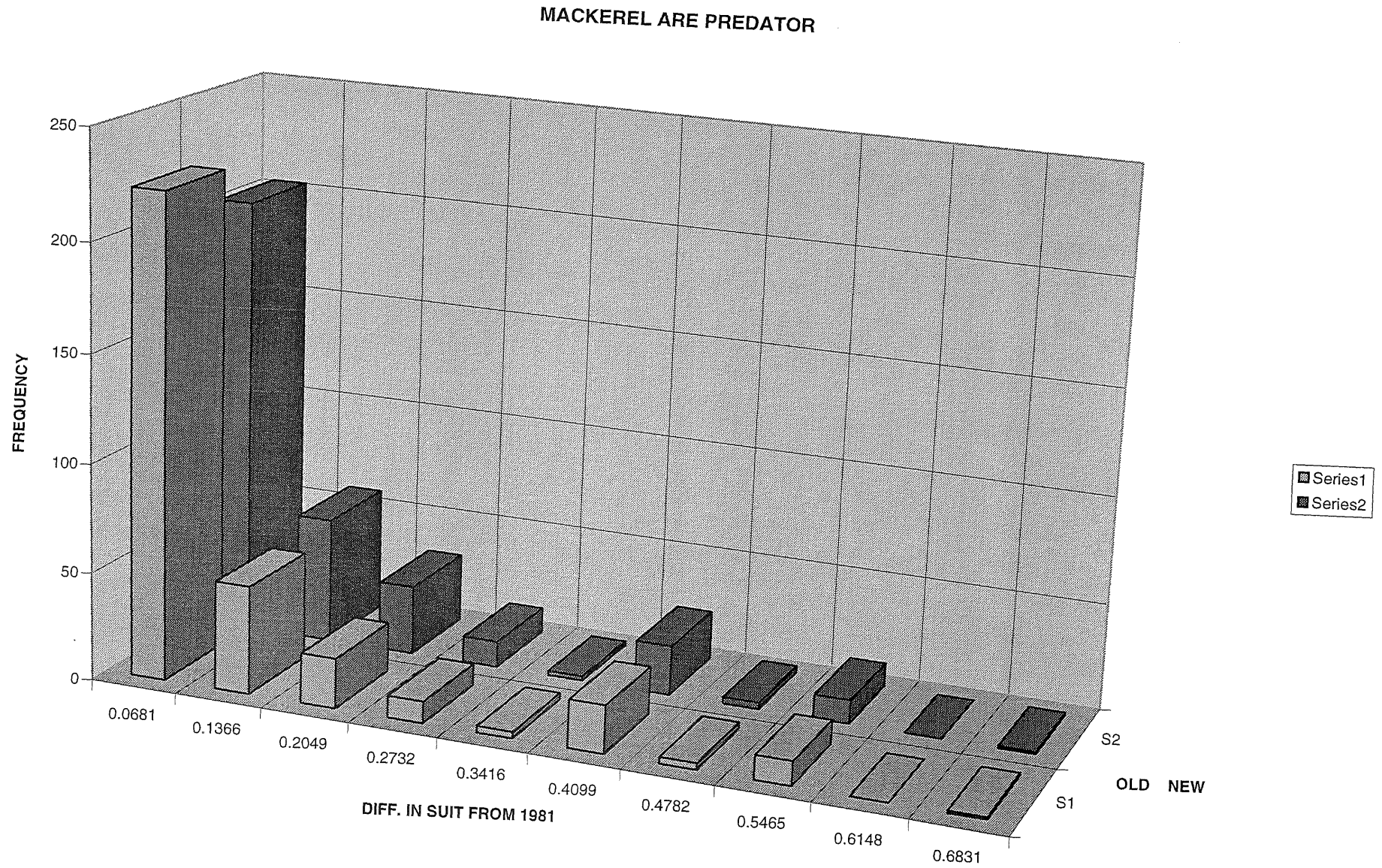


Figure 6.2.6e Frequency histograms of differences plotted in Figure 6.2.4, for each predator pooled across all prey. Series 1 uses old 1991 data; series 2 uses new 1991 data.

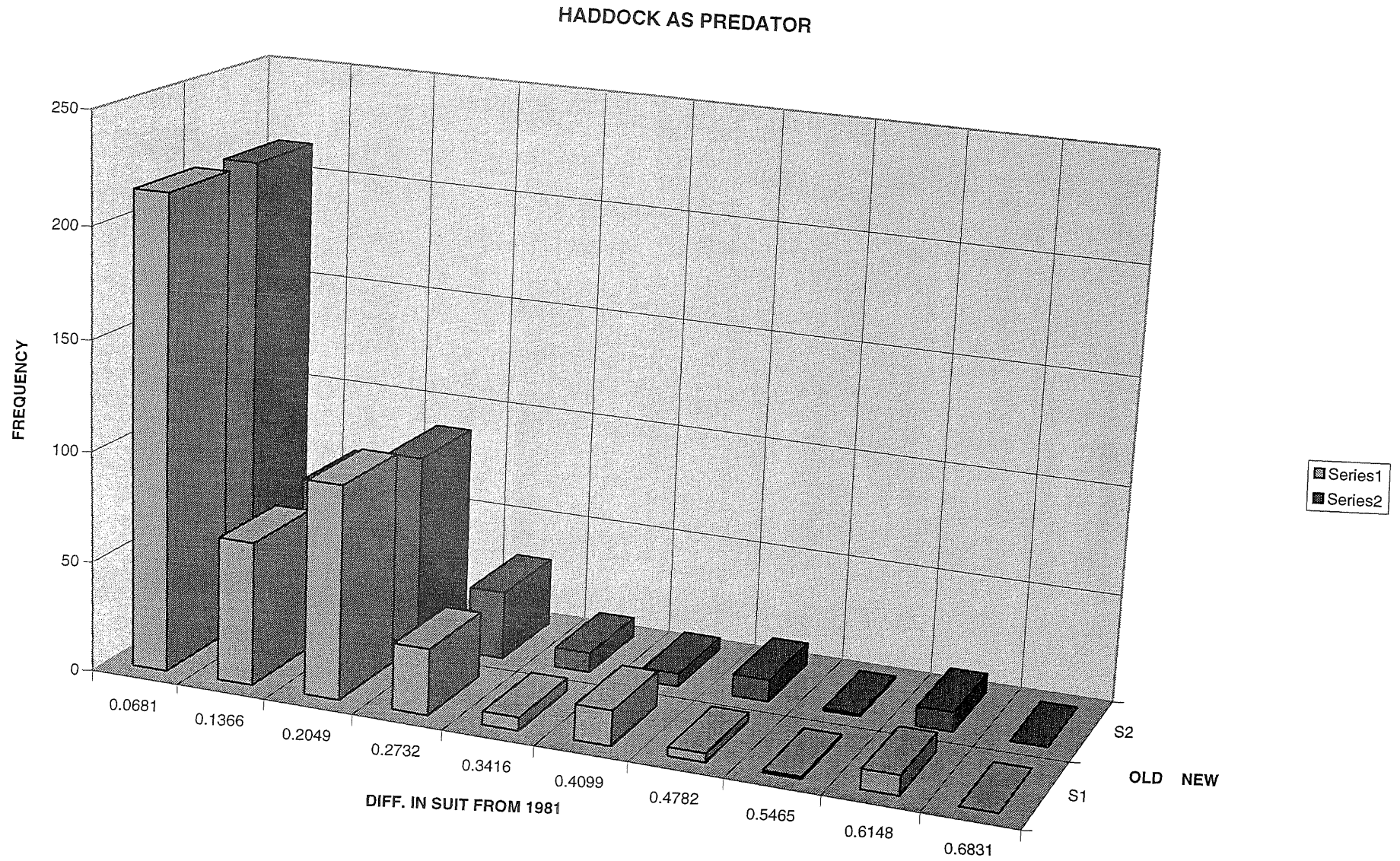


Fig. 10.2.1 - Cod Yield on Cod Effort

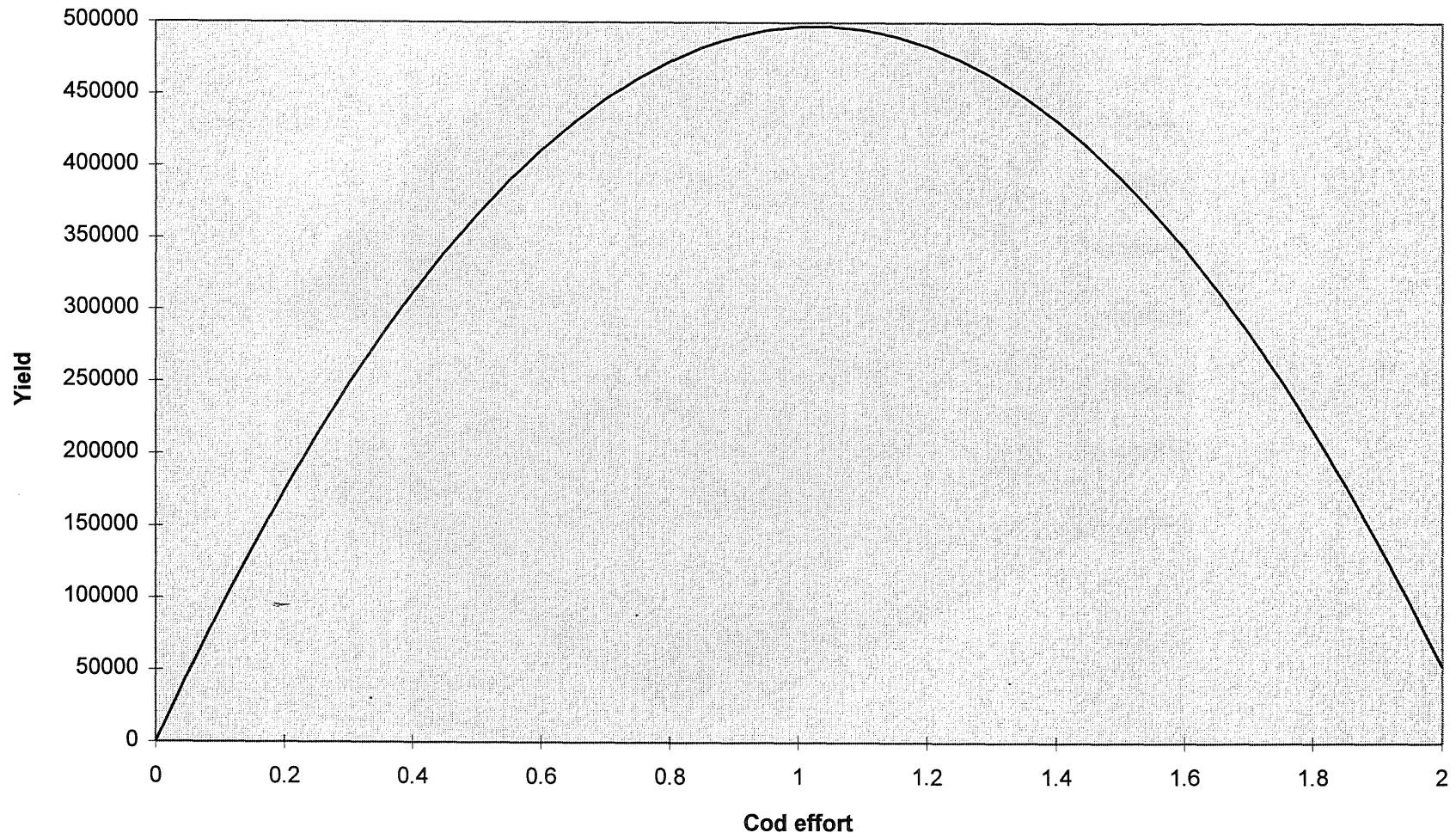


Figure 10.2.2 Capelin yield relative to cod and capelin effort

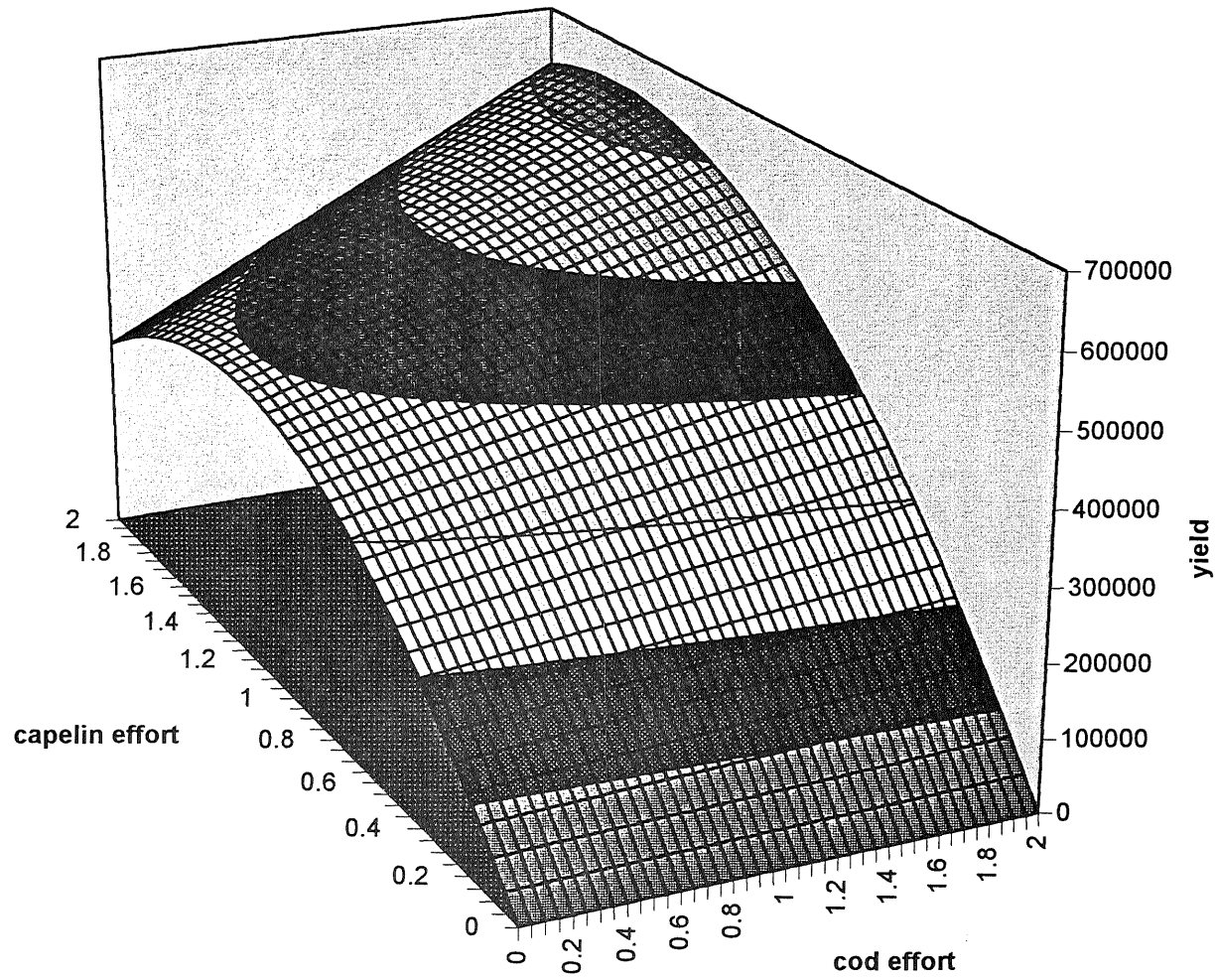


Figure 10.2.3 : Shrimp yield in terms of cod and shrimp effort

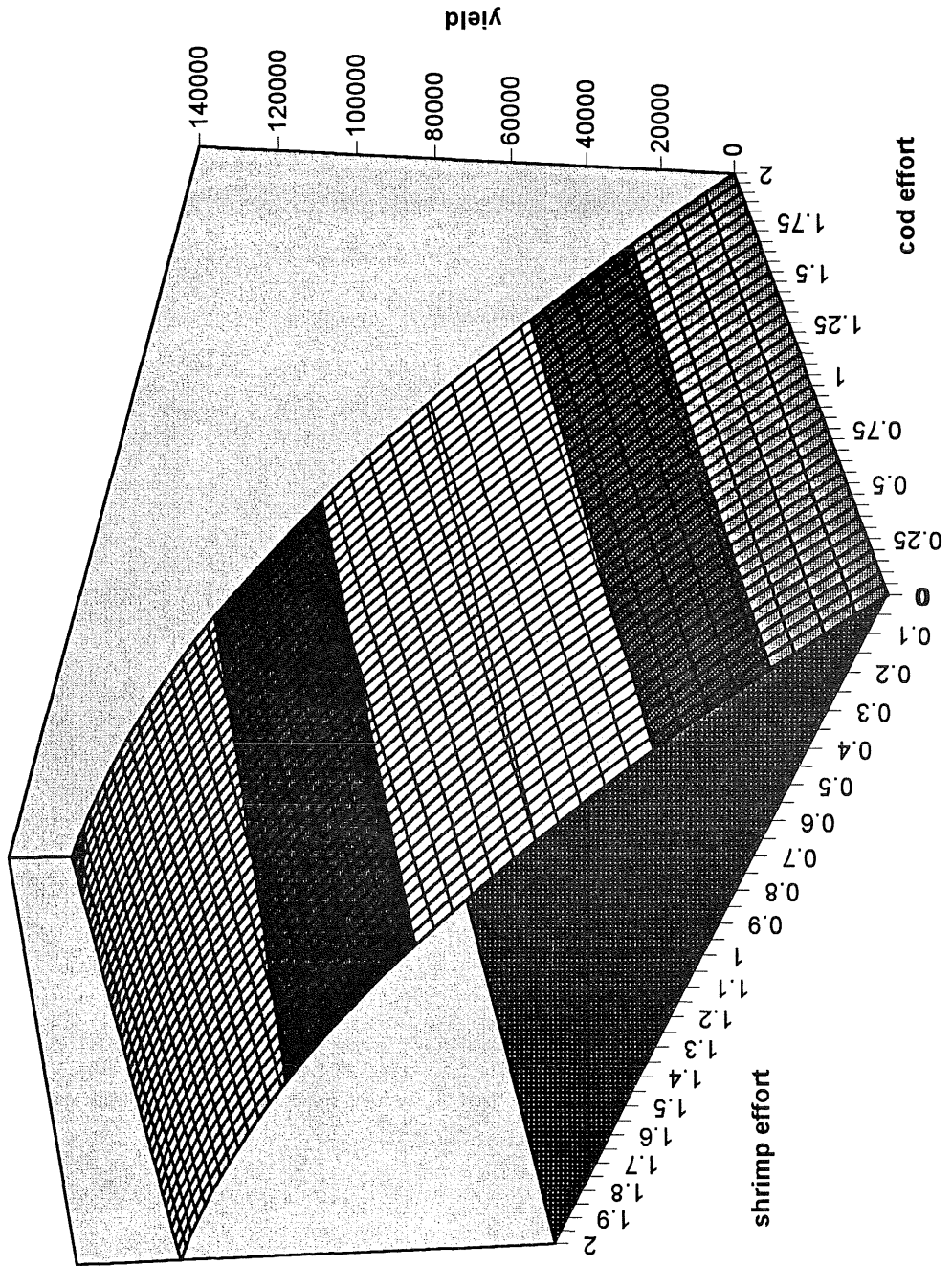


Figure 10.2.4 Herring yield as a function of cod and herring effort.

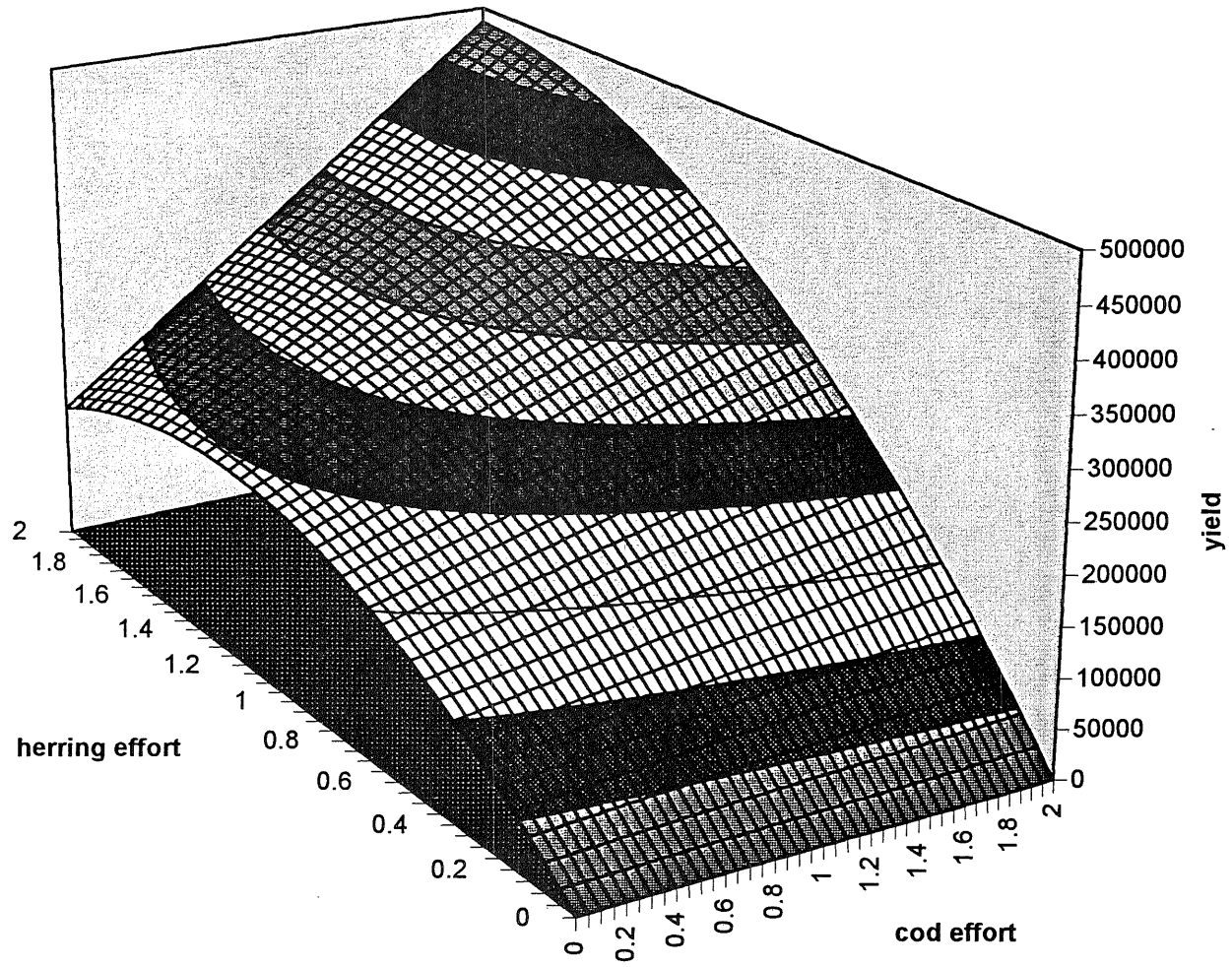


Fig 10.3.1 Summary of UM2 values for capelin by cod in season 1 (January to March), from the 3-area formulation of BORMICON, plotted as a function of biomass of cod as predator.

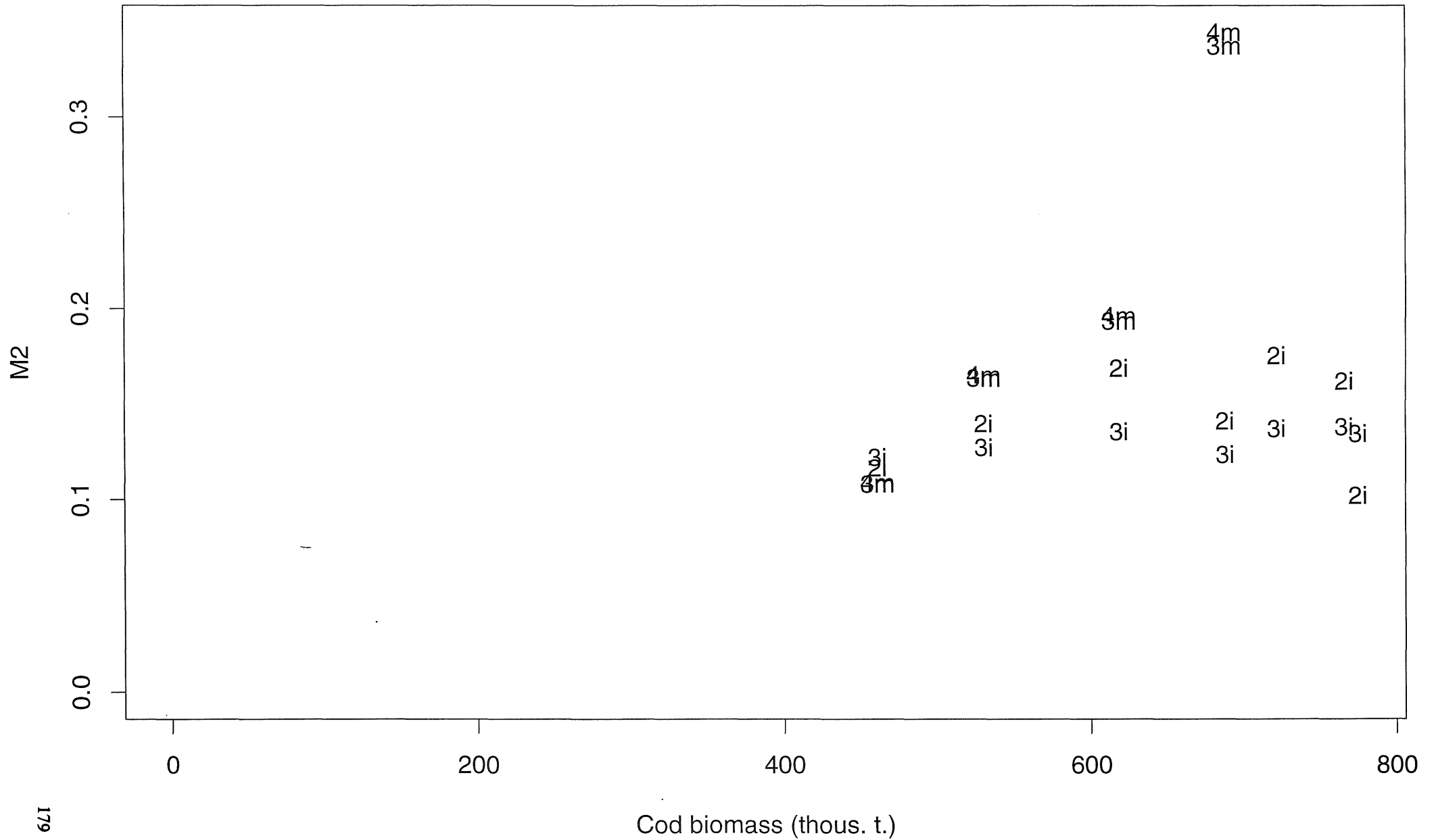


Fig 10.3.2 Summary of UM2 values for capelin by cod in season 2 (September to December), from the 3-area formulation of BORMICON, plotted as a function of biomass of cod as predator.

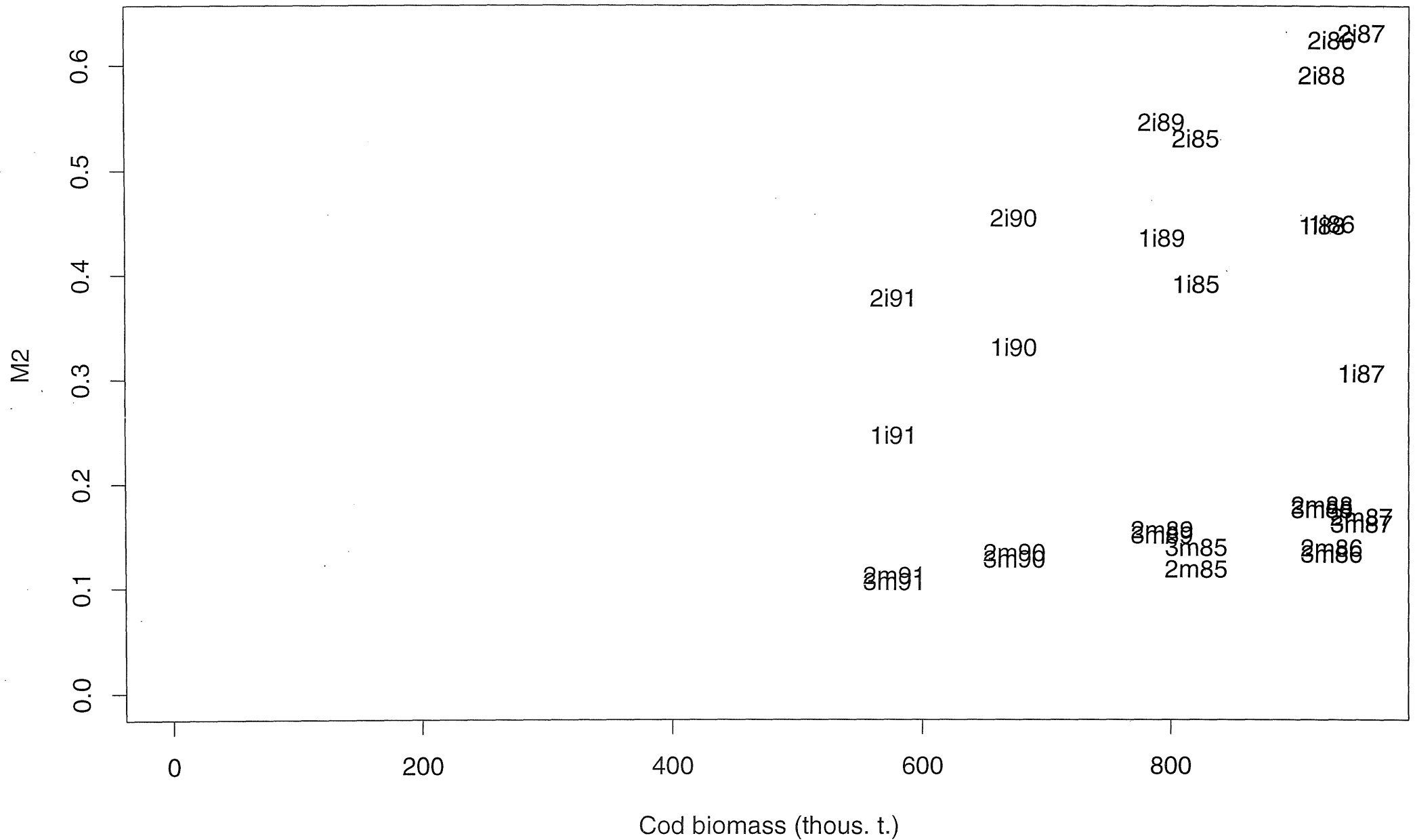


Fig 10.3.3 Summary of UM2 values for capelin by cod in season 1 (January to March), from the Estimation run formulation of BORMICON, plotted as a function of biomass of cod as predator.

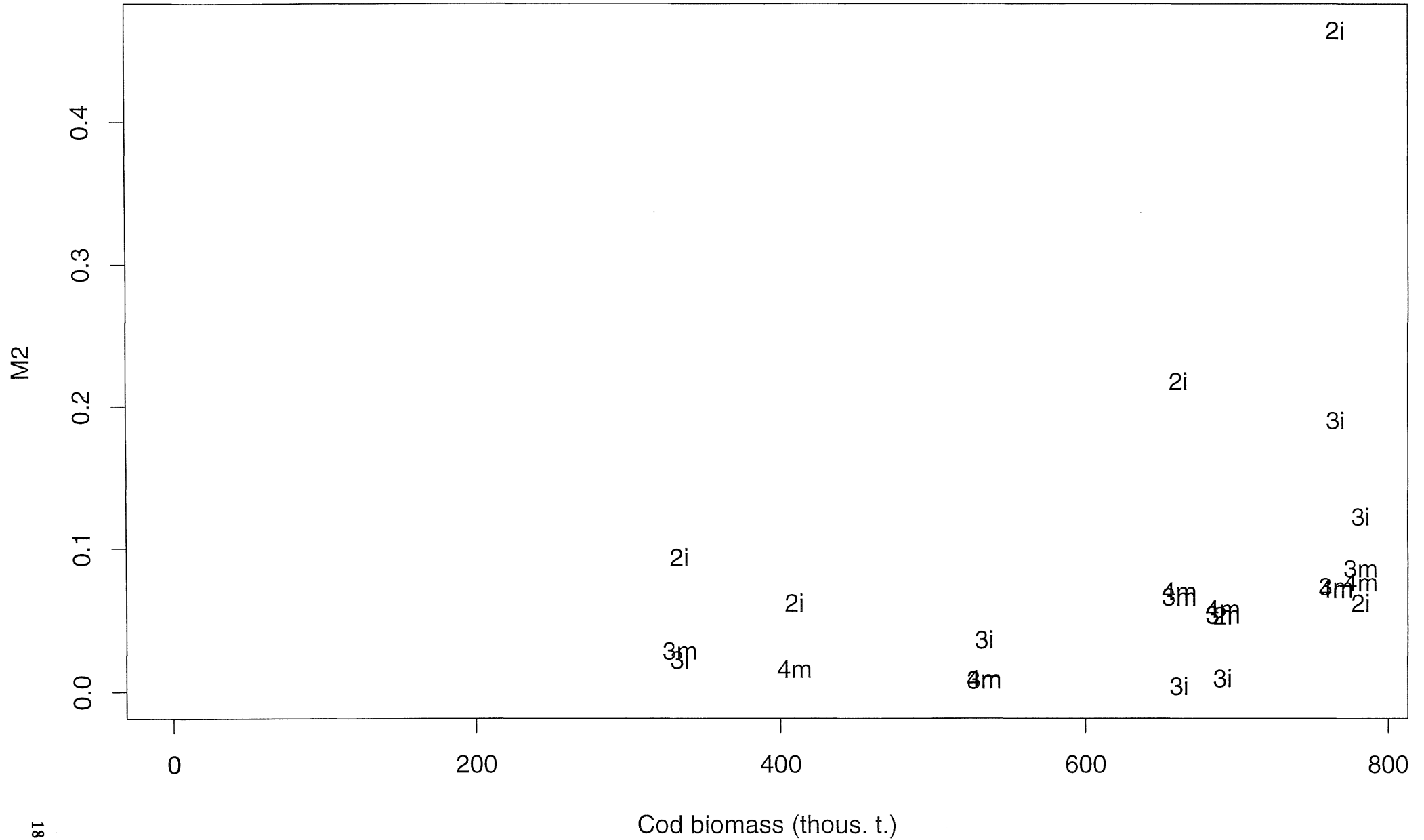
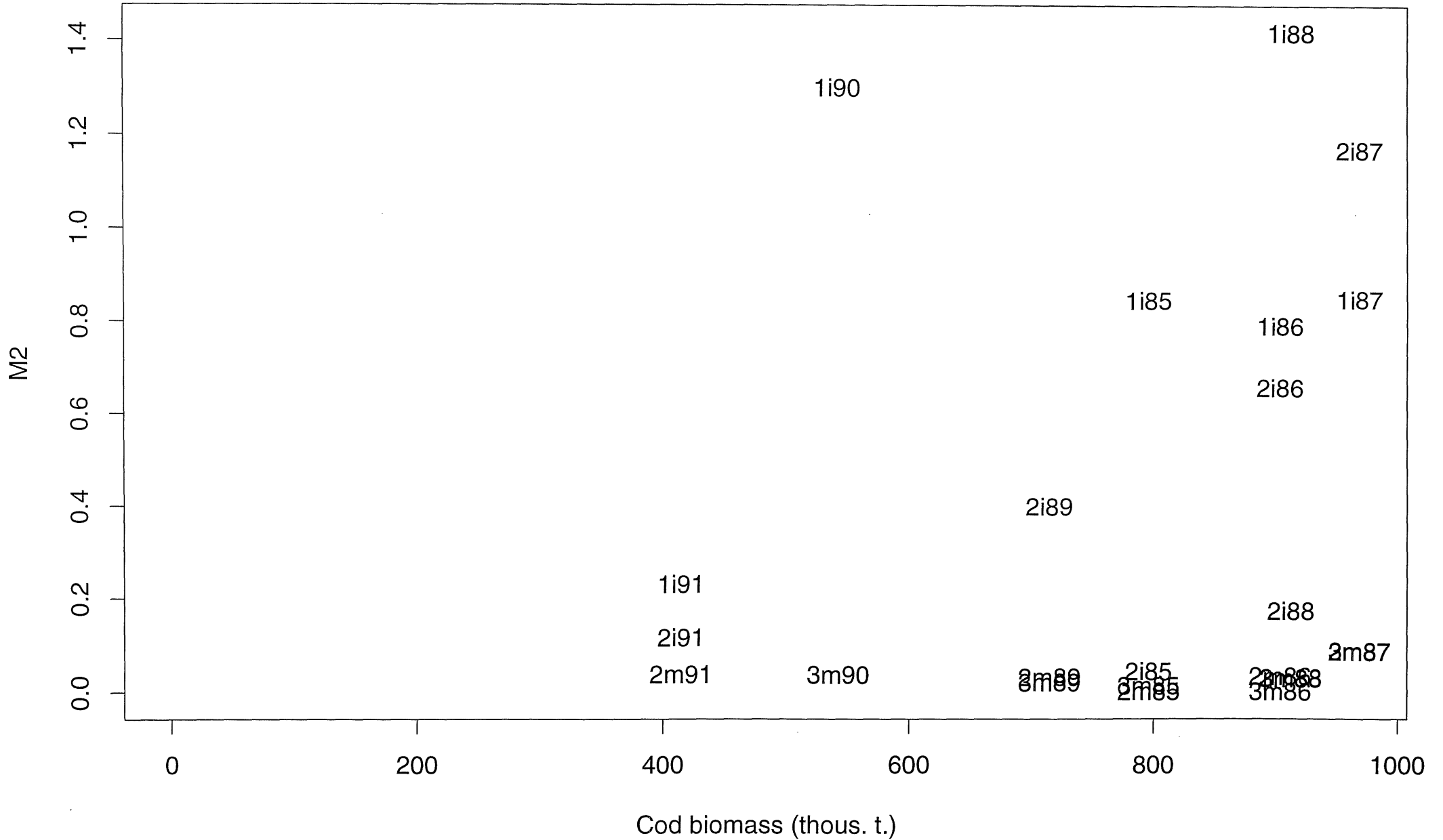


Fig 10.3.4 Summary of UM2 values for capelin by cod in season 2 (September to December), from the Estimation run formulation of BORMICON, plotted as a function of biomass of cod as predator.



APPENDIX 1

CHARACTERISTIC	MULTSPEC	BORMICON	MSVPA/MSFOR
Number of species	Fixed - 3 (option of including marine mammals as well)	Flexible	Flexible, 11 for North Sea, 3 for Baltic, 4 for Barents Sea
Area divisions	Data prepared for 7 areas	Data prepared for 16 areas, only 13 used	No area divisions in present MSVPA/MSFOR
Time step	One month time step for all calculations but predation can be calculated with smaller time steps	One month time step for all calculations but predation can be calculated with smaller time steps	Quarterly time step for all calculations
Stock structure	Single stock for cod and herring but immature and mature substocks for capelin (substocks for herring when coupled to HERMOD)	Flexible number of substocks for each species, e.g. age, sex, maturity etc.	No substocks
Stock divisions	Numbers and weights by age and length	Numbers and weights by age and length and substock	Age (with fixed weight and maturity at age) structure
Catch	Age dependent fishing mortality	Length dependent "predation" by fishing fleet or age (and length) dependent catch in numbers	Age dependent fishing mortality
Food for plankton feeders	Constant annually, but varies seasonally within area density dependent effect on capelin and herring growth	Not available in Icelandic data. Growth of capelin read from an external file	Not modelled
Other food for predators	Constant annually, but varies seasonally within area, calculated from stomachs	Varies annually and seasonally within area read from an external file	Constant
Temperature	Varies annually and seasonally within area, read from external file	Varies annually and seasonally with area, read from and external file	Not used
Migration	First order Markov transition matrix, probabilities for mature capelin estimated from stomach data, other probabilities from external file	First order Markov transition matrix, all probabilities from an external file	Not modelled at present
Growth	Growth in length and weight calculated separately, length vector updated in time step by increment for each length group determined by consumption, spread of lengths not modelled	Growth in length and weight calculated separately, length vector updated in time step by distribution of increments for each length based on consumption, i.e. spread of length is modelled	Constant
Residual natural mortality (M1)	Constant annually, age dependent	Constant annually, age dependent	Constant annually, age dependent
Maturity	Proportion mature at length determined once a year, modelled for capelin only, estimated from survey data	Proportion becoming mature at age and length determined in each time step	Constant annual maturity at age by species for calculating spawning stock size
Spawning	Modelled for cod and capelin only, predetermined spawning areas, no capelin post spawning survival	Predetermined spawning areas, survival and weight loss after spawning modelled	Not modelled
Recruitment	Stock-recruit relationship for cod and capelin, herring from external file (stock-recruit relationship in HERMOD)	Treated as immigrants, number of age 3 cod read from an external file	Estimated in MSVPA. Constant or stochastic recruitment around mean in MSFOR. Some experiments with stock-recruitment relationship carried out.
Immigration/emigration	For herring only	Immigration for all stocks allowed	No immigration (visiting predators can be included)
Consumption	Consumption determined by feeding level, parameters estimated from stomach data, maximum consumption dependent on temperature and weight (Jobling)	Consumption calculated from feeding level, length of predator and temperature (Jobling)	Constant consumption, feeding level not modelled
Suitabilities	Length based suitabilities, input from external file with some interpolation where necessary	Length based suitabilities input from external file, or suitability functions utilized	Quarterly age based suitabilities calculated iteratively from VPA numbers at age and stomach contents

