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REPORT OF THE PLANNING GROUP ON MULTISPECIES ASSESSMENT OF BOREAL SYSTEMS

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International Council for the Exploration of the Sea

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TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 Participants 1
1.2 Terms of Reference 1

2 MODELS OF BOREAL SYSTEMS 1
2.1 Objectives in Multispecies Modelling in Boreal Systems 1
2.2 Identification of Relevant Models and Present State of the Models 2

3 COMPARISONS OF MODELS 3
3.1 Brief Description of the Models 3
3.1.1 MULTSPEC and related models 3
3.1.2 BORMICON 3
3.1.3 MSVPA/MSFOR 4
3.1.3.1 Present form of MSVPA/MSFOR 4
3.1.3.2 Boreal MSVPA/MSFOR 5
3.2 Comparisons Between the MULTSPEC and BORMICON. 5

4 TESTS OF THE MODELS AND EVALU-ATION OF MODEL PERFORMANCE 6
4.1 Specification of Tasks 6
4.2 Definition of Base Run 6
4.3 Tests 7
4.4 Evaluation of Model Performance 7

5 INPUT - OUTPUT 7
5.1 Input 7
5.2 Output 8

6 SUMMARY AND RECOMMENDATIONS 9

7 ACKNOWLEDGEMENTS 10

8 REFERENCES 10

APPENDIX 1 - Status of Newfoundland research on multispecies assessment methods 11

1 INTRODUCTION

The group met at the Institute of Marine Research in Bergen, Norway, on 24 -27 January 1995. The main task of the group was to specify, plan and organise work on boreal multispecies models to be carried out in advance of, and at the meeting of the Multispecies Assessment Working Group in Bergen from 21 - 28 June.

1.1 Participants

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1.2 Terms of Reference

The Terms of Reference (C. Res. 1994/2:6:7) for the meeting were:

a) identify multispecies models to be examined by the Multispecies Assessment Working Group in their June 1995 meeting, and make the necessary arrangements for those programmes to run on computers which will be available at that meeting;

b) examine the structure of the models identified in a), clarify their structural similarities and differences (including how common processes, such as growth and food selection are represented) and develop strategies to allow them to operate in ways as similar as possible. The strategies might include allowing modules of different models to be interchanged, allowing outputs of one model to be used as inputs to other models, etc.;

c) establish explicit criteria on which the performance of the models will be evaluated, including, where appropriate, sensitivity tests, robustness trials and statistical tests of parameter estimates, forecasts, or hindcasts, and prepare for software to be available to conduct the necessary tests at the June meeting of the Multispecies Assessment Working Group;

d) report to the Multispecies Assessment Working Group;

2 MODELS OF BOREAL SYSTEMS

2.1 Objectives in Multispecies Modelling in Boreal Systems

In order to ease the discussion, the Group defined three kinds of uses for multispecies models.

1. A simulation tool, a model to mimic "reality" and to provide insight into the system and also to answer "what if" questions. An estimation part which uses data to obtain values of parameters used in simulations, might be included. A stochastic component is desirable.

2. A model to obtain parameter estimates which can be used as input in other management procedures or to provide direct or indirect management advice. Such models will in general be a parsimonious and very simplified representation of the real world with few parameters to estimate. This type of model together with control rules forms a management procedure.

3. System model (operating model) to use as a representation of the real system. Used to generate data for testing management procedures (cf. the operating model used by the International Whaling Commission to test proposed management procedures, see Kirkwood, 1992). The management procedures should be tested under a variety of assumptions about the "correct" functional forms of the various processes modelled. It is therefore not necessary to get these forms and their parameter values "precisely right". Such a model must necessarily include a stochastic component in the data-generating procedure.

A type 1 model is the first step; i.e. a model run whose output "makes sense". It can include parameter estimation e.g. by maximum likelihood, but this is not essential. In fact all of the parameter values can be assumed or guessed. The objective with this type of models is to provide a realistic representation of the real world. Outputs e.g. in the form of parameter estimates from models of this type could conceivably be used in management procedures of type 2.

It was also agreed that a multispecies system model (i.e. a model to test management models of type 2) was of great importance. MULTSPEC is closest to reaching the state where it can be used in this capacity, but considerably more work on stochastic data generating procedures are required. This may indeed turn out to be the most important use of elaborate and complex multispecies models like MULTSPEC.

The question of how multispecies and single species assessments and advice can be compared is of great importance and the superiority of multispecies advice over single-species advice needs to be demonstrated at some stage if spending a great deal of effort on multispecies models is to be justified. A possible approach is the use of a system model to test the performance of management procedures, both single species procedures and procedures based on multispecies concepts. This might also give ideas of how strong interactions must be for a multispecies approach to show a clear superiority.

There are certain properties which boreal models must have. The Group did not have time to come up with an exhaustive list, but some necessary characteristics were recognised. Primarily, variable consumption and variable growth, must be included. Furthermore, area structure is an essential feature, i.e. the inclusion of migration to explain variations in spatial overlap. At some stage it will be useful to define all the desirable properties and features which boreal models should have.

There are some notable differences between boreal systems and temperate systems. The former has fewer biological components; a large part of the diet consists of a few key prey species (in particular capelin), and the "reservoir" of other food is probably smaller than in temperate systems, such as the North Sea where MSVPA has found its primary application. Thus "other food" as defined in the MSVPA and used there as a buffer to ensure that fish always obtain the required amount of food, is only available to a much lesser extent in boreal systems. This means that consumption per fish is more variable and consequently so is individual growth.

Another important difference between the two types of systems is the variability in the environment, which is much greater in boreal systems. This entails the necessity of including some environmental variables, temperature being the minimum requirement. Initially, the values of these variable should not be modelled, but the values read from an external file.

In general, the number of fleets and their diversity is smaller in boreal systems. Modelling the fishing operations should therefore be easier and in addition, management strategies easier to implement as there are fewer participants.

2.2 Identification of Relevant Models and Present State of the Models

At present there are two principal boreal models:

1. MULTSPEC. Work on this model has been going on at the Institute of Marine Research in Bergen for some years. It is a forward simulation model which contains a part for estimating parameters using maximum likelihood methods. The model includes the following species: cod, capelin, herring, harp seal and minke whale. It has area structure, using migration matrices, consumption of food is calculated and cod growth also. The model is now running with tentative migration matrices. MULTSPEC is a type 1 models, i.e. it is intended to "mimic reality", but it also estimates some parameters which can be used in giving management advice.

2. BORMICON (BOReal MIgration and CONsumption model) is being developed at the Icelandic Marine Research Institute. This work is now at the stage where programming has more or less been completed whereas preparation of data has not. Every effort will be made to have a running model ready by the time of the MSAWG meeting in June, concentrating on cod capelin interactions, migration of both species and cod growth. Eventually a part for estimating parameters will be added, but this will not be done by June. The first version of BORMICON is a type 1 model.

   The group agreed that the primary emphasis should be on fish-fish interactions. Inclusion of modules with marine mammals should be born in mind though, but work should concentrate on the former to begin with.

   In addition to the above, the group identified the following models which have been developed for boreal systems or can potentially be applied to such systems.

3. CAPSEX and AGGMULT. Both are simplified versions of MULTSPEC and can act as multispecies models in their own right.

4. MSVPA/MSFOR. There are some problems associated with applying the present ICES version to boreal systems. For example, capelin, the main prey species, is short-lived and has almost total spawning mortality, and therefore not suitable for VP analysis. Acoustic abundance estimates are available however, and these estimates should be utilised. Possible modifications to deal with this are discussed in 3.1.3.2. The Planning Group agreed that it was important to continue with developments of MSVPA and the possibility of extending it to include variable consumption as well as migration should be investigated. The use of MSVPA to calculate suitabilities which can then be used in other models might also be investigated.

   It was reported that work is being carried out at VNIRO in Moscow on applying the MSVPA for the Barents Sea. Not much is known about how this work is progressing, but is was recommended that IMR in Bergen contact the relevant persons. Attendance of somebody from the Russian group at the WG meeting in June was encouraged.

5. The "Stefánsson" model (Stefánsson *et al;* 1994) is primarily a model for investigating harvesting strategies and can therefore be classified as a system model, i.e. a model of the third kind. Interactions between cod, capelin and shrimp are modelled; cannibalism in cod is accounted for, growth of cod is

modelled using empirical equations linking growth to the size of the capelin stock. Natural mortality of capelin varies in some accordance with the size of the cod stock and predation of shrimp by cod is modelled using a biomass model.

6. ECOPATH II. Some initial work on applying this steady state model to inter-relationships between fish species off West Greenland has been carried out in Denmark (Pedersen, 1994). Work on steady-state bulk biomass model for the West coast of Newfoundland and Labrador Shelf is also underway and a preliminary working paper was tabled at the 1993 Multispecies Assessment Working Group meeting (Shelton, P.A. and G.R. Lilly. 1993).

Although all these approaches are relevant, it was felt that for the purpose of focusing the work and discussion at the MSAWG meeting in June, that the primary emphasis at the meeting in June should be on MULTSPEC and BORMICON. It is essential for the success of that meeting that running versions of at least one model, preferably both, be available at the meeting. Some time should also be devoted to considering possible boreal extensions of MSVPA / MSFOR.

3 COMPARISONS OF MODELS

3.1 Brief Description of the Models

3.1.1 MULTSPEC and related models

The MULTSPEC model is a multispecies model for the Barents Sea, where the stocks are divided on area, age, length and sex. The stocks modelled are cod, capelin and herring. Only a part of each year class of herring stays in the Barents Sea and it lives there only until it becomes 3-4 years old. Therefore, the herring is not modelled with its full stock dynamics in MULTSPEC, rather each year class is exogenously entered into the model. In addition, minke whales and harp seals are modelled. The marine mammals are not divided on length. The migration is modelled using transition matrices between the 7 areas in the model. The predation is modelled using a feeding level function and monthly area distributed stomach content data for estimation.

The MULTSPEC model has been used to study the subsystem mature capelin --- cod, which involves the processes maturation of capelin, migration of mature capelin and predation from cod on mature capelin. In this system the parameters have been estimated from data, where a reduced set of migration matrix elements have been estimated year by year using the geographical distribution of capelin in the cod stomachs.

Two simpler models have been derived from the MULTSPEC model. The CAPSEX model is the area aggregated capelin part of the MULTSPEC model with a length-aggregated cod stock. In the CAPSEX model, the influence of herring on the capelin recruitment is modelled through its effect on the Beverton-Holt stock-recruitment half value. The primary use of CAPSEX is to estimate capelin maturation parameters, although it may serve as a multispecies model on its own. The AGGMULT model is an area and length aggregated version of the MULTSPEC model, designed as a versatile tool in a national research programme where biology is linked to the economy of the fishing fleet.

Separately from MULTSPEC an area distributed herring model --- HERMOD --- has been constructed. This model describes the stock dynamics of herring and the migration through its whole life cycle, where migrations across the Norwegian Sea to overwintering areas near Iceland is a possibility. 16 areas are used. Rather than expanding MULTSPEC the two models are coupled by file communication to one Norwegian Sea --- Barents Sea multispecies model. MULTSPEC can thus be used in two different ways, either as a standalone model with exogenous input of 0--group herring or as model with endogenous herring in the coupled version. For a more detailed description see Bogstad, Tjelmeland, Tjelta and Ulltang, 1992.

3.1.2 BORMICON

BORMICON is a multispecies forward simulation model that is being developed and programmed at the Icelandic Marine Research Institute.

It is designed for simulation of interactions between stocks that can be divided into sub-stocks with a uniform pattern of behaviour and whose abundance numbers and mean weights can be kept by age and length..

BORMICON is designed to allow for agreed 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 temperatures are also all read from an external file.

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.

For simulation the interactions between cod and capelin in Icelandic waters, one might divide the cod stock into the following sub-stocks:

Immature cod age 3-8 years; mature cod age 4-12 years and the capelin stock into:

Immature capelin, age 1-3 years; mature capelin, age 2-4 years.

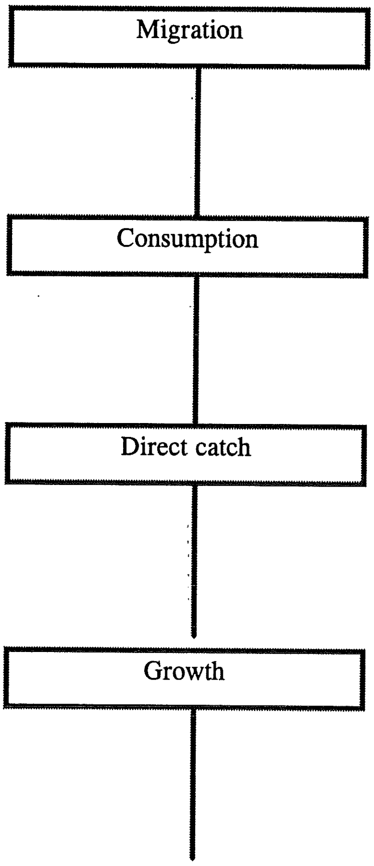
An even better division of the capelin stock is:

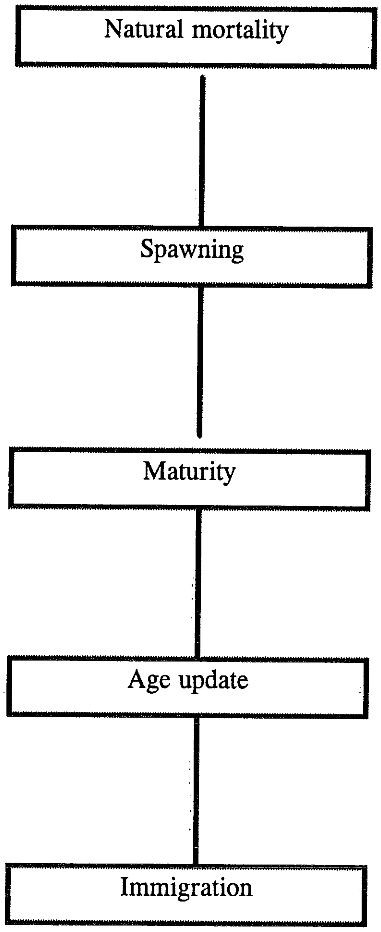
Immature capelin, age 1-3 years; mature male capelin, age 2-4 years; mature female capelin, age 2-4 years,to account for the differences in growth between male and female capelin.

In addition to the sub-stocks, the other entities in the model are fleets and "other food". The fleets predate in the same way as the predating sub-stocks, and have suitabilities for the preys.

"Other food" is another group of prey, in addition to the sub-stocks, that is preyed upon. This approach allows the predators to have a certain suitability for it and allows for more than one kind of "other food" to be included.

The simulation flow chart is :





Major component not included in the simu where this is done separately for each area. The only lation is a spawning stock - recruitment relationship. At present the recruits are introduced as immigrants and information on them is read from an external file. A working paper describing BORMICON was available at the meeting (Stefánsson, 1995).

3.1.3 MSVPA/MSFOR

3.1.3.1 Present form of MSVPA/MSFOR

This multispecies model was developed throughout the 1980's and has been the backbone of the modelling work of the Multispecies Assessment Working Group up till now. The development has primarily been directed towards the North Sea system, but the model has also been applied to the Baltic system for some years.

The MSVPA/MSFOR consists of two parts, the MSVPA which performs an historic analysis of catch and stomach data, and the MSFOR which predicts the future development of the stock using information from the MSVPA. In the present context, the boreal prediction models are best compared with the MSFOR, while the MSVPA can be regarded as an estimation module. In this respect it has some resemblance to the use of e.g. the

MULTSPEC for parameter estimation although there is a fundamental difference since the parameters in MSVPA are computed in a backward process, and not by estimating parameters by comparing predicted results with observations.

The MSVPA is basically a VPA for each species, starting with input terminal F's for each year class cohort. However, the natural mortalities include predation mortalities. The computation of predation mortalities is based on suitabilities, which are computed in the MSVPA from the relative prey species composition in the predator stomachs, and the VPA derived abundances of the prey stocks, leading to an iterative process. The suitabilities are assumed to be constant over the years, thus only one year's stomach data is needed. In the MSFOR, each cohort is projected forwards in time according to the mortalities. The predation component of the natural mortalities is computed using the suitabilities from the MSVPA and the current stock numbers. New cohorts are introduced as recruitment numbers (constant or stochastic with a given distribution). The fishing mortalities are usually taken from the MSVPA. Several fleets can be included, each characterised by its partial fishing mortalities.

The only interaction between the species is through the selection of food by predators. The total amount eaten by each predator individual is assumed to be constant. To ensure sufficient food a large amount of "other food" is assumed. This is in accordance with the experience from the North Sea where shortness of food does not appear to be a problem for the predators. Growth is not modelled. In the present version no migration is implemented. Thus, the assumption of constant suitabilities includes an assumption that the geographical overlap between predator and prey remains unchanged from year to year. The models operate on a quarterly time scale.

Only species for which there are catch at age data can be fully included in the model. However, there is an option to include "visiting predators", the abundance of which is not modelled, but which contribute to the predation mortality. It would be possible to include a "visiting prey" in a similar way, but this is not implemented at present.

3.1.3.2 Boreal MSVPA/MSFOR

The question has been raised on several occasions whether it would be feasible to adapt the MSVPA to the boreal systems. The following is an outline of how this could be done for the Barents Sea.

The stocks to be included should be cod (predator and prey), capelin (prey) and herring (prey). Capelin and herring have two things in common: They disappear abruptly from the system at some age (capelin because it dies after spawning, herring by emigration when it reaches mature age), and there is virtually no fishery except for the spawning capelin. Thus, assessing these stocks by a VPA is not feasible.

The most promising alternative seems to be to input both as a "visiting biomass" quarter by quarter, without attempting to model the dynamics of these stocks within the MSVPA or MSFOR. Since these species are included in the stomach data, and their biomasses are "known", their suitabilities as food for cod can be computed by the standard procedure used in the MSVPA. A by-product will be the computed consumption of these prey. In MSFOR, by using the suitabilities and input biomasses, the consumption of these prey can be predicted.

For cod, the MSVPA/MSFOR will in practice constitute a single species assessment, except for the predation mortality for the youngest cod. This will only affect cod which has not yet recruited to the fishery, however.

Thus, the main achievement of applying the MSVPA to this system will be an alternative way of estimating suitabilities. Moreover, since stomach data are available for every year, the stability of the suitabilities can be studied. In addition to generating suitabilities using different sets of stomach data, a useful exercise may be to compare the estimated consumption of prey with that underlying the input prey biomasses.

In order to do this, the MSVPA/MSFOR must be modified to include "visiting prey". The biomasses of capelin and herring will most likely have to be generated using MULTSPEC or one of its derivatives for capelin and some model based on acoustic data for herring.

3.2 Comparisons Between the MULTSPEC and BORMICON.

A comparison between the way the various characteristics and variables are handled in the three models is presented in Table 1.

The simulation parts of the two models primarily under consideration, MULTSPEC and BORMICON are very similar with respect to how the processes are modelled, since BORMICON has essentially adopted the MULTSPEC modelling approach. Therefore there are good arguments for aiming towards a generic boreal multispecies model. However, in view of special features in each region, for example different kinds of data, it is probably necessary that the estimation part of the model be case specific. The simulation part of the model can be generic. Since BORMICON, is more recent, it has made use of new programming techniques (object orientated programming) and its flexibility is greater. Thus, adopting the BORMICON code for a generic boreal seems an attractive possibility. However, it was felt that for the time being at least, the developments of the two models should be separate.

It was recognised that there are still many open questions regarding the estimation part in the models, and in fact there is at present no estimation part in BORMICON and will not be added before the June meeting. Working papers relating to the estimation part of MULTSPEC will be presented for discussion at the meeting in June.

A table giving a comparison between MULTSPEC, BORMICON and MSVPA/MSFOR is at the end of this report.

4 TESTS OF THE MODELS AND EVALUATION OF MODEL PERFORMANCE

4.1 Specification of Tasks

MULTSPEC and BORMICON can be thought of as consisting of two parts, an estimation part (cf. MSVPA) and a simulation part (cf. MSFOR). The difference from MSVPA/MSFOR is that both parts are done in forward mode. There will be little scope to do tests involving the estimation part during the June meeting. Any such runs must be completed prior to the meeting.

It was agreed that the following task must be completed by June.

To get MULTSPEC and BORMICON to run on Barents Sea data and Icelandic data respectively, for cod and capelin (migration of both species, consumption and growth of cod modelled). Cod cannibalism should be included.

In addition, both models should be run on the same data set (Barents Sea, Iceland or both). This task has a lower priority, and it may not be possible to complete it in time.

It is necessary to define a base run, i.e. the set of parameters values, functional relationships and data to be used in a scenario run (simulation). The output of this run will be the reference against which the output of sensitivity runs will be compared. Some of the parameter values (e.g. elements of the migration matrices) will be ad hoc or intelligent guesses (the majority in the present version of BORMICON) and some will be estimated or calculated in a fully specified manner (MULTSPEC).

Any parameter estimation must be done prior to the meeting in June. The set of parameters will then be available on a file so that participants can do further runs with different values (sensitivity /robustness tests). Runs involving parameter estimation should be the exception at the meeting (but not completely excluded). Therefore, the main emphasis at the meeting in June should be on scenario runs, not estimation runs.

It must be possible to evaluate the output in some empirical way; past history can be simulated (inputting known recruitments) and observed and calculated values of for example growth, abundance, consumption, compared. The group did not come up with specific evaluation criteria, but this needs to be done eventually.

4.2 Definition of Base Run

A) The components are cod and capelin and the following processes will be modelled: migration of both species, predation, cannibalism and growth of cod. Growth of capelin will be modelled in MULTSPEC, but read from an input file in BORMICON.

B) Values of non-estimated parameters are to be selected by the respective groups developing the models and reported in appropriate working documents.

C) Functional relationships are as in present versions of both models and will be documented in the description of the models.

D) Estimation of parameters. Applies only to MULTSPEC at present (note that stomach data from the Barents Sea exists from 1984 and capelin acoustic abundance data from 1972).

For MULTSPEC, two base runs are required for the June meeting, including only cod and capelin. The first run will be based on parameters estimated from the entire set of September capelin acoustic estimates and cod stomach content data for the 1972 to 1994 period. These parameter estimates will then be used to run the model forward from 1972 as a starting year.

A second run should also be carried out in which the parameters will be estimated from the fit of the model to the 1972-89 data. This run is in fact a sensitivity trial, since the purpose is to compare the values of estimated parameters with those estimated using the whole data series, as well as comparing with observed values in 1990-94. There will therefore be two sets of parameter estimates.

The simulated data will be used for the detailed comparison of modelled variables with observed variables. The same simulated data will be used for a series of sensitivity trials in which the output of the base run will be compared with the output from a run in which one or other of the parameters have been altered. In some cases where parameters that are highly correlated, this requires that if a parameter is changed in a sensitivity trial, the correlated parameters will have to be re-estimated from the historic data used for the base run. This latter work will be carried out in advance of the meeting by the MULTSPEC group.

4.3 Tests

The models can be tested by two types of tests:

I. Performance tests: Compare simulated output to actual observations, i.e. retrospective predictions.

II. Sensitivity/robustness tests: Vary parameters and functional relationships and look at the effect on the output (estimated parameter values and/or simulated trajectories). No reference to a real system needed for this type of test. The output should be compared to the simulation results from base run with parameters estimated from complete data set.

The following is a tentative list of the sensitivity trials which the group came up with:

1. Change order of events in the models (e.g. switch order of predation and removal of catches).

2. Change length of time steps, calculate predation for shorter time steps than a month.

3. Explore different feeding functions (specification to come later).
4. Perturb migration matrices or use different migration matrices which nevertheless give "reasonable" behaviour.

5. Use a bias parameter (set a fixed value, e.g. 1.5) for abundance estimation of capelin in MULTSPEC. Reestimate parameters and compare to base run parameters and base run simulation.

6. Include herring in the Barents Sea.

7. Change area structure. This is difficult to do in MULTSPEC, but is easier in BORMICON because of the flexible modelling approach adopted there. Aspects such as the number of areas can be altered, e.g. use one or two areas instead of 13 which is the default number. The purpose with this test is to investigate the importance of the area structure.

The following test was also suggested as being of possible interest for MULTSPEC: Get stability and then decrease capelin abundance. Then observe what is the increase in consumption of other prey. The question of interest here is: Can the model capture the observed lack of compensation i.e. small increase in the consumption of other prey when capelin consumption falls (Anon., 1992)?

4.4 Evaluation of Model Performance

Adequate time must be set aside in the June meeting for a thorough evaluation of the strengths and weaknesses of MULTSPEC, BORMICON and MSVPA/MSFOR for modelling boreal ecosystems. The primary focus should be on the ability of these models to behave in a manner which is sufficiently similar to the behaviour of the real systems. Important insights into the behaviour of the models can be obtained by comparing modelled cod growth and feeding to the sample data bases that have been subject to detailed empirical analysis at two previous Multispecies Assessment Working Group meetings. In addition, the ability of the models to adequately represent the migration and maturation of capelin from the information in stomach data and from acoustic surveys needs to be carefully examined. Analyses of model output with respect to feeding level parameters (maximum consumption and biomass at half maximum consumption) and spawner stock-recruitment should be revealing as well.

Evaluation of some of the output from the model will require software to be prepared prior to the meeting. For example, evaluation of the modelled migration of mature capelin estimated from the stomach data could be carried out using an animation program based on the estimated migration probability matrix. Further the animation program could be used to aid in generating alternative probability transition matrices, e.g. by speeding up migration between certain areas at certain times.

It is envisaged that the some of the parameters will be available for "playing around with" at the meeting in June. A list is given in the following section.

As regards tests of performance (i.e. how well the simulated values approximate observed values) comparisons of calculated and observed stomach content is not possible at present. In estimation procedures, comparisons are made between consumption calculated in the model and consumption calculated from stomach data using a digestion model. Similar comparisons can be made when evaluating performance. One can for example use first 10 years of data to estimate parameters (migration matrices etc.) and then simulate next 10 years and compared calculated values to "observed" values of consumption. If comparisons between observed and calculated stomach contents is desired, then it is necessary to transform the consumption calculated in the model into stomach content via a model of feeding behaviour and a digestion model. This is not a trivial exercise.

5 INPUT - OUTPUT

5.1 Input

For the sake of convenience, the input was separated into three groups:

1. Fixed parameters and parameters where setting up runs with a different value involves considerable work (e.g. number of areas and perhaps migration matrices). In general these will be fixed in runs made during the meeting in June.

2. Parameters, functional relationships etc. which can easily be altered in runs made at the June meeting.

3. Input data (data for initial year, time series of recruitments, etc.).

As discussed above, there will be little scope at the June meeting to carry out runs involving parameter estimation or runs which require retuning of the models.

In general, the following will have to be fixed and can not be changed for runs made during the meeting:

- The area division can in general not be changed, but it may be possible to run MULTSPEC on one area and BORMICON on or two areas.

- Changing the number of age and length groups will not be possible in MULTSPEC, but may be possible in BORMICON.

- It will not be possible to change the input data.

The following features (data, parameters, functional relationships, settings) can be changed in runs made during the meeting:

- Time period for runs (BORMICON will have a fixed starting year) MULTSPEC will always start at October 1

- Temperature (for runs into the future) (will affect growth and feeding only)

- Maximum consumption, feeding level function (type II/type III), suitabilities, other food

- Maturation parameters

- Fishing mortality and fishing pattern

- Selected migration parameters

- Residual natural mortality

- Growth parameters/functions

- Stock size scaling factors

- All processes can be turned on and off.

5.2 Output

MULTSPEC and BORMICON will use the same output format.

It should be possible to obtain output at the same level of disaggregation as the programs work, but this may not be feasible due to restrictions on file size and computer time.

The most disaggregated levels of output, which will probably be used only in very special cases, are

1. State of stocks (number and weight by area, age, length and time).

2. Predation (including catch) data (number/biomass consumed by age and length of predator and prey, by area and time).

In most cases, one will want to aggregate these data to some level. In particular, it will in many cases be desirable to aggregate the output over length groups. Thus, outputs showing the length distributions will be optional.

Two standard output files were agreed upon; state of stocks file and predation file. Both files are ascii files with explanatory text in the first line.

State of stocks file:

One file for each substock (or aggregation of substocks)

On each line, separated by spaces

Year - month - area - age - number - mean length - mean weight - st. dev. of length - number caught - total number consumed

All numbers indicate status at the end of the month.

Units:

Stock number : million
Individual weight - kg
Length : cm
Year, month, area and age as represented as integers, the rest as real numbers.

Predation file

One file for each predator substock - prey substock combination
On each line, separated by blanks:

Year - month - area - predator age - prey age - number consumed - biomass consumed - mortality induced

Input data should be made available on the state of stock-file format.

6 SUMMARY AND RECOMMENDATIONS

The initial goal in modelling boreal systems should be the construction of models which mimic reality and can provide insight into the behaviour of the system. There are at present two boreal models which have advanced some way along this path, MULTSPEC and BORMICON.

The main attention at the MSAWG meeting in June, should be focused on these two boreal models, but working papers on boreal extension of MSVPA/MSFOR are also encouraged. A necessary condition for the meeting to be productive is that running versions of the two models (or at least one of them) are ready at the meeting, together with the output from a number of runs carried out in advance of the meeting and ready for analysis. The main objective therefore, is to get MULTSPEC and BORMICON to run on Barents Sea data and Icelandic data respectively, for cod and capelin (migration of both species, consumption and growth of cod modelled). Cod cannibalism should be included. The next step is to get one or both models to run on the same data set, but some uncertainty remains whether this can be achieved in time for the June meeting.

Some parameters are estimated in MULTSPEC, but BORMICON does not yet contain an estimation part (but will in the future). Due to time limitations, all runs requiring parameter estimation must be carried out in advance of the June meeting. Therefore runs made during the meeting will be scenario runs, not requiring parameter estimation.

A base run i.e. specification of components, processes modelled, functional relationships, parameter values, input data etc. is specified. The output of this run will be the reference against which the output from other runs will be compared. Evaluation of the models can be made by comparing output to historical data and by investigating the sensitivity of the output to the assumptions made. Some suggested sensitivity test are given in this report.

Detailed specification of the evaluation of the performance of the models in terms of defining output statistics and specifying performance criteria must be addressed in the future. This was discussed at the planning meeting and a number of ideas aired, but detailed specification remains a task for the future. This is likely to be an interactive process, as the output from various runs is analysed.

Testing and evaluation of the models will be a very long process. The experience of the IWC when developing and testing management procedures can be cited in this respect. This process took a number of years, with new evaluation criteria being constantly suggested and further tests developed as the results become available and were analysed (Kirkwood, 1992).

A number of recommendations and suggestions were put forward by the planning group.

1. The group encourages the participation at the meeting in June of those who are working on other approaches to boreal multispecies models e.g. people working on multispecies models applied to Greenland waters and Russian scientist working on MSVPA for the Barents Sea.

2. Necessity of having another workshop on stomach evacuation rates in view of recent work and developments.

3. The group recommends the presentation of working papers on results of simultaneous sampling of stomachs and prey abundance and presentation of plots of cod length vs. capelin length in stomach (for assessing suitability values). Empirical work on suitability should be presented at meeting.

4. The group wants to draw attention to existing tagging data which can be useful in determining the elements in migration matrices.

5. The main emphasis at the planning meeting was on applying MULTSPEC or BORMICON to the Barents Sea and Iceland. However, the group recommends that when a generic model is being developed, application to Newfoundland should be considered. However, limited data might be a problem and therefore, improvements in the database are encouraged. A report of the status of Newfoundland research on multispecies assessment methods is given in the Appendix.

6. Detailed documentation describing the two models (both technical description and conceptual overview) must be made available. This description must incorporate the estimation procedures used in the models. Working papers describing the aggregated output of the base run are also necessary.

7. The group wants to emphasise the importance of people coming prepared to the meeting. Therefore it recommends that the documentation describing the two models should be distributed prior to the June meeting.

8. Evaluation of some of the output from the model will require software to be prepared prior to the meeting. For example, evaluation of the modelled migration of

mature capelin estimated from the stomach data could be carried out using an animation program based on the estimated migration probability matrix. Further the animation program could be used to aid in generating alternative probability transition matrices, e.g. by speeding up migration between certain areas at certain times. This will be looked into by the IMR in Bergen.

Further developments - some suggestions.

1. Inclusion of more species. Shrimp, polar cod and marine mammals are primary objects for consideration.

2. Investigate the possibility of reverse simulation in a MULTSPEC- like model in obtaining parameter values.

7 ACKNOWLEDGEMENTS

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Appendix. 1

Status of Newfoundland research on multispecies assessment methods

Although multispecies considerations have influenced management of fish stocks on the east coast of Newfoundland and Labrador shelf for some time, no attempt has been made to build a multispecies assessment model. The cod fishery is presently closed, but when it reopens there would be considerable interest in predicting cod weights at age from prey abundance for use in projections, provided the predicted weights can be demonstrated to be better estimates than the currently used mean weights. Similarly, there is interest in attempting to improve the current single species assessments of capelin by replacing average survival rates used in projections with survival rates predicted from predator abundance, consumption and diet. Again it would be necessary to demonstrate that using the predicted survival rates is better than using averages. Such rather stringent requirements are discussed further in Shelton (1992)

Our ability to construct multispecies models for Labrador-Newfoundland is constrained by data limitations and uncertainty regarding the dynamics of the stocks and the nature of their interactions. An important data limitation is the inadequate seasonal sampling of cod stomach contents; time-series exist only for the seasons during which groundfish bottom-trawl surveys have been conducted, viz. autumn on the southern Labrador Shelf (NAFO Divisions 2J and 3K) and spring and autumn on Grand Bank (Division 3L). There is also uncertainty regarding capelin stock structure and change in capelin abundance over time.

Current research on cod-capelin interactions is focusing on empirical analyses of cod stomach content data in relation to prey (e.g. Lilly 1994, Fahrig et al. 1993). Work is planned to look at the relationship between abundance of capelin in cod stomachs and cod growth in terms of weight, extending the analyses done at the 1990 and 1992 Multispecies Assessment Working Group meetings. Preliminary results may be available to table at the June meeting.

In addition to cod-capelin interactions, there is considerable interest in the possible effect of the apparently increasing harp seal population on the recovery of the collapsed cod stock. The population dynamics of harp seals is being modelled and the consumption and diet determined. Further analyses to consider the possible impact of this magnitude of consumption on the recovery of the cod stock are likely to be extremely speculative. There is increasing acceptance that to provide insight into this kind of problem requires the construction of a "minimal realistic model" (Anon 1991). This model is then exercised under a wide range of feasible parameter values and assumptions to look for predictions that are robust to the prevailing levels of uncertainty. Of primary importance is the ability to predict the direction of an effect. Predicting the magnitude of the effect would be the next step. For example, the intuitive prediction that removal of seals from the system will increase the potential yield of cod may not be a robust conclusion. Because the minimal realistic model includes other predators of cod and other prey of seals, it is quite feasible that certain parameter values and assumptions lead to the prediction that removal of seals may decrease the yield of cod. The usefulness of the minimal realistic model approach, suggested in Anonymous (1991) has recently been explored in some detail in the context of the fur seal-hake interaction in the Southeast Atlantic by Punt (unpublished report).

Recent increased harvests of shrimp and crab off Newfoundland and Labrador coinciding with the decrease in groundfish stocks is also of considerable interest. However the ability to build predictive models of these interactions is likely to be much more severely hampered by data limitations than models of cod-capelin interaction.

In addition to multispecies models for predicting effects, there is some interest in Atlantic Canada in using a multispecies simulation model as an "operating model" or artificial system on which the performance of alternative multispecies and single species estimation procedures can be evaluated. The approach (as outlined for example in Kirkwood 1993) is already being utilised to evaluate single species procedures (e.g. Gavaris 1994, Shelton 1994) although the operating models currently being used do not contain multispecies interactions. In this context it would be very useful if the requirements for a multispecies operating model for boreal systems could be considered in some detail in the June meeting. For example to what extent do parameters for such a model have to be estimated from the data, rather than assumed, if the purpose of the model is solely to reproduce reasonably realistic behaviour, rather than predict the value of any variable?

There is also some interest in building "speculative" models for guiding research programmes and for maintaining an overall system view of fishery assessment and management problems. Such models are assumption driven and have heuristic value irrespective of data limitations. For example, such models may demonstrate the possibility of counter-intuitive behaviour, broadening our understanding of potential responses of the system to management measures. A further multispecies modelling exercise that may be useful in Boreal systems, primarily for guiding research, is the building of a steady state bulk biomass model. Such a model is under development for the NAFO Division 2J3KL area. This model may indicate gross inconsistencies between consumption by predators and production by prey and thus indicate where more research is required. However, cases where production and consumption balance are not necessarily informative because the balance may arise out of incorrect assumptions or poor data.

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CHARACTERISTIC	MULTSPEC	BORMICON	MSVPA/MSFOR
Number of species	Fixed - 3 (option of including marine mammals as	Flexible	Flexible, 9 for North Sea, 3 for Baltic
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 predat can be calculated with smaller time steps	One month time step for all calculations but predat 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 herrin when coupled to HERMOD)	Flexible number of substocks for each species, e. age,sex, maturity etc.	No substocks
Stock divisions	Numbers and weights by age and length	Numbers and weights by age and length	Age (with fixed weight and maturity at age) structure
Catch	Age dependent fishing mortality	Length dependent "predation" by fishing fleet	Age dependent fishing mortality
Food for plankton feeders	Constant annually, but varies seasonally within ar density dependent effect on capelin and herring gr	Not modelled, growth increments for plankton fee read from an external file	Not modelled
Other food for predators	Constant annually, but varies seasonally within ar calculated from stomachs	Varies anually and seasonally within area read from an external file	Constant
Temperature	Varies annually and seasonally within area, read fr external file	Varies annually and seasonally with area, read from and external file	Not modelled
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 o increments for each length based on consumption, i.e. spread of length is modelled	Not modelled
Residual natural mortality (M1)	Constant annually, age dependent	Constant annually, age dependent	Constant annually, age dependent
Maturity	Proportion mature at length determined once a ye modelled for capelin only, estimated from survey	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 surviv	Predetermined spawning areas, survival and weight loss after spawning modelled	Not modelled
Recruitment	Stock-recruit relationship for cod and capelin, herri from external file (stock-recruit relationship in HERMOD)	Treated as immigrants, data input from external file of estimates from single species VPA	Constant or stochastic recruitment around mean, 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, param estimated from stomach data, maximum consump dependent on temperature and weight (Jobling)	Consumption determined by feeding level, maxim is temperature and weight (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	Age based suitabilities calculated iteratively from VPA numbers at age and stomach contents