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Report from a special meeting of the Multispecies Assessment Working Group

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1 Introduction.

1.1 Participants.

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H. Loeng	Norway
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S. Murawski	USA
O. Nakken	Norway
I-H. Ni	Canada
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G. Stefansson	Iceland
B. Stensholt	Norway
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K. Sølna	Norway
K. Tande	Norway
S. Tjelmeland (Convener)	Norway
Ø. Ulltang	Norway
L. Walløe	Norway
N. A. Øritsland	Norway

1.2 Terms of reference.

The terms of reference (C. Res. 1989/2:4:24) are:

To review progress in modelling multispecies interactions in boreal systems.

In the resolution the various national laboratories with specific interests in boreal ecosystems or in general aspects of multispecies modelling and management were urged to participate.

1.3 Background and objectives.

This special meeting of the Multispecies Working Group (MSWG) was proposed to address the desire of its menbers to expand the focus of the WG to include analyses of multispecies fishery problems outside of the North Sea area. The MSWG has, since its inception, strived to not only conduct specific

scenario analyses related to multispecies management (i.e., for the North Sea) but to develop and evaluate methodology of general applicability for such problems. An important consideration in this regard is the need to evaluate multispecies interactions as resulting from a series of processes which may be more or less important in any system. The MSWG has been committed to understanding the basic processes determining species and fishery interactions, and to developing appropiate indicators for comparing processes among multispecies ecosystems. In this regard, the MSWG has in the past, and continues to regard itself as primarily a methodology working group, which has purview outside specific ecosystems such as the North Sea.

Several modelling analyses related to boreal systems (e.g., Barents Sea, Iceland) have from time to time been presented at MSWG meetings in the past. Because of the fullness of the agenda, these analyses did not receive the full consideration and comment they deserved, nor was cooperative work in boreal multispecies ecosystems proposed within the ICES MSWG. Based on results presented at the 1988 and 1989 meetings of the MSWG, it was proposed that a special meeting of the WG be conducted specifically to evaluate the current state of boreal system multispecies research, and to determine the interest and scope of cooperative multispecies research in boreal systems that could profitably be conducted under the purview of the MSWG. The Institute of Marine Research in Bergen graciously proposed to host the meeting, with Dr. Sigurd Tjelmeland as convener.

The main objetives of the meeting were to provide background descriptions of important enviromental features and species interactions in three boreal systems (Barents-Norwegian Seas, Iceland, Newfoundland), review current and proposed multispecies modelling approaches used in the three boreal systems, and to determine if, and under what circumstances, cooperative work on these systems should proceed under the purview of the Multispecies Working Group. It should be noted that an additional boreal system, the Greenland region, was proposed as an important area to be considered in these evaluations.

Acknowledgments

The MSWG wishes to express its appreciation to the staff of the Institute of Marine Research for making its facilities available to the WG, and for the warm hospitality extended to the attendees.

1.4 Comments of the rapporteurs.

The main focus of the meeting was to overview the boreal systems, especially contrasting then with more temperate water systems such as the North Sea and Baltic, and to discuss appropriate modelling strategies for such systems. Accordingly, this report is structurally very different from previous reports of the MSWG (which must delight most readers). The report summarizes the lively and at times heated discussions by the meeting participants as to the philosophy of modelling and the expectations of products to be derived from modelling work. Rather than being a compilation of computer output and other 'facts', this report summarizes the overview presentations and mostly the opinions on various subjects expounded by the participants. This report was, of course, very difficult to compile, and the appreciation of the MSWG to the rapporteurs is expressed.

Nevertheless, the meeting concluded in an approach for further work that might provide a robust framework for joint advancement, and that is supportive of the work of the various national laboratories.

Also, in establishing some joint working community for arctic boreal areas we feel that it may be a longer way to go than previously thought. Thus, the meeting turned out to be useful in the sense that various levels of working experience and expectations could mingle.

In view of the somewhat verbal style of the meeting we have chosen to connect the various opinions and talks to the individual persons. The various points referred to in the report may look somewhat loosely connected. They are however, selected for the potential importance for modelling.

2 Overview of ecosystems.

2.1 Presentation of working documents/talks.

Overview of ecosystems: Environment.

Harald Loeng, IMR, presented an overview of the environment of the three areas, including topography, water volume, mean depth etc, and current system, water masses and temperature and salinity regimes. He then gave an overview of long term climatic variations in the three systems. In all three areas certain periods of positive and negative anomalies were demonstrated, both for temperature and

salinity. Finally he explained the atmospheric driving force for the circulation in these areas; the Icelandic low and the Azores high.

In the discussion following the presentation, various aspects of modelling the environment were touched upon. There seemed to be general agreement that prediction of parameters like temperature and salinity on a relatively short time scale should be possible from measurements made upstream. Several speakers thought it premature to go about modelling phenomena such as the distributions of nutrient salts or primary or secondary producers.

Dag Slagstad (SINTEF, Trondheim) then gave a presentation of his zooplankton model, and argued that it is possible to model, for instance, the production of copepods a given year given physical input data and knowledge about the starting conditions.

The discussion revealed large differences in the thinking as to the feasibility and necessity of building models to simulate environmental processes. Several speakers felt that the uncertainties in any case are too large to allow such models to be used for management purposes.

Others argued that some kind of modelling of the environmental impact on various biological processes seems to be inevitable, but could in many instances be simplified by drawing lines directly from environmental parameters to various "boxes" higher up in the systems, and could be in the form of indices.

Still others (Skjoldal, Slagstad) argued that we have come quite far already in modelling functional relationships between key environmental factors like temperature, light and nutrients and primary production, and were much more optimistic about the possibilities of including such relations into models involving higher trophic levels as well.

Some speakers (Niels Daan, Jake Rice and others) pointed to the fact that the relationships between physical factors and biology are not simple, and may well be different from area to area. A shift in sea temperature of 2 deg C might for instance have very different effects on organisms in the North Sea and in the Barents Sea. John Pope suggested that one should try to reduce the dimensions, e.g. by talking of an area being warmer or colder than usual, beeing warmed up faster or slower than usual, being warmer in the southern than in the northern part etc.

Overview of ecosystems: Fish.

Peter Shelton, St. John's, presented an overview of fish in the three ecosystems. His talk was based upon the working paper "Overview of three boreal ecosystems: Fish" authored by himself, George Lilly and Jim Carscadden from Canada, Hjalmar Vilhjalmsson from Iceland, and Harald Gjøsæter from Norway. He covered the main physical features of the three systems, descriptions of the major fisheries, and then stock structure, abundance, distribution and life history of cod and capelin. Lastly, he discussed possible multispecies interactions in the three areas, focusing on interactions between capelin and cod.

He summed up the conclusions in eight points:

1. The importance of species interactions within the fish community is widely recognised.
2. These systems are complex, and although similarities between the three systems can be recognised, there also exist important differences.
3. In each of the systems both cod and capelin are considered to be of primary importance, in each of the systems cod eats capelin, and in each of the systems there is at least some evidence of an effect of cod abundance on capelin dynamics or capelin abundance on cod dynamics.
4. There do not appear to be any analyses where these effects have been shown to be statistically significant.
5. There are two possible responses for dealing with species interactions given this situation: Build speculative models based on assumptions, or attempt to obtain more and better data from boreal systems.
6. In all three systems there are quite complicated seasonal patterns of spatial abundance in both cod and capelin, which are known to be, or are presumed to be, influenced by physical factors.
7. For each of the systems there is considerable knowledge of the diet of cod.
8. Multispecies models already exist for two of the three boreal systems considered in this overview and a modelling approach is presented for the third system at this meeting (Fahrig et al.). The challenge for the future will be to harness the considerable knowledge of fish biology that exists for boreal systems within multispecies models which can be demonstrated to outperform or supplement single species models as useful tools for resource management. Since at least some of the issues are common to the three systems, it is consid-

ered that this can best be achieved by a coordinated approach to multispecies analyses within boreal systems.

The discussion that followed his talk took up much the same problems that were touched upon previously: To model or not to model. Jake Rice suggested that a multispecies model could help us identify management strategies which cannot be observed with single-species models. Lenore Fahrig on the other hand, stated that we have to be able to predict something not built into the model itself to be able to use it for predicting harvesting strategies, and unless this is possible, she could not see the point of multispecies modelling at all. Peter Shelton was of the opinion that if we do better with including relations between species, we should do so, even if we don't understand all the mechanisms. Several speakers argued that in this situation it is important to sample relevant data to check for the relations we assume exist. Sampling should be conducted in a way which enables statistical treatment of the data, in order to be able to draw firm conclusions about possible interactions.

Overview of ecosystems: Invertebrates.

Arne Hassel, IMR, concentrated on the Barents Sea ecosystem in his introductory speech.

In August-September, which is the most important growth season for capelin, 90–95 % of the zooplankton consists of copepods. The generation time for the most important species, *Calanus finmarchicus*, which is found in the south, west and central parts of the sea, is one year, while the generation time for the more north- and easterly-distributed species found in arctic water, *Calanus glacialis*, is two years. This is in contrast to the North Sea, where there may be two generations or more per year. The capelin is dependent on copepods to survive to sizes where it can eat krill. Copepods, however, play a major role in the diet also above that size.

Based on data from 1984, a rough calculation shows that the capelin needed 6.6 million tonnes of food to sustain the observed growth. The zooplankton biomass was in the autumn 2.1 — 3.5 million tonnes, krill not included. These numbers imply that the capelin in fact may be able to reduce the zooplankton biomass considerably. However, the numbers cannot be compared directly since the zooplankton referred to is biomass at a specific time, not production throughout the growth season of capelin.

In the discussion, Lilly pointed out the significance of the plankton community dynamics for the bottom feeding fish (cod). Cod may feed directly on zooplankton and indirectly through feeding on crabs and shrimp. John Pope put forth the idea of using particle size distribution instead of species, on the assumption that a particle size distribution would have more stable dynamics than each species. Brodie pointed out that one then has to know the turnover rate of each particle stratum. According to Hassel there is many gaps in the knowledge of generation times for the most important species of zooplankton.

In introducing to the general discussion on modelling of invertebrates, Skjoldal showed that "the oldtimers" (Hjort, Zenkevitch) had modern ideas on the significance of the zooplankton dynamics for fish recruitment and fish growth. When it comes to the question of entering the zooplankton community into models of fish the crucial question is whether there is any feedback. Can the grazing of plankton feeders reduce the zooplankton abundance to a level where the plankton feeders get reduced growth? Also, it is a rule of the thumb that the growth of plankton feeders relate to area, one of the reasons presumably being different plankton densities in different areas.

In the general discussion, John Pope asked the question whether the aim should be to model the whole thing or simply use the plankton and environmental information as data sources. Peter Shelton added that before any modelling was done we should be able to actually observe the relations between fish and plankton. Skjoldal replied that this might be possible, but we will then have to link to an oceanographic model.

Jake Rice commented that multispecies models used for management may differ from other multispecies models, and a link to lower trophic levels may not be needed. We may learn a lot from complicated models, but not necessarily provide better management advice. This was supported by Niels Daan, replying that the managers are only interested in what can be controlled, sophisticated models with too many details are of little use with management.

In the discussion of the significance of plankton-fish interactions, Skjoldal pointed out that after the capelin stock declined in the Barents Sea, the zooplankton abundance increased. Also, the young cod shifted to amphipods.

Overview of ecosystems: Marine mammals

I-H. Ni in his introductory speech gave an overview of mammals in the three

areas. The largest and best known stock of harp seals is in the Newfoundland area, where for the 3 million seals capelin constitute 48% of the diet. Thus there might be competition for food between harp seals and cod, although this may not be effective at the present high level of the capelin stock. However, if Canada starts to exploit the capelin stock harder, this relation might be considered important for management (rapporteur's note). The direct impact of harp seals on the population abundance of cod is, presumably, small, as cod constitute only 1% of the diet. Transfer of parasites is, however, a big problem as 99% of the seals have nematodes; 800–900 worms per animal is common. In a management context, therefore, there are potential interaction terms both in the population domain and the economic domain.

Hooded seals and ringed seals, although abundant, stay so far to the north as to be of minor importance in a multispecies modelling context.

These characteristics of the Newfoundland seal stocks are probably also valid for the Barents Sea and Iceland, although the population abundance of harp seals is smaller in these areas.

The whales and the seals have opposite north-south components of the annual migration. During winter the whale populations stay further to the south and may have an impact on the fish stocks in arctic boreal waters during their northwards summer migrations.

The minke whale is the potentially most important whale predator on fish, primarily capelin, in all three areas. However, a scarcity of stomach content data and poor age composition data make the analysis of the interactions between minke whale and capelin difficult. Estimations based on energy requirements suggest that the predation from minke whales cannot be ignored in comparison to the fishery and to predation from cod.

In his talk and working papers, Paul Brodie strongly advocated using surface area instead of biomass as index of the mammals' predative capacity on fish, because the energy requirements due to heat loss and propulsion should have a stronger correlation to surface area than to body mass. As a consequence, seals may have a higher impact on the fish stocks relative to whales than estimated using an equation where the energy requirement is proportional to body mass.

Øyvind Ulltang presented the Norwegian marine mammals research programme. This programme was started in 1989 and will continue until 1993. The programme was started because the knowledge of population structure and

stock size for marine mammals was considered to be inadequate. Such knowledge is in great demand both because of the seal invasion and the heated debate in the IWC on catch of minke whales. In the first two years of the programme, the whale research has had the highest priority, but a higher priority will now be given to seal research.

In order to include marine mammals in multispecies models, one must know the stock size, the total consumption by size (age) and the diet composition. Especially for whales, it is very difficult to get data on the diet composition. It was suggested that a relatively small number of stomachs would be sufficient if the co-distribution of predator and prey is well known. N.A. Øritsland suggested that an international "model lab" (suggested size: several square km) for marine mammals should be constructed.

As mammal stocks vary more slowly than fish stocks, it should from a fish modeller's point of view be possible to regard the mortality induced by marine mammals as a residual mortality. One would then have to assume that the overlap in time and space is relatively constant, and the diet composition must of course be well known.

3 Modelling.

3.1 Existing models.

Dankert Skagen reviewed the MSVPA model for the North Sea and gave some hints on planned areas for future work.

Sigurd Tjelmeland presented the IMR multispecies model for the Barents Sea, MULTSPEC, and the work done on the cod-mature capelin subsystem in this model. The work in the Barents Sea is a Soviet-Nowegian cooperation having a rather long tradition. In 1985 specific multispecies research started by building up a joint data base for stomach content data. The importance of cod as predator on capelin is evident from the stomach content data. Since the Barents Sea capelin is regulated by assessing the impact of the fishery on the spawning stock, the MULTSPEC approach is to start by studying this process, with the aim to evaluate the effect of the cod stock as assessed at the ICES Arctic WG meeting on the coming spring's spawning stock of capelin. The most severe problem is the highly variable geographical overlap between the species. The data support for this is primarily the geographical distribution of capelin as obtained from the

cod stomach data, making it difficult to extrapolate results backwards unless some relation to environmental indices can be found.

The focus for the cooperation between PINRO and IMR is now to establish data bases for larger sets of data, and to start joint modelling work. So far, however, only the Norwegian side has been responsible for the modelling. Øyvind Ulltang suggested that the VPA stock estimates used for cod in the model should be improved by taking cannibalism into account.

Kjartan G. Magnusson presented the Icelandic cod-capelin model (Magnusson and Palsson 1990) [2] which so far has been used to study the effect of capelin abundance on the growth rate for cod. The significance of capelin as source of food for cod is demonstrated, and the model can be used for management of the Icelandic cod and capelin stocks.

Lenore Fahrig presented the Canadian plans for multispecies modelling, as given in the working paper by Fahrig et. al. The most important question to be answered in the Newfoundland area is : Can multispecies modelling be used to develop an improved long-term management strategy for cod in the Newfoundland area?

They plan to develop an empirically-based dynamic multispecies model in the following way: Start with single-species models. Then demonstrate significant multispecies effects (most interesting: The effect of capelin on cod growth/recruitment.) The single-species models should then be linked to a multi-species model, so that the predictions of single-species models vs. multi-species models could be tested. The problem is that so far they have not been able to find any significant relationship between capelin biomass and cod growth/recruitment. In Icelandic and Norwegian waters, this relationship has been found, but only at lower capelin stock levels. This demonstrates how important it is to make use of the experiments of nature.

3.2 Requirements for boreal ecosystem models.

The discussion on which processes should be included in boreal ecosystem models was chaired by Lenore Fahrig. Based on experience from Iceland and Norway, the following minimum requirements for multispecies modelling in the two areas were presented:

Iceland

1. Capelin maturation
2. Cod stock
3. Predation of cod on
   a. Capelin
   b. Other relevant prey (cod, shrimps)
4. Cod growth with respect to:
   a. capelin abundance
   b. Physical factors.
5. Overlap between cod and capelin, by an overlap function.
6. Growth of capelin with respect to physical factors.
7. Predation by marine mammals? Must then differentiate between whales and seals. Small seal stock, large whale stocks. For the time being, this has no practical value.

Barents Sea

1. Capelin stock — maturation
2. Cod stock — cannibalism.
3. Mortality on capelin caused by cod.
4. The dependence of cod growth on capelin abundance and temperature.
5. Overlap between cod and capelin, two alternatives:
   a. Geographically distributed model and submodel for migration
   b. Overlap function related to environmental indices.

Two different approaches to modelling were discussed; models based on empirically verified mechanisms, as opposed to modelling as a research tool.

3.3 Processes of special significance.

Predation.

Consumption calculations George Lilly gave a talk on "Stomach sampling and calculation of consumption". He based his talk on a working paper called "Notes for discussion of stomach sampling and calculation of consumption".

He discussed some of the techniques used to estimate numbers and weights of prey consumed, and mentioned some of the problems encountered. He classified the estimation of consumption rate into direct and indirect methods, the former being further classified into the "Gut content and gastric evacuation rate method

(GER)" and the "Reconstructive method". The indirect method was divided into bioenergetics and production-based approaches. His next theme was stomach sampling. He emphasized the need to cover the complete area, both in space, (horizontal and vertical) and time (whenever something changes). He said that the sample size would depend both on the variability and the precision desired. His third aspect was interpreting feeding behaviour, keywords were: distribution, functional feeding response, size selectivity and electivity.

The discussion that followed focused on the questions of whether laboratory experiments could be compared to field conditions, and which of the gastric evacuation models (linear or curvilinear) should be chosen. No definite answers to these problems were proposed; the conclusion was that "more investigations are needed!" There was, however, no disagreement to the final conclusion drawn by Lilly (after J.J. Ney (1990)):

In fisheries, scant attention we pay,
to the little fish known as prey.
But those that would eat 'em,
we discuss ad infinitum
Too often with little to say.

Functional feeding relationships.

Dag Aksnes, University of Bergen, emphasized the importance of taking biological considerations into account when working out functional feeding relations. For cod, one of the most important factors is visibility, making ambient light (day-night, summer-winter) an important entity. For details, see [1].

Gislason pointed out the need to segregate between functional feeding relationships at different levels: Individual, local, population. Factors that are important at lower levels, may even out at the population level, allowing for simplification of the relations in population models(ref MSVPA).

John Pope pointed out that the functional feeding relationship, at least on the population level, only can be observed through models. This also points, in more general terms, to the usefulness of models as a tool to understand the data.

Migration.

The main problems when including migration in a model are how to represent it (overlap functions/ migration matrices etc.), how to estimate it, and how

to incorporate it into assessment models. In the case where migration is represented using an area-structured model, the catch may cause problems because of insufficient reporting by area.

Including migration in models can give a better understanding of the system and give improved estimates of predation mortality. However, the introduction of area structure in a model may introduce more sources of errors, as was forcefully pointed out by several participants.

Assuming one has found the yearly migration patterns for a time period, the question of prediction arises. This must be done by linking the observed migration to oceanographical data. However, independent of such work it should be possible to utilise knowledge about the range in variation in migration, and hence the range of variation in overlap and predation, for management purposes.

Uncertainty.

Jake Rice gave an overview of the uncertainties connected to the functional forms and parameters in models. Uncertainty in parameters and residual noise in data can be transferred to the results as distributions of the outcomes. Uncertainty in functional forms may be handled by taking more factors into account, i.e. increasing the complexity, but this may in turn increase the uncertainty. As an alternative to functional models data base approaches may be useful, describing the probability structure of the output by relations of the type P (y|x) = f(observations).

In the discussion, it was pointed out that functional forms should be reserved for relations that are well understood. Some parameters are included in models mainly for logistic convenience, e.g. M1 in a MSVPA. Their actual value, as long as it is constant, has little impact on the results. A model must ultimately rely on data, if a situation appears that is not covered by historical data, a good model should say: "Don't use me".

4 Recommendations.

It was agreed by participants that future work on boreal multispecies systems was an appropriate focus for the MSWG, and that a common basis for such work was of primary importance in developing the proper modelling framework and supporting analyses. Accordingly, the participants proposed recommendations reflecting the desire to continue the process of developing coordinated approaches

to boreal multispecies systems, and for conducting specific analyses deemed important.

The following proposal for future multispecies modelling work for arctic boreal systems was adopted:

1. Continue the development of Multispecies Models for Arctic/boreal ecosystems, focusing on problems of joint management of interacting species.
2. Conduct statistical analyses of the underlying relationships of cod growth in relation to prey abundance and environmental variability, focusing on time-series data concerning:

    a. cod growth increments
    b. population abundance of cod and its prey
    c. environmental conditions
    d. stomach content, consumption data

3. Construct comparable energy budgets for the three Arctic/boreal systems (Barents Sea, Iceland, Newfoundland), for average levels of production and energy flux among system components.
4. Analyze potential environmental influences on the codistribution of predators and prey in boreal systems, as a determinant of predation mortality rates.
5. Compile and explore existing predation data (stomach content, consumption estimates) for fish, marine mammals, and birds, and make such data available in a common (disaggregated) format for future analyses.

It was proposed that the terms of reference for the Multispecies Working Group meeting in December 1990 (Woods Hole, USA) be modified to include items 1, 2 and 5 above, and that the revised terms of reference be submitted for approval to ICES. As accomplishing the additional tasks would take some time, national coordinators were nominated for developing data bases consistent with items 2 and 5. Finally, the meeting participants considered how to more fully integrate boreal multispecies research into MSWG activities. It was envisioned that future meetings of the MSWG could vary in their emphasis, depending on the state of analyses being conducted in various ecosystems (North Sea, boreal systems), the nature of questions asked by ACFM, and appropriateness of scientific issues to be considered.

Appendix A Working papers.

Most, but not all, of the session introductions were based on working papers. For those interested, the authors should be contacted.

1. Jake Rice: Handling uncertainties in multispecies models.
2. Lenore Fahrig, Peter Shelton and Russel Millar: An approach to Newfoundland boreal multispecies modelling.
3. Paul F. Brodie: Comparative energetics of marine mammals and their potential interaction with fisheries; a technique for graphic presentation of data.
4. Paul F. Brodie: Body temperature variation on Grey and Harbour Seals (*Halichoerus grypus* and *Phoca vitulina*), based upon postmortem measurements of newborn and adult animals.
5. I-Hsun Ni and G.B. Stenson: Marine mammals in the Northwest Atlantic.
6. George R. Lilly: Notes for discussion of stomach sampling and calculation of consumption.
7. Peter Shelton, George Lilly, Jim Carscadden, Hjalmar Vilhjalmsson and Harald Gjøsæter: Overview over three boreal ecosystems: Fish.
8. Sigurd Tjelmeland: From a single-species model of the Barents Sea capelin to a multispecies model for the Barents Sea.

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