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PROCEEDINGS OF THE WORKSHOP

ON

ECOSYSTEM CONSIDERATIONS FOR KRILL AND OTHER FORAGE FISHERIES

Halifax Fisheries Research Laboratory
Lower Water Street, Halifax, Nova Scotia, Canada
2 - 4 April 1997

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TABLE OF CONTENTS

Abstract

In late 1995, DFO received a proposal to develop a 1000t experimental fishery for krill, a forage species, on the Scotian Shelf and in the Bay of Fundy. In 1996, this proposal was reviewed through the Regional Advisory Process (RAP), which commented that it would have a negligible effect on the ecosystem. Concerns were raised, however, in anticipation of future requests to expand this harvest. These concerns apply equally to any fishery directed at a forage species. Thus, in late 1996, the RAP Steering Committee decided to hold a workshop to consider the broader implications of fisheries on forage species. The broad objective of the workshop was to provide guidance for the future development of forage species fisheries in the DFO Maritimes Region.

The workshop was held in April 1997, to which both national and international experts were invited, as well as local interested parties. The workshop included a number of talks: some relating general problems in applying ecosystem considerations to forage fisheries, a series describing the ecosystem approach to the management of the krill fishery in the Antarctic (the CCALMR approach), and three relating to existing or proposed krill fisheries within Canada. Two working groups then considered questions which comprised the central issues of the workshop. The results of the working group discussions were reviewed in a plenary session on the final day of the workshop. These Proceedings summarise both the presentations made at the workshop as well as the conclusions of the working group and plennary session discussions.

Resumé

À la fin de 1995, le MPO a reçu une proposition visant la pêche expérimentale de 1 000 t de krill, espèce fourrage, sur la plate-forme néo-écossaise et dans la baie de Fundy. En 1996, cette proposition a été examinée dans le cadre du Processus consultatif régional, et il a été jugé qu'elle aurait un effet négligeable sur l'environnement. La perspective de voir se développer cette exploitation a toutefois suscité des inquiétudes. Ces préoccupations s'appliquent également à toutes les pêches visant une espèce fourrage. C'est pourquoi, à la fin de 1996, le comité directeur du Processus a décidé d'organiser un colloque pour examiner les incidences à grande échelle de l'exploitation des espèces fourrage. Le grand objectif du colloque était d'établir une orientation pour le développement futur des pêches d'espèces fourrage dans la région des Maritimes du MPO.

Le colloque a eu lieu en avril 1997, et rassemblait des experts canadiens et internationaux, ainsi que des personnes intéressées de la région. Il a comporté un certain nombre d'exposés : certains sur les problèmes généraux de l'application d'une approche écosystémique à la pêche d'espèces fourrage; une série décrivant l'approche écosystémique de la gestion de la pêche du krill dans l'Antarctique (l'approche de la CCALMR); enfin, trois présentations sur des pêches existantes ou projetées du krill au Canada. Deux groupes se sont ensuite penchés sur les questions qui constituaient les grands dossiers du colloque. Les résultats des travaux des groupes ont été revus lors d'une séance plénière le dernier jour du colloque. Les actes résument à la fois les exposés présentés et les résultats des travaux des groupes et des débats de la plénière.

EXECUTIVE SUMMARY

Recent declines in traditional groundfish fisheries on the East coast of Canada have lead to growing interest in the exploitation of non-traditional species, including some which are forage species i.e. prey to fish and other species at higher levels in the food chain. In late 1995, DFO received a proposal to develop a 1000t experimental fishery for krill, a forage species, on the Scotian Shelf and in the Bay of Fundy. In 1996, this proposal was reviewed through the Regional Advisory Process (RAP), whose recommendation was that it would have a negligible effect on the ecosystem. Concerns were raised, however, in anticipation of future requests to expand this harvest. These concerns apply equally to any fishery directed at a forage species. Thus, in late 1996, the RAP Steering Committee decided to hold a workshop to consider the broader implications of fisheries on forage species. The broad objective of the workshop was then to provide guidance for the future development of forage species fisheries in the DFO Maritimes Region.

A steering committee (T. Platt (chair), E. Head, R. O'Boyle, D. Sameoto, M. Sinclair , H. Whitehead) was struck to organize the workshop, for which E. Head agreed to act as convenor. The workshop was held in April 1997, to which both national and international experts were invited, as well as local interested parties. The workshop included a number of talks: some relating general problems in applying ecosystem considerations to forage fisheries, a series describing the ecosystem approach to the management of the krill fishery in the Antarctic (the CCAMLR approach), and three relating to existing or proposed krill fisheries within Canada. Two working groups were then set up to consider questions which were determined to comprise the central issues of the workshop. The results of the working group discussions were considered in a plenary session on the final day of the workshop. The general conclusions of the workshop can be summarized by the responses to these questions.

The first set of questions related to the overall objectives for forage fisheries in Canadian waters.

What should be the conservation objectives related to fisheries on forage species?

- maintenance of ecological relationships/ ecosystem integrity
- minimization of risk of irreversible decline
- maintenance of ecosystems and constituent species within the bounds of natural fluctuation
- maintenance of full recruitment potential (including genetic diversity)
- allowance of fisheries which meet conservation objectives (and maximize knowledge returns)

Under what fishery conditions can the full set of objectives be met?

- the knowledge base must be adequate to allow risk evaluation
- there should be confidence that monitoring and controls are adequate to allow management decisions (i.e. responses to change) to be made and implemented in timely fashion
- monitoring of direct impact and indirect impact on dependent species and of by-catch is required
- ongoing assessment of natural levels of fluctuations in species and ecosystem is required
- proponents should bear the incremental costs of acquiring knowledge and managing the fishery

The next set of questions related to the application of the CCAMLR (Commission for the Conservation of Antarctic Living Marine Resources) approach to the krill and other forage species. The CCAMLR approach is comprised of two parts: 1) a model which enables calculation of a precautionary catch limit and 2) a program to monitor the health of dependent species. For instance, for Antarctic krill, the model projects population dynamics over a 20 year period, at a constant annual catch. The less biological information available, the lower will be the catch. Annual catch is calculated for two conditions: 1) the minimum spawning stock biomass does not fall below 20 % its unexploited level, and 2) the spawning stock biomass does not fall below 75 % of its unexploited level. The first criterion relates to considerations of stock viability and the second to predator requirements. The annual catch is set to the lower of these two values.

The ecosystem monitoring program for dependent species includes observations on the health and reproductive success of penguins, albatrosses, and seals in colonies near to and distant from krill fishing areas. The recognition of adverse effects related to fishing effort would automatically lead to the cessation of fishing.

Is a 'refined' CCAMLR approach appropriate for a krill fishery on the Scotian Shelf?

- the CCAMLR model can provide a template for the Scotian Shelf
- the accumulation of knowledge will allow for enhancements to the model

What would be the requirements for scientific knowledge to implement the CCAMLR model for krill on the Scotian Shelf and in surrounding areas?

- estimates of pre-exploitation biomass
- estimates of maximum age of krill
- estimates variation in recruitment
- estimates of natural mortality
- estimates of growth rates and maturity and selectivity ogives

What would be the appropriate sampling design for krill on the Scotian Shelf and in surrounding areas?

- there should be a synoptic acoustic survey, which should include a regular series of net tows
- the design should be one of random transects with some stratification to reflect the known distribution of krill
- there should be target trawls at the Scotian Shelf break, where species diversity is high
- estimates of recruitment and growth rate etc. could be obtained during such a survey

There was a relatively high degree of consensus amongst a wide variety of stakeholders that the CCAMLR approach should be used to assess TACs for krill and other forage species on the East Coast. Some participants however argued that even very low level exploratory fisheries should not be allowed before implementation of the CCAMLR approach (i.e. before appropriate modeling has been done for target species, and before relevant ecosystem monitoring programs are in place). In the particular instance of the proposal for a low level krill fishery, even though it was agreed that the current estimate of biomass is probably an underestimate, and that the proposed 1000t catch is only about 1 % of this low estimate, some participants thought that a new, more credible estimate of the pre-fishery biomass of krill on the Scotian Shelf would be needed, together with full implementation of the CCAMLR approach. The question which applies here and to all new potential forage fisheries is how to assess the level of risk, when the level of knowledge is poor.

In May 1997, the RAP steering committee met to discuss the findings of the workshop and made a series of recommendations, the main features of which are:

1. The conservation objectives for forage fisheries as described above should be adopted.

2. The CCAMLR approach should be adopted for the management of forage species (existing and emerging).

3. Decisions made concerning these fisheries and their scientific justification must be credible to a broad range of stakeholders.

4. The CCAMLR model requires knowledge of virgin biomass and biological parameters. In the case of the proposed krill fishery, the requirements are outlined above.

5. The CCAMLR approach requires ongoing monitoring of the biological health of dependent species. In the case of krill, one such species would be hake. Steps would need to be taken to identify dependent species and initiate monitoring programs for any emerging or existing forage fisheries.

6. There is a need to define a consistent and credible method for estimating the risk of taking the first step towards any forage fishery. Guidelines should be developed, perhaps at another workshop, but until they have been, proposed fisheries should be considered as scientific monitoring exercises, with the emphasis being on data collection and with the harvest levels remaining low relative to the size of the resource.

INTRODUCTION

With the recent decline in the traditional groundfish fisheries on the East coast of Canada, there has been growing interest in the exploitation of non-traditional species. This has not only involved species such as monkfish and skate, but also those which are considered forage i.e. prey to fish higher up in the food chain. In late 1995, the Department of Fisheries and Oceans (DFO) received a proposal to develop a 1000t experimental fishery for krill, one such forage species, in Scotian Shelf and Bay of Fundy waters. Upon review through the Regional Advisory Process (RAP), it was considered that this fishery would have negligible effects on the overall marine ecosystem. However, concerns were raised that there may be expectations for an expanded harvest of this resource, and what the consequences this expanded harvest may have for the ecosystem. These concerns apply equally well to any fishery which would exploit a forage species.

In October, 1996, the RAP Steering Committee agreed to hold a workshop to consider the broader implications of fisheries on forage species. The issues to be considered include:

- Under what circumstances should there be harvests of forage species, given their role in the ecosystem, and what can be learned from the international and Canadian experience?

- What assessment approaches can be used to describe the dynamics of forage species, given that data are sparse?

- What are the scientific monitoring requirements of forage species fisheries?

The broad objective of the workshop was then to provide guidance to the future development of forage species fisheries in the Maritimes Region of DFO.

A committee (R. O'Boyle, E. Head, T. Platt (chair), D. Sameoto, M. Sinclair, and H. Whitehead) was struck to organize the workshop. E. Head agreed to act as workshop convenor. Both national and international experts as well as local participants were invited. The list of participants is given in Appendix I. A number of invitees unfortunately could not attend due to a violent snowstorm.

After opening remarks by the Maritimes Regional Science Director, J. Loch, the first day of the workshop (Appendix II) was devoted to presentations on the general issue of ecosystem considerations with forage fisheries and the international experience with krill fisheries. The second morning considered the Canadian experience. In the afternoon, workshop participants were split into two working groups to consider the issues posed above. A plenary session was held on the third morning to consolidate the discussion. Following this, the workshop adjourned and the workshop organizational committee met to discuss its main conclusions. These and the workshop report were further discussed at a RAP Steering Committee of 1 May 1997, and recommendations for management developed. These are given in Appendix III. Abstracts of the talks are given in Appendix IV.

SESSION I. HOW CAN THE QUESTION OF ECOSYSTEM INTEGRITY BE ADDRESSED IN RELATION TO FORAGE FISHERIES? - A GLOBAL OVERVIEW

Recent developments in International Law - Application of the Precautionary Principle and the Precautionary Approach (J. Rice, DFO/NHQ)

Dr. J. Rice outlined the concepts of the Precautionary Principle and Precautionary Approach to environmental problems and their relevance to fisheries questions. He then discussed the legal obligations Canada has as a signatory to the UN treaty on migratory species and straddling stocks and related how these considerations might be applied at home for forage fisheries. These considerations included the ideas of ecosystem monitoring, in its broadest interpretation, risk/benefit analyses, and pre-agreed responses to ameliorate adverse "signals" in the environment. He also pointed out how ecosystem considerations effectively broaden the client base of DFO, so that decisions must be made following broad-based consultation, and to the extent possible, consensus.

Dr. Rice then went on to discuss the application of these considerations in a multispecies context. Although an empirical approach (understanding the ecosystem in its entirety) might be desirable, he thought that this is an unattainable goal. Modeling provides a more tractable method. There are two different types of modeling approach - taking fishery assessment models and adding multispecies interactions and taking food web or ecosystem models and adding fisheries interactions. Most current fisheries models do not include inter-species interactions, or environmental interactions, although models such as the ICES Multispecies VPA have made some progress in adding predation effects into stock assessment computations. Several groups are trying to add fisheries effects to food web type considerations although Dr. Rice was not optimistic bout the utility of such models. There will often be inadequate data, and high uncertainty about fish behavior (e.g. dietary switching etc.). Finally, the multiple pathways characteristic of marine fisheries food web models imply that these models should not be used to predict specific consequences of perturbations like fishing on a new species.

The Other F (fishing mortality) : The need for increased forage considerations in fisheries management (R. Stephenson, DFO/SABS)

Dr. R. Stephenson outlined a number of issues relating to forage species fisheries which have arisen recently in both local and international contexts, including:

- the request for a krill fishery on the Scotian Shelf
- the possible effect of a sand eel fishery on sea bird colonies in the North Sea
- the possible effects of capelin fishing on the haddock and Arctic-Norwegian cod
- the poor recruitment of Atlantic salmon and the potential lack of forage fish
- the decline in Eastern Canadian groundfish stocks to the level where the grey seal population may be having a significant impact.
- the increase in Minke whale abundance off Iceland to the level where they may be seriously depleting a low cod stock.

Dr. Stephenson described efforts to model forage interactions. He focused specifically on an approach to multi-species modeling, which uses a formulation for total mortality, including a term which takes account of predation mortality (the "other F"). He went on to re-iterate the ideas expressed in the Precautionary Approach and other international agreements, including the Rio Declaration and the UN Conference on migratory and straddling stocks. He concluded by outlining the context for future management, stating the needs for the improved biological knowledge basis for management of forage species (e.g. more information on species interactions etc. and improved models) and improved considerations of forage and multi-species considerations in management (development of strategies which include ecosystem considerations).

Q. Is the "forage" mortality model different from the MSVPA being developed/applied within ICES?
A. No

Q. Have there been observations of forage impacts?
A. There is no information to allow such assessments.

Q. Were any documents other that the Code of Conduct used in formulating Rob Stephenson's recommendations?
A. Not really, although Rob recognizes that there are other documents which could be considered.

C. MSVPA was developed for North Sea stocks, and it is used to predict medium, not short-term impacts.

C. One of the problems is that "forage" is a rate which decreases with the decrease in biomass of the "foraged" species. Thus, models which are based on absolute biomass should be avoided.

C. If we use the "F" concept then predators could be considered as fishing units

Krill fisheries of the world and their management (S. Nicol, Australian Antarctic Division)

Dr. S. Nicol from the Australian Antarctic Division described existing krill fisheries around the world and the management strategies under which they operate. Initially he made some points about krill. Krill are not planktonic, likewise they are not fish, and they are in fact composed of different species in different areas; some of which may be herbivorous, some omnivorous and some carnivorous. He also pointed out how little research has been done in most cases. The krill fishery off the coast of Japan operates without quotas to fulfill the needs of local aquaculture operations, and amounts to some 100,000 tons. There is external regulation by the number of licenses, the size of the boats, and the duration of fishing effort and self-regulation, to keep the prices up. The Japanese are planning a synoptic biomass survey in the near future. The Antarctic fishery is now operated under the principles set out by CCAMLR (Commission for the Conservation of Marine Living Antarctic Resources), i.e. an ecosystem management regime. Fishing effort was at its peak when the rules were brought in, and has recently declined dramatically due to the cessation of fishing effort by the former Soviet Union. The Japanese are the main players in the fishery which now amounts to some 200,000 tons per year. The catch (2-10 tons per net haul) must be processed within 2-3 h of capture, since it spoils extremely fast. The Japanese use it for direct human consumption (fresh boiled or peeled and frozen), as fish meal (ground and frozen) and as bait (sport fisherman) and fish food (fresh frozen). The most important use is expected to be in the aquaculture industry in future. In order to run the CCAMLR model for assigning a TAC for krill, estimates of biomass, recruitment proportion, and growth rate are needed. There are problems in determining all of these because of the biology of krill. Antarctic krill form dense swarms which can occur at surface, mid-water or bottom depths. In addition, there is no very good way to age krill, although the first year individuals can generally be distinguished. Finally, in the laboratory, Antarctic krill can undergo negative growth when starved, with adults regressing to lose their secondary sexual characteristics. The extent to which this occurs in situ is unclear, however. Antarctic krill may live for up to 6 years. Information of this type is nearly non-existent for krill in other areas of the world. Dr. Nicol expects the demand for krill to increase in future and he pointed out that if the harvesting of krill is prohibited in one area of the world it will lead to increased pressure elsewhere. He also suggested in the light of the proposed fishery on Canada's east coast, and existing (albeit small) fishery on the west coast, that Canada should take a more active role in CCAMLR, of which it is already a member, which could provide a forum for comparisons of approaches for conservation strategies, and for the exchange of expertise.

C. It was commented about the increased demand for "enzymes" from krill - the rapid decay of krill is due to the presence of extremely active proteases and other digestive enzymes.

Q. What effective management measures are used (in the Antarctic)?
A. The CCAMLR agreement was the first step. It applies precautionary catch limits.

Q. How do you know that landings are reported accurately?
A. There is no real incentive to cheat, since the catch has always been below the precautionary limit.

Q. Is there consensus on the life span of *Euphausia superba* (the Antarctic krill)?
A. Most people accept a value of 5 years.

Q. How do you deal with the lateral mobility of the species, when assessing biomass?
A. The "Flux factor" will be addressed by Inigo Everson.

Q. What about age at maturity?
A. In the laboratory it is 2 years.

Q. What about fecundity?
A. About 2,000-5,000 eggs per batch. (Inigo) There are several spawnings per season.

Q. Are there both increases and decreases in length when the animals moult?
A. Animals can decrease in length from 50 to 26 mm in the laboratory, loosing their secondary sexual characteristics, so as to look immature again.

Q. How about the use of lipofuscin as an index of age?
A. It doesn't work.

Q. Does the level of activity (e.g. swimming speed) change with temperature?
A. Krill generally live in waters with a restricted range of temperatures, which only vary by about 3-4^{o}C.

Q. Does the difficulty in aging individuals prohibit the use of an age structured model to estimate biomass?
A. No, annual biomass can be estimated.

Q. Is by-catch significant?
A. There had been concerns about there being a by-catch of larval fish (since fish stocks are in decline), but in fact it does not seem to be a problem. One factor is that krill swarms seem to exclude other species and another is that the boats do not want a high by-catch, since some of their product is fresh frozen, and contamination will decrease the price.

Q. In there any evidence for the nature of the S-R relationship?
A. Unknown.

C. The evidence is that abundance is environmentally driven, but over-exploitation could be envisioned.

Q. It appears that the TAC is 10 % of the biomass.
A. David will discuss how the level was reached. It has been broadly accepted.

Q. How do currents and the presence of predators affect the movements of krill swarms (so as to affect your estimates of biomass)?
A. The objective of our survey design is to minimize temporal and spatial effects.

Q. Would the krill be even more mobile in a temperate environment?
A. Swimming speed increases with temperature, but temperatures on the Scotian Shelf might not be so very different from those in Antarctic waters.

C. Modellers are trying to examine the effects of vertical migration and predator avoidance (on estimates of biomass).

Q. To what extent are catch statistics used to evaluate biomass estimates (derived from the model)?

A. The CPUE approach is not useful, since the fishermen search out the swarms using acoustics and then fish. Also, the swarms are attracted to surface lights at night and the fishing effort is concentrated in a small area. In addition, once the catch is brought in, it must be processed immediately, leading to down time for fishing effort. The most useful assessments have been made using a "random time log book". In this random times are set out, for each day of a trip, and the observer records what the ship is doing at each point (e.g. searching, fishing, processing, hove to etc.).

Krill management in a single species context: Acoustic estimation of krill abundance (I. Everson, British Antarctic Survey)

Dr. I. Everson described the acoustic system which is being used to estimate krill abundance in the Antarctic. Considerations included: the operating frequencies; robustness; and the need for calibration. He then described the factors which can affect the signal: the size, shape, orientation, composition (e.g. lipid content), distribution (whether in swarms) etc.

Q. What is the acoustic survey design ?

A. The Jolly and Hampton method has become the accepted approach: randomly spaced transects, mean density is estimated for each transect and means are expanded to whole survey area.

Krill yield model development and application in CCAMLR (D. Agnew, Imperial College, Univ. of London)

Dr. David Agnew described the CCAMLR model used in management of the krill fishery in the Antarctic. One important consideration was that you cannot get annual surveys, and certainly not synoptic ones. The model is an extension of one set out by Beddington and Cooke and it incorporates concepts of uncertainty in estimated parameters, a seasonal fishing effort, and seasonal growth by the target organisms. The higher the level of uncertainty in any parameter, the more conservative will be the estimate of TAC. The model has been developed in consultation with CCAMLR members and arrived at by consensus. One of its advantages is that it sets a fixed catch for a 20 year period. This is based on the initial estimate of biomass, and several other parameters (variation in population age structure, recruitment, mortality etc.), and the requirements that (a) the biomass should not decrease significantly (< 10 % probability of dropping to 20 % of the original), to minimize the likelihood of the demise of the species, and (b) that the median biomass should not drop below 75 % of its original value, to minimize the effect on dependent species. These are the so called $\gamma 1$ and $\gamma 2$ levels which appear in the subsequent discussion.

Q. Were predator requirements considered in establishing the second decision rule ($\gamma 2$) of the CCAMLR approach?

A. No, the value chosen (keep krill biomass at 75% of Bo to ensure that enough are available for predators) was arbitrary. There have been a number of studies of predator requirements but the data are not very good in some cases. Modeling studies are presently being done to better assess predator requirements but there are problems due to inadequate data.

Q. What field data are used in the model ?

A. Age composition, size at recruitment, size at maturity, recruitment variability (in terms of proportion of one-year-olds in the population).

Q. Interesting to note the weight given to arbitrary figures in decision rules, e.g. the 10% or 75% levels here, or F0.1 elsewhere.

A. Yes, they are arbitrary.

Q. The model does not appear to incorporate spatial effects, which might be particularly important for predators feeding on swarming animals.

A. Yes, there are a number of factors which cannot be covered by the model, for example "flux" between regions.

Q. What is the spatial scale of the model ?

A. The model treats the entire Atlantic sector of the southern ocean as a single population but catch is spread among subareas to ensure that there is no local overharvesting. It is not known whether there are different populations but it is considered important to spread effort. There are ongoing discussions in CCAMLR as to how to spread effort.

Ecosystem integration: CCAMLR's approach to ecosystem considerations. The ecosystem monitoring programme (D. Agnew, Imperial College, Univ. of London) and CCAMLR's approach to the integration of ecosystem considerations into management of krill (I. Everson, British Antarctic Survey)

Dr. Inigo Everson described the ecosystem monitoring program which is an essential element of the CCAMLR approach (as distinct from the model), which assesses whether the krill fishery is in fact impacting its dependent species. The approach also includes a pre-agreed remedy to ecosystem change i.e. if negative ecosystem impacts occur, fishing will stop. The dependent and accessible species in the region where the fishery is be pursued includes some penguin species, crab-eating seal and albatrosses, although study sites in areas with no fishery are included as "control" sites. In assessing the impact of the krill fishery it is desirable to design indicators of the health of the populations. In addition, it is desirable that the indices be simple and inexpensive (relatively) to measure. For the penguins this includes such things as: adult weight on arrival at the breeding colony, duration of the first incubation shift (after egg-laying), duration of foraging trips, chick diet, chick weight at fledging etc. Analogous indices are monitored for other species. One essential feature of the program is that the record be uninterrupted.

Before discussion of Dr. Everson’s presentation, David Agnew went on to describe certain features of the program being operated. He discussed the idea that harvesting effects must be separated from environmental effects, and pointed to a data set in which all indices had shown and "bad krill year" whether they were measured near to or far from the fishing area. He also pointed out there are seven nations taking part in the monitoring (none of them being actually involved in harvesting krill).

Q. Could one look at old (1930's-40's) whaling statistics which give lipid content early and late in season as an indicator of environmental conditions or krill fluctuations ?

A. Good idea especially since that would give information from a time when krill were not exploited.

Q. Is the longline fishery operating in summer during bird breeding ?

A. No, it is restricted to winter. The target species is Patagonian toothfish. Birds are also caught by the tuna longline fisheries to the north of the CCAMLR convention area. This mortality of birds continues, in addition to mortality in the more recent longline fishery for toothfish.

Q. How might the decision rules change if the relative impact of harvesting and of environmental variability were known ?

A. CCAMLR is working toward this, too early to say at present. It has been very important to keep the research interests focused on providing advice for management.

Q. How does the cost of monitoring relate to the value of catch ?

A. Value of catch comes nowhere near cost of research programs, but countries are backing CCAMLR objectives by funding Antarctic research, and many other studies are being done in addition to the ecosystem monitoring described here. The actual incremental cost of the monitoring is quite low since it is piggybacked on other Antarctic research programs.

CCAMLR is all voluntary, Working Groups identify problems and countries volunteer to work on the problems - only sometimes countries do not undertake the exact program identified.

Q. Such monitoring programs must be maintained over the long term to be valuable; are countries committed for the long term ?

A. No countries can really commit for the long term but the intention is to continue monitoring. Some series have been discontinued for various reasons.

Q. How were the parameters to be monitored selected; they are quite a diverse set ?

A. "By committee"; since States will be funding the monitoring they must fully support the parameters to be monitored. Although perhaps not the "ideal" monitoring parameters, they are parameters which can be monitored relatively easily and there is some confidence that these could be maintained over the long term. Monitoring is done at various technical levels, i.e. some parameters can be monitored with pencil and paper, instrumentation has been developed for others.

Q. The relation between feeding and chick survival was remarkable, especially the big decline in 1991; was this related to krill availability ?

A. There are some correlations but unlikely to be related to the fishery which is removing a very small proportion of the total krill biomass. Monitoring programs should be looking for big signals and changes due to the relatively small fishery removals would not likely be detected by monitoring.

The role of krill in ecosystem structure in the Bering Sea (D. Bowen, DFO/BIO)

Don Bowen described the structure and function of the Bering Sea ecosystem, and how drastically it has been changed by whaling, sealing and fishing efforts over the last 40 years. Between the 50s and 70s some 300,000 sperm and baleen whales were taken, together with large numbers of fur seals. Then the ocean perch were fished to negligible levels, followed by the herring and saith. When the "natural" fish species had gone, the area was taken over by pollock, and its levels have increased from 2M metric tons in the 70s to 16M metric tons in the 80s, when it was 80 % of the fish biomass. During this period the stellar sea lion and harbor seal populations declined, perhaps in response to decreases in the abundance of capelin and sand lance, the latter of which are forage for the pollock. The suggestion is that the removal of the baleen whales may have lead to an increase in zooplankton (and krill) levels which in turn may have lead to the proliferation of species which compete for forage with the sea lions and harbor seals. The message seemed to be that selective fishing pressure can have dramatic and not easily predictable effects on ecosystem structure.

Q. Fur seals declined due to harvest; maybe the subsequent increase in pollock abundance was due to predator release ?

A. Unlikely since the timing is wrong; seals do eat pollock but herring and sand lance are the preferred prey.

Q. Is there information on squid abundance to go with the other species ?

A. No, no data.

Q. The information on temperature regimes presented here suggests changes on the scale of a decade between warm and cool conditions; this is quite different from the situation in the Antarctic where changes occur on a shorter period, warm and cool years are the norm.

A. Yes, the major temperature signals in Bering Sea are on decadal scale.

Approaches to setting quotas when actual data is limited (R. Mohn, DFO/BIO)

Bob Mohn then gave a talk in which he pointed out some of the practicalities of modeling in the real world. Firstly, he pointed out that many models are hopelessly complicated and data hungry. Thus, he suggests you often have to do what you can get away with, based on the information that you have. An added point is that the information that you are able to get, will have to be supported by the value of the fishery. He also discussed some particular case studies describing the modeling approaches which had been taken.

C. In the case of krill we shouldn't discount fishery information entirely, for example although catch rate information may not be much use for krill (since densities remain high in swarms), a combination of catch rate and spatial information might be of some use.

SESSION II. THE CANADIAN EXPERIENCE IN KRILL FISHERIES

Assessment of the abundance and distribution of krill on the Scotian Shelf (D. Sameoto, DFO/BIO) and Krill and copepod harvesting in the Gulf of St. Lawrence (J. Runge, DFO/IML) (presented by Doug Sameoto)

Doug Sameoto re-iterated the talk he had given at the previous RAP Habitat Sub-committee meeting which included estimates of the biomass of krill in waters deeper than 200 m on and around the Scotian Shelf. He described patterns of seasonal abundance in Emerald Basin, and length frequency relations for krill from Emerald Basin and Cabot Strait. He also described the acoustic system that Norman Cochrane has developed and showed how estimates of krill biomass using it were generally much higher than those made using nets or the BATFISH. He then presented data provided by Jeff Runge (IML, who could not be present) showing the estimates of abundance of krill in the Lower St. Lawrence Estuary for the past 3 years. It seems that 1995 was a particularly "high" year, since although estimates since then have been much lower, the latter are close to estimates from other areas (e.g. the Antarctic and Scotian Shelf). The fishing effort on krill in the Lower estuary appears to have stopped, because quotas could not be reached and fishing is therefore not economically viable.

Note: Appendix IV contains the research document produced by G. Harding which was the source of the material for D. Sameoto’s talk.

Description of the krill fishery in British Columbia (R. Tanasichuk, DFO/PBS)

Ron Tanasichuk presented data on the krill fishery on the West Coast. The fishery started in 1970 and is restricted by regulation to a low level (500 tons) and small area of operation in the Strait of Georgia. It is essentially unmonitored, and under pressure to increase quotas. There are 19 licenses and no more will be granted. The market is the aquaculture industry. The fishery provides little information which is of use to DFO. He then discussed his own work on the abundance and biology of krill in Barkley Sound. Features he noted were multiple spawnings per year and an apparent lack of correlation between growth and temperature. He remarked on the recent demise of krill and hake stocks, which he thinks are linked, and which may also be linked to large scale oceanographic processes (El Nino).

C. An account of acoustic surveys by D. Mackas et al. in Jervis Inlet between 1991 and 1996, is available on the IOS home page http://www.ios.bc.ca/ios/plankton/~romaine/psarc96.htm). There were large fluctuations in biomass both seasonally and interannually (3-10 fold), but declines could not be attributed to fishing efforts, and were ascribed to natural causes.

WORKING GROUP DISCUSSIONS

The participants of the meeting were invited to join one of two working groups, each to discuss the following questions:

Working Group 1:

1. What should be the conservation objectives related to fisheries on forage species?
2. Under what fishery conditions can the full set of objectives be met?
3. What are the appropriate target and limit reference points for fisheries on forage species - using krill as an example?

Working group 2:

1. Is a "refined" CCAMLR model applicable to the Scotian Shelf?
2. How do we best estimate the biomass of krill (tools)?
3. What would be the appropriate sampling design for the Scotian Shelf?

The results of the working group discussions are reported below.

Working Group 1 (R. Stephenson, chair)

The working group first defined forage species as being:

- low on food chain
- critical position in food web
- high predation mortality

Under these criteria, a number of existing (herring, capelin, shrimp, and squid) and candidate (billfish, krill, sandlance, and copepods) would be classified as forage species fisheries. When considering the objectives and strategies established in harvesting these fisheries, one must take into account the fact that Canada has accepted FAO Code of conduct, and Precautionary approach. This implies that the evaluation of the level of risk of any new/ proposed fishery should be in context of all other species at same trophic level. Thus, there may be instances where risks may make it inappropriate to exploit some key forage species in some or all parts of their range. The opinion was expressed by some that it may in fact be inappropriate to exploit some key forage species at any time, anywhere. It was clarified, however, that the issue in the case of the krill was that the risk profile of harvests had not yet been estimated (even though it was considered low) and not that any risk level, however low, was unacceptable. It also implies that the standard of proof used should be commensurate with the risks.

The working group considered that the following could be considered as conservation objectives for fisheries on forage species:

- maintenance of ecological relationships/ ecosystem integrity
- minimization of risk of irreversible decline
- maintenance of ecosystems and constituent species within bounds of natural fluctuation
- maintenance of full recruitment potential (including genetic diversity) of target species under likely range of environmental conditions

- allowance of fisheries which meet conservation objectives and which generate maximum knowledge returns

Further desirable attributes are that economic rent should exceed full costs of management and that one should use fishing technology which minimizes impact on non target species and habitats.

Regarding the questions ‘Under what conditions...’, the following conditions should apply:

- the knowledge base must be adequate to allow risks to be evaluated and risks should be shown to be acceptable.
- there should be confidence that fishery can be monitored and controlled and that decisions (i.e. responses to changes) will be made and implemented in a timely fashion.
- monitoring of the direct impact on target species and of direct and indirect impact on ecologically related species including by-catch is required.
- information on natural levels of fluctuations in species and ecosystem and where we sit in relation to these should be assessed (to allow the formulation of acceptable levels of perturbation)
- proponents should bear the incremental costs of acquiring knowledge and managing fishery

Regarding the question on reference points, there are both Limit and Target Reference Points to consider. The former should never be exceeded while the latter represent desirable system properties to be achieved. Limit Reference for consideration include:

- portion of virgin biomass - above level of negative impact on predators
- minimum SSB of target species
- need for measurable, indicative property of key dependent species as indicator of impact (to be developed), all with agreed actions

A target reference point would be to keep SSB in range where the probability of poor recruitment is minimized or at least does not increase, and resilience to negative environmental impacts is maximized. There was not adequate time for the group to investigate limit and target reference points further. This is a complex topic that requires further development and discussion.

Working Group 2. (M. Chadwick, chair)

The answer to the first question lead to a general discussion of the CCAMLR model, which followed the lines shown below, and during which it was concluded that the CCAMLR model could be applied to a krill fishery on the Scotian Shelf and surrounding areas.

- Removals are expressed as a constant catch over a relatively long term period. This is useful for economic planning
- The model determines levels of removal in terms of risk: high versus low risk outcomes of harvesting levels
- There is no requirement for annual estimates of biological growth or biomass.
- The results are simple to explain to managers and other stakeholders.
- The complexity of the model can be increased in response to increased information.
- The model could provide a template for the Scotian Shelf , although this would be a modified version of the original and should be viewed as a pragmatic interim scientific solution which would be modified as the information base increases.

It was recognised that implicit in the first question was the necessity of defining the parameters that would be needed to run the CCAMLR model for a krill fishery on the Scotian Shelf. These were:

- Maximum age of krill
- Variation in recruitment - which requires sampling over the whole shelf population, data which cannot be obtained from commercial tows
- Natural mortality
- A survey of biomass and its variance
- Maturity ogives
- Selectivity ogives
- Growth curves

The third question related to the design for a survey appropriate for the Scotian Shelf. The group concluded that:

- Some seasonal growth and recruitment data could be obtained by analysis of existing samples (SSIP - data over 5 years)
- There should be a synoptic acoustic survey of the Shelf and surrounding areas (e.g. Laurentian Channel, Bay of Fundy etc.), which should encompass a regular series of net tows.
- The design should be one of random parallel transects with some stratification to reflect the known and expected distribution of krill
- There should be target trawls at the shelf break, where species diversity is highest
- Industry could finance (part or all of) the project
- A net survey could not be substituted for the acoustic survey, because of net avoidance with small nets and under-sampling of young stages with commercial nets

In addition the group also discussed the possibility of the industry providing scientific information. The group concluded:

- The fishery cannot provide all the information necessary to run a CCAMLR type model
- The fishery can provide biological samples for length determinations, which will show which segment of the population they are taking
- The fishery can provide a "random time" log, such as has been used in the Antarctic fishery to record activities (searching, fishing, processing etc.) to enable an assessment of fishing effort.
- The fishery can provide a fishing log.

This working group recommended the following action items:

- The CCAMLR scientific reports should be purchased and kept in the BIO library. (These describe the way in which the CCAMLR approach was reached, and document its acceptance by the international community)
- The SSIP samples should be re-analyzed to identify krill by species, and to construct length-frequency distributions (although it has subsequently been pointed out that only samples collected at night should be used, since tows were only to 200 m, i.e. to depths shallower than the daytime depths frequented by most of the population)
- The Scotian Shelf should be sub-divided into stock units
- The possibility of carrying out the acoustic survey of the Scotian Shelf should be examined. In particular the acoustics equipment options (rental, industry involvement) should be examined
- A working group should be set up to implement the CCAMLR model for krill on the Scotian Shelf

Additional points were made:

- It is essential to develop the survey and model now, before any commercial fishing has occurred
- It would be advantageous to continue to share experiences from other krill fisheries around the world (e.g. more active involvement in CCAMLR)
- It is not necessary to produce annual advice for a krill fishery (provided an ecosystem monitoring program is in place)
- A synoptic survey is essential (one ca. 4 week cruise, not a number of shorter ones)
- Programs should be developed to improve our estimates of biological parameters
- Examination of historical data and local experience at BIO can be used to great advantage

PLENARY SESSION

On Friday morning, the groups met in Plenary Session and presented their results for general discussion. There was a relatively high degree of consensus that the CCAMLR approach should be used to assess TACs for krill and other forage species on the East Coast. Some participants, however, did not like the idea that low level exploratory fisheries could be allowed before the appropriate modeling had been conducted for the target species and before the relevant ecosystem monitoring programs were in place (See Appendix V). In the particular instance of the proposal for a low level krill fishery, it was felt that a credible estimate of the pre-fishery biomass of krill on the Scotian Shelf would be needed, even though it was agreed that current estimates were low, and that the proposed 1,000 ton catch was only about 1 % of this low estimate. The question which applies here and to all new potential forage fisheries is how to assess the level of risk, when the level of knowledge is poor. It was suggested that the coupled approach of setting catch levels based on single species models, together with an ecosystem monitoring program directed at dependent species (i.e. the CCAMLR approach) would be acceptable to a wide variety of stakeholders. The inclusion of pre-agreed remedies in response to ecosystem change would also be necessary. It was noted that the possibility of small-scale operators participating might be limited if the incremental costs of such ecosystem monitoring programs were to be fully borne by the proponents.

CLOSING REMARKS

The convenor, Dr. E. Head thanked the assembly for their ideas and lively debate over the duration of the workshop. A good foundation has been laid for the further development of protocols required to manage fisheries on forage species. It was noted that the RAP Steering Committee would consider the discussion conducted during the workshop and make a series of recommendations for action to DFO line management.

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APPENDIX I. List of participants.

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APPENDIX II. Workshop Agenda

Wednesday, April 2

09:00 Opening remarks - John Loch (DFO/BIO)

SESSION I. How can the Question of Ecosystem Integrity be addressed in relation to Krill and Other Forage Fisheries? - a Global Overview

09:15 Recent developments in International Law - Application of the Precautionary Principle and the Precautionary Approach (J. Rice, DFO/NHQ)

09:45 The other fishing mortality. The need for increased forage considerations in fisheries management (R. Stephenson, DFO/SABS)

10:30 Coffee

10:45 Krill fisheries of the world and their management (S. Nicol, Australian Antarctic Division)

11:45 General Discussion

12:00 Lunch

13:00 Krill management in a single species context: Acoustic estimation of krill abundance (I. Everson, British Antarctic Survey)

13:30 Krill yield model development and application in CCAMLR (D. Agnew, Imperial College, Univ. of London)

14:00 Ecosystem integration: CCAMLR's approach to ecosystem considerations. The ecosystem monitoring programme (D. Agnew, Imperial College, Univ. of London)

14:30 CCAMLR's approach to the integration of ecosystem considerations into management of krill (I. Everson, British Antarctic Survey)

15:00 Coffee

15:15 The role of krill in ecosystem structure in the Bering Sea (D. Bowen, DFO/BIO)

15:30 Approaches to setting quotas when actual data is limited (R. Mohn, DFO/BIO)

16:00 General Discussion

Thursday, April 3

SESSION II. The Canadian Experience on Krill Fisheries

09:00 Assessment of the abundance and distribution of krill on the Scotian Shelf (D. Sameoto, DFO/BIO)

09:45 Krill and copepod harvesting in the Gulf of St. Lawrence (J. Runge, DFO/IML) (to be presented by Doug Sameoto)

10:15 Coffee

10:30 Description of the krill fishery in British Columbia (R. Tanasichuk, DFO/PBS)

11:30 General Discussion

11:45 Workshop Steering Committee meeting to decide on the distribution of topics and participants among working groups

12:00 Lunch

Working Group Discussions

13:15 Working groups meet to discuss topics

16:30 End of Session

Friday, April 4

09:00 Plenary Session to report on Progress in Working Groups and reconstitution of Working Groups

10:00 Working groups meet to discuss topics

Plenary Session

11:45 Plenary Session to report on Progress in Working Groups

12:15 Lunch

13:15 Steering Committee meeting to discuss main conclusions of Workshop

APPENDIX III. RAP Steering Committee Recommendations

Recommendation 1.

The conservation objectives for forage fisheries agreed upon by the workshop are endorsed by the RAP Steering Committee and are as follows:

- to maintain ecological relationships/ecosystem integrity
- to minimize the risk of irreversible decline
- to keep ecosystems and constituent species within the bounds of natural fluctuation
- to maintain full recruitment potential (including genetic diversity) of target species under the likely range of environmental conditions.
- to allow fisheries which meet these conservation objectives and which generate maximum knowledge returns

Recommendation 2.

The CCAMLR approach be adopted for the management of forage species (existing and emerging) on the East Coast. In addition, DFO staff should become more involved with CCAMLR than it has until now. This will aid in the long-term development of regional expertise on the management of krill and other forage species.

Recommendation 3.

The decisions made on these fisheries and their scientific justification must be credible to a broad range of stakeholders. DFO needs to maintain and invigorate its commitment to an open process, where all stakeholders can participate and are confident of their access to all relevant information.

Recommendation 4.

The CCAMLR model requires knowledge of biomass and various biological parameters (e.g. population age structure). In the case of the proposed krill fishery, an initial synoptic acoustic survey of the Scotian Shelf, with ground truthing net tows, is required to assess virgin biomass of the krill. It should be noted, however, that the CCAMLR approach does not require this survey annually. Assessments of age structure and other parameters could be made during such a survey and variations in these could be assessed by analysis of existing samples, including those collected during the SSIP program.

Recommendation 5.

The CCAMLR approach requires ongoing monitoring of the biological health of dependent species. These include species that are likely to be impacted, but not necessarily the most potentially impacted, and those species that are tractable for cost-effective monitoring. In the case of krill, one such species would be hake, and for existing forage fisheries such monitoring species could be identified and steps taken to initiate monitoring programs, cost-shared with the proponent.

Recommendation 6.

There is a need to define a consistent and credible method for estimating the risk of taking the first step towards any forage fishery. This is a complex topic which warrants a workshop at either the zonal or national level. Until such guidelines can be developed, it is essential for proposed fisheries be considered as scientific monitoring exercises during which the emphasis is on data collection and harvest levels are low in relation to the size of the known resource.

APPENDIX IV. Presentation Abstracts

The precautionary approach and fisheries on intermediate trophic levels

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The precautionary principle is a highly proscriptive principle, developed to address pollutants traceable to a point source. First adopted by the German government in 1980, is rose in prominence at the Intermediate Ministerial Meeting (of EU Ministers of the Environment) in London in 1988, where it was adopted at the London Declaration.

The Rio Convention of 1992 modified the precautionary principle into the precautionary APPROACH, as part of the Rio Declaration and Agenda 21. Several scientific meetings and documents since that time have worked to specify how the precautionary approach would operate in fisheries management. Some of these agreements may be binding in international law; others have strong moral weight in influencing government practices.

The precautionary approach stresses:

- Being more cautious as uncertainties become greater
- Defining precautionary limit and target reference points
- Using management strategies which make it unlikely that limit reference points will be approached
- Establishing with industry pre-agreed actions which will be taken if limit reference points are approached
- If a natural event has adverse impacts of a stock, taking actions which ensure fisheries do not amplify the impacts of the environmental event.
- The standard of proof for a decision should be proportional to the risks, taking account of the potential benefits

To implement the precautionary approach in fisheries, among the things which are needed are biologically realistic reference points, and methods for estimating the probability / risk that a stock is approaching or exceeding them. That need has prompted much scientific activity, and new or improved analytical tools are emerging quickly. Almost all of these tools are for single species applications, however. The need for a larger ecosystem perspective is acknowledged, but has been given a secondary priority.

When considering fisheries on intermediate trophic levels, the multispecies concerns become an extremely high priority. It is essential to know the level of predation mortality the species will experience, whether one is estimating the degree to which a reference point for a trophically intermediate species is risk averse, or the likelihood a reference point will be approached. There seem to be two approaches to obtaining such estimates:
Work down the food web from existing fisheries assessment models towards prey of the species presently modeled.
Take food web or ecosystem models and have them predict parameters of relevance to fisheries management as presently practiced.

MSVPA is the most fully developed model for adding predator - prey interactions to stock assessment computations. It incorporates both the data sets (commercial catch at age, survey indices, etc) and analytical algorithms characteristic of single species SPA, as well as stomach contents data for all the species one chooses to include in the model. MSVPA partitions the natural mortality parameter of single species SPAs into a portion attributed to predation by other species in the multispecies model, and the remainder due to other sources. The "other" natural mortality is still fixed outside the model. The predation mortality parameters (one for each combination of predator species and age, prey species and age, and quarter) are estimated iteratively with traditional SPA numbers at age and fishing mortality at age.

MSVPA is not the only multispecies assessment model. There are at least two assessment models for use in boreal cod - capelin systems; BORMICON and MULTSPEC; as well as some excellent models which are basically single species SPAs that use predation models to produce recruitment forecasts or explain variation in past year class strengths.

None of these multispecies assessment models will be much help in setting reference points or evaluating risks in krill fisheries. The boreal models focus on spatial migratory dynamics of the predators and prey. The predation - on - recruits models ask fundamentally different questions than are relevant for evaluating fisheries on krill. MSVPA addresses the proper question, but requires more stomach data from predators than will be available, a time series of catch (or at least abundance) data on the krill as a prey species, and that a significant part of the total mortality on the prey (krill) be caused by either the fishery or the other predators whose populations are being modeled within MSVPA. These conditions will not be met for krill on the Scotian Shelf.

There is little more justification for optimism that food web models can be structured to provide outputs directly applicable to management decisions. Qualitative models which merely reflect trophic linkages cannot produce quantitative reference points or risk estimates. They merely organize representations of possible relationships.

Quantitative food web models of marine systems based on predator - prey equations (Lotka - Volterra, Michaelis - Menton , etc) suffer from instabilities due to indirect competition & predation (multiple pathways between nodes), life history omnivory (different ages/ life history stages feeding at trophically different levels) , and narrow "waists" (a small number of intermediate species are connected to many prey below and many predators above). Any one of these properties will ensure directional instability to predictions of consequences of perturbations like fishing. The models will collapse, or will predict that anything can happen.

Mass balance ecosystem models do not have the predator - prey algorithms to cause analytical instabilities. However, there are multiple pathways among boxes, and generally too few data to constrain the family of parameter estimates. Such models cannot predict how consequences of a perturbation (e.g. a krill fishery) will be distributed among all the boxes (species) linked to the perturbed box either upward (predators on krill) or downward (prey or competitors of krill). Moreover, these models are not structured to deal with uncertainty at all, let alone in a context of quantitative risk evaluation. Any level of risk chosen as a limit or target can be exceeded, simply by greater and greater disaggregation of components in the mass - balance models.

I believe these are nearly fatal flaws for using existing SPA or food web models to evaluate the consequences of krill fisheries in quantitatively reliable ways. Different approaches must be explored. Risk evaluations will have to confront uncertainty directly, rather than burying it in unreliable models. When ecosystem relationships are a major consideration in making precautionary decisions, scientists and manager may require very different evaluation criteria than we are used to using when managing single species fisheries. The work of the ICES Working Group on Ecosystem Effects of Fishing has begun to explore such criteria and associated models. The results of the work they have begun may be extremely valuable in providing frameworks for precautionary management of fisheries on species at intermediate trophic levels.

Increasing forage considerations in management: The other F?

(Based on a paper presented at the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Anchorage, Alaska. November 13-16, 1996)

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It is common fisheries evaluation and management practice to partition mortality into that resulting from fishing (F) and that from all other "natural mortality" causes (M). Forage considerations, or the trophic contributions made to predatory species, usually are considered part of a natural mortality rate, which most often is assumed to be a constant value. However there has been increasing awareness, interest and concern about the necessity to include forage considerations as a specific factor in resource evaluation of common prey species (such as krill), and as a quantifiable element in "ecosystem" or multi-species management. More recently there has been the call for explicit inclusion of forage considerations in management objectives and allocations. It is predicted that explicit consideration of forage issues will be required as the changing philosophy of management moves towards a Precautionary Approach. Primary forage relationships should be considered as a specific term in the partitioning of total mortality.
Recent attempts to include forage considerations specifically in evaluation and management indicate that it is difficulty to do. The issue is complicated by a lack of information on the dynamics of non-commercial forage species, and on the degree of reliance on specific prey species by particular predators. Resolution of these issues requires both improved knowledge of the dynamics of forage species, and development of a context in which available information can be most optimally used in evaluation and management. It appears that proper consideration of the role of significant prey species as forage for other species represents an important, but as yet unarticulated, management objective.

Introduction

Approaches to the management of fisheries, and to the care of aquatic systems generally, are changing. There is an increasing movement towards explicit consideration of the full range of impacts of management actions. With this will come more emphasis on forage issues.

Krill like other so-called "forage" species is abundant, schooling, low on the food chain, and preyed upon by many species of seabirds, marine mammals, and other fish so as to be considered "important" in the food web. The forage issue should include not only the dynamics and management of these forage species themselves, but also management in reference to forage - for example how these species are managed in relation to their predators and prey.

Evidence of the growing forage issue

There has been increasing public awareness of the importance of species at lower levels of the food web (including forage species), and increasing awareness of interactions and tradeoffs in management involving forage species. These have been reflected in questions from interested parties, resulting in articles in the media, and in political issues, such as:

- criticism of proposed development a new fisheries for species (e.g. krill) which are considered important forage species;
- criticism of existing fisheries on forage species (such as herring, sand lance, capelin), on the basis that fisheries are reducing forage for segments of the ecosystem such as marine mammals or birds;
- suggestions that fisheries on forage species (such as herring) be reduced to allow for the recovery, or maintenance, of other fish stocks (such as depleted groundfish stocks); and

- suggestions that management should be taking a more "ecosystem" or multi-species approach.

Stock assessment and advisory bodies face increasingly complex stock assessments, and increased requested from clients, as a result of forage considerations. Recent reports of the International Council for Exploration of the Sea (ICES) Advisory Committee on Fisheries Management (ICES 1996a, 1997a), for example, illustrate the growing forage issue by consideration of items such as:

> 1) the effect of northeast Atlantic sandeel fisheries on local aggregations of sandeels in sensitive areas close to important wildlife assemblages such as seabird colonies. This request was the result of "public concern over the large-scale harvesting of fish species which constitute the prey of other fish, birds, and marine mammals" (ICES 1997b).
>
> 2) Assessments for Arctic cod, haddock and capelin which had been revised due to progress in understanding the pivotal role of capelin abundance as a forage species for cod and haddock, and an increase in predation and cannibalism by cod in the absence of capelin (ICES 1997c; see below).
>
> 3) The recent issue of poor juvenile Atlantic salmon survival - perhaps the result of predation or of changes in available forage for juvenile salmon while at sea.
>
> 4) Changes in growth rates or maturity ogives presumed to be linked to forage, and of natural mortality of some species, resulting from multi-species VPA (MSVPA) calculations.

In the western Atlantic, there are questions regarding the impact of changing forage considerations of recovery of the 4VsW cod stock. The grey seal population has been increasing rapidly off eastern Nova Scotia. Cod is a forage species for seals, making up about 15% of the seal diet in spite of reduced cod abundance (DFO 1996). A model of grey seal predation on cod (Mohn and Bowen 1994) indicated that predation by seals on cod is substantial, and that it increased by about 12% in 1995 over 1994. The coincidence of an increase in predation with an apparent period of low production and reproduction for cod is considered to be increasing the ecological pressure on the cod population.

Similarly, there are questions concerning the impact of changes in community structure and forage relationships on Georges Bank off the northeast coast of USA. Perturbations due primarily to heavy fishing pressure over the past four decades on Georges Bank are hypothesized to have resulted in a change in species composition, and energy flow (Sherman et al 1981, Fogarty and Murawski in prep). There have been major shifts in the forage fish assemblage (herring/mackerel/sand lance), and an increase in the abundance of species of low commercial value has been documented, with an apparent replacement of gadoid and flounder species by small elasmobranchs (dogfish and skates). It is hypothesized that a change in forage relationships may be further hampering stock recovery of commercially important groundfish.

It seems inevitable that future fisheries resource evaluation and management will require explicit consideration of forage and multi-species issues such as these.

Forage considerations

Past fisheries evaluation and management has included forage relationships along with other non-fishing or "natural" mortality. The usual approach has been to partition total mortality (Z) into that resulting from fishing (F) and that from all other "natural mortality" causes (M):

$$Z = F + M$$

While forage considerations have been included in the equation, management has, of course, focused on fishing mortality. Natural mortality has most often been an assumed value (often 0.2) and has usually been assumed to be constant.

Increased consideration of forage relationships would require explicit consideration of mortality to key predators, so that total mortality would become the sum of Fishing mortality + Forage mortality + other natural Mortality:

Z = Fishing + Forage + M

The creation of a specific term for forage mortality would raise the profile of this issue, and would provide the context for evaluation of the forage interactions. Perhaps more importantly, it would provide the focus the establishment of management objectives which would guide decisions with respect to forage considerations.

It is anticipated that the forage term would be a composite of specific predator-prey relationships (e.g whales, cod, etc). It would probably not include all predation - but a number of specific interactions which are considered dominant or in some other way of particular importance to management. Specific consideration of these major relationships would ensure, for example, that the fishing F does not compromise forage.

Recent attempts to include forage considerations in assessment and management

The state of management with respect to forage issues is illustrated by the following recent examples from the north Atlantic.

Multi-species VPA

The multi-species VPA (MSVPA) which dates from 1979, is one of the most successful multi-species models in fisheries (Magnusson 1995). Developed within the ICES (International Council for Exploration of the Sea) community, it has been applied primarily in the North Sea and Baltic (ICES 1996b, Sparholt 1991). In North Sea applications, it commonly includes four prey species (sprat, herring, Norway pout, and sandeels; two predators (saith and mackerel), and three species which feature both as predator and prey (cod, whiting, and haddock). MSVPA is a direct extension of single species models. It partitions total mortality (Z) , not only into F and M; but M into M1 and M2 - where M2 is the predation mortality due to specific predators included in the model, and M1 is the residual natural mortality:

Z = F + M + M2

M2 is calculated inside the model, taking into account prey availability, size , and suitability as prey for the predator.

Use of this model for the past decade has given considerable insight into the magnitude of feeding relationships. Importantly it has indicated that natural mortality rates for a number of forage species are higher than previously assumed, and are likely to be variable from year to year. These revised natural mortality estimates and knowledge of feeding relationships have been used in traditional single species VPA assessments. But multispecies models (e.g. MSVPA) have not yet led to multi-species management (Sissenwine and Daan 1991, Magnusson 1995). This seems to be due to continued scientific uncertainties concerning complex feeding relationships, and perceived difficulties in gaining acceptance of multi-species management advice (Magnusson 1995).

The most recent report of the ICES Multi-species Assessment Working Group (ICES 1996b) describes two other models currently being developed for boreal systems: MULTSPEC (developed at the Institute of Marine Research in Bergen, Norway) which has modules to simulate many types of multi-species interactions in the Barents Sea, from primary production to marine mammals, and BORMICON (developed at the Marine Research Institute in Iceland. Advice for these species now considers the need for management of the three species in the context of their impact on one another.

Multi-species management off Iceland

Multi-species biological, assessment and harvesting models have been used to develop management strategies which include forage considerations in Icelandic waters (Stefansson et al 1995). These have included management of cod in light of its impact on capelin and shrimp (forage) fisheries. Recent modeling studies have indicated that continued increase in whale populations will result in reduced cod production (a 10% reduction in the fishery is estimated), due to forage competition.

The requirement for explicit consideration of forage issues

Further impetus for consideration of forage issues in fisheries management comes from international agreements adopted by many countries in recent years, including the Rio Declaration on Environment and Development, the United Nations Conference on Highly Migratory Fish Stocks and Straddling Fish Stocks, and the FAO Code of Conduct for Responsible Fisheries. These agreements contain statements which can be transcribed into specific objectives regarding the need to include forage considerations in management. The Code of Conduct for Responsible Fisheries (FAO 1995a) is a good example. It states, under general principles:

"6.5 ...should apply a precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment, taking account of the best scientific evidence available. The absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or dependent species and non-target species and their environment"

Further with respect to the precautionary approach, the Code states:

7.5.1 " States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment. The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures."

7.5.2 " In implementing the precautionary approach, States should take into account, inter alia, uncertainties relating to the size and productivity of the stocks, reference points, stock condition in relation to such reference points, levels and distribution of fishing mortality and the impact of fishing activities, including discards, on non-target and associated or dependent species as well as environmental and socio-economic conditions."

The topical move towards management based on the "precautionary approach" will require major change in the current approach to fisheries management. The precautionary approach requires use of the "best scientific evidence" speaks of a broad consideration of impacts, and that "absence of adequate scientific information should not be used as a reason for postponing or failing to conservation and management measures". While forage does not appear to be mentioned explicitly in these agreements or in recent key papers on the topic (e.g. FAO 1995a, 1995b, Garcia 1994, 1996), it is quite apparent that forage considerations are implied in this initiative which links fisheries management intimately with environmental management. The reference in the code of conduct to management of "associated or dependent species and non-target species and their environment" would seem to be a clear reference to forage considerations of the type discussed at this Symposium. Further, the recent paper by Garcia (1996) resulting from a June 1995 consultation on the precautionary approach to capture fisheries, contains two particularly relevant practical guidelines:

#14 "expand the range of fisheries models (e.g. bio-economic, multi-species, ecosystem and behavioral models), taking account: (a) environmental effects; (b) species and technological interactions, and (c) fishing communities' social behavior;" and

#17 "develop scientific guidelines and rules for multi-species and ecosystem management as a basis for agreement on acceptable degrees of disturbance".

Context for future management

Multi-species management will be difficult, however I suggest that multi-species consideration, including forage relationships, must be worked into management particularly under the precautionary approach. This can only be done if forage considerations become a part of specific objectives in management, under an appropriate management context, or framework.

A number of recent papers have pointed out the problems associated with management of fisheries generally - caused in part by the inherent complexity and variability of marine ecosystems, the unobservable nature of aspects of the natural dynamics of fish stocks, multiple and conflicting objectives, and management systems that are not responsive to required rapid change. In previous papers (Stephenson and Lane 1995, Lane and Stephenson 1995) we proposed adopting techniques developed in the field of management science to meet an urgent need to improve fisheries evaluation and management by moving towards management of multiple objectives. This calls for the merging of previously disparate disciplines of fisheries science, fisheries management and management science into a new discipline Fisheries Management Science (FMS) which would involve "the rigorous application of the scientific method of problem solving in the development of strategic alternatives and their evaluation on the basis of objectives that integrate biological, economic, social, and operational factors into management decision making". This framework would facilitate the management of forage considerations which would become articulated as specific objectives, and which would be the subject of evaluation, management and review.

Several forage species (e.g. herring, sardine, anchovy) are subject to large fluctuations and rapid change in the absence of fishing, and with fishing pressure become vulnerable to very rapid stock collapse. In these cases it is especially important not only to determine appropriate targets and thresholds , but also to use these in a management system which can react quickly (e.g. Stephenson 1997).

The major future issues concerning management with respect to forage considerations then involve both the dynamics of forage species, and the context in which forage can be considered in management. Important elements would appear to be as follows:

1) Improved biological basis for management of forage species:

- continued improved understanding of forage relationships and mechanisms, including better definition of preferences and prey switching

- development of appropriate biological reference points for key prey (=forage) species and predators; and

- development of an expanded range of fisheries models (e.g. multi-species, ecosystem and behavioral) with which to test scenarios regarding forage considerations.

2) Improved consideration of forage and multi-species consideration in management:

- development of management consistent with the Precautionary Approach;

- development of specific objectives which reflect forage considerations; and

- development of appropriate harvesting strategies which explicitly address forage issues.

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Krill fisheries of the world and their management

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Krill (euphausiids) have been viewed as a possibly the largest single untapped source of harvestable marine protein yet they have only been commercially harvested in a small number of locations and these fisheries are relatively recent developments. Perhaps the best known krill fishery is that for Antarctic krill (Euphausia superba). The catch of Antarctic krill reached over half a million tonnes a year in the 1980s when the Soviet Union was the major fishing nation, but it has undergone a series of fluctuations since then and in 1995/96 only 95,000 tonnes were harvested - all from the South Atlantic. Antarctic krill are caught near the continent in summer but there is also a fishery around South Georgia in the wintertime. Most of the krill is caught by Japanese vessels (64%), Polish vessels catch 21% of the catch and Ukrainian vessels, 14%. The fishery for North Pacific krill (Euphausia pacific) is less well known but has reached levels of over 100,000 tonnes a year in the waters off Japan in the early 1990s. Currently, the harvest for this species is somewhat smaller (60,000 tonnes per year). This species is also the subject for a small-scale commercial fishery off the coast of British Columbia, Canada which has been under way since the 1970s. Two other species (Euphausia nana and Thysanoessa inermis) are the subject of small-scale fisheries off the coast of Japan with less that 5,000 tonnes being taken. Recently, there have been moves to establish fisheries on species of North Atlantic krill off the East coast of Canada and there has been speculation about experimental krill fishing off the South East coast of Australia.

Krill as a product have a number of problems including: rapid spoiling, high shell fluoride levels and a generally small size. These problems have restricted the growth of krill fisheries. Currently most of the krill catch is used in aquaculture and it is to service this industry that most of the likely expansion of these fisheries will occur. Krill is also used for human consumption, for aquarium fish feed and for sport fishing bait. There are a number of valuable chemicals found in krill (chitin, proteolytic enzymes, pigments and fatty acids) and development of the use of these is also a pointer to future expansion of krill fisheries.

There are a number of recent developments that point to an increase in krill harvests worldwide and this development will bring with it a number of management challenges. Because the market for krill is likely to be a global one, management restrictions in one area will put pressure on krill stocks in another. Currently, widely different approaches to management are adopted in each of the existing krill fisheries but there are a number of initiatives to generalise the findings from the different fisheries and to adopt common management approaches.

The Antarctic krill fishery has probably the greatest potential for expansion and the combined precautionary catch limits on krill in the area managed by the Commission for the Conservation of Antarctic Marine Living resources (CCAMLR) currently stand at 1.95 million tonnes. Precautionary catch limits are calculated to be a conservative estimate of what can safely be taken without contravening the underlying principles of the convention which requires an "ecosystem approach" to management and specifies that the needs of dependent and related species be taken into account when setting fishing limits. They are calculated using a mathematical model (see text by Agnew) and this requires information on the distribution and biology of the krill population. The primary pieces of information are: an estimation of the pre-exploitation biomass (B0), estimates of recruitment proportion and its variability and knowledge of the growth rates of krill. The biomass information comes from acoustic surveys; these have used historical data in the past but there has been a trend recently to designing surveys specifically to provide information so that CCAMLR can calculate precautionary limits. Recruitment proportion and its variability can be measured from samples obtained from representative net surveys of the region. Growth rates are obtained from laboratory measures, field-based approaches and from models of growth trajectories. Interpreting life history information for krill has been frustrated by the apparent ability of adult krill to shrink and regress to an immature form during winter - an ability shared with other species of euphausiids. this feature of their physiology has made ageing of krill problematic. Early estimates suggested that the longevity of Antarctic krill was of the order of 2-3 years; more recent studies have indicated that 5-10 years may be more appropriate.

Krill fisheries require particularly careful management because of the central ecological role of these species in most of the world's marine ecosystems but krill remain one of the world's few marine stocks that could sustain far higher levels of exploitation.

Acoustic Estimation of Krill Abundance

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Three approaches have been used to the estimation of krill abundance in the Southern Ocean. Direct assessment using net surveys, acoustic surveys and indirect methods based on total krill consumption by predators and their turnover rate. Here I address the direct estimation procedures

Acoustics relies on the sound reflecting properties of the target organisms and consequently this imposes several constraints to the method. Firstly, the acoustic systems must be calibrated and stable electronically. Secondly, the system should be appropriate for the target organisms. Thirdly, the target species should be recognizable and easily separated from other acoustic reflectors.

Recent advances in electronics and digital signal processing have meant that current systems are extremely stable, can be calibrated with precision and can also be programmed to take account of local environmental conditions, temperature and salinity. Arising from the current use of digital systems, it is now possible to analyze individual echoes in considerable detail.

Acoustics has the advantage that large areas can be covered at the normal cruising speed of the research vessel. Analysis of the returned echo signal can provide further detailed information at a very fine spatial scale, of the order of centimeters. The acoustic signal provides an indication that something was present in the water which had different acoustic properties to the surrounding ocean but no direct information on the actual cause of the echo. Identification of acoustic targets can be inferred from the composition of net catches, examination of patterns on echocharts and analysis of acoustic data at different frequencies. When the identification of targets has been determined with reasonable confidence, the acoustic signal must be scaled so as to provide estimates of absolute abundance using the target strength. Much work has been undertaken recently on the target strength of euphausiids using empirical at sea observations and models.

The largest acoustic survey undertaken on krill was FIBEX (First International BIOMASS Experiment) during the BIOMASS (Biological Investigations Of Marine Antarctic Systems and Stocks) programme. This involved nine research vessels working for one month and covered large parts of the Atlantic and Indian Ocean sectors of the Southern Ocean. In the Atlantic Ocean sector, randomly spaced parallel North/South transects between 30 and 70 degrees West were surveyed. In the Indian Ocean, the transects were aligned along lines of latitude because of the very much larger area, from 15 to 90 degrees East, that was covered during the survey. A recent survey undertaken by the Australian Antarctic Division covered a further large area of part of the Indian Ocean sector and a small part of the Pacific Ocean sector. The standing stock estimates provided by these surveys have been used by CCAMLR in setting precautionary catch limits for krill.

The CCAMLR Approach

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Although I gave two separate talks at the workshop, one on CCAMLR's Krill Yield model and one on the CCAMLR Ecosystem Monitoring Program (CEMP), for the purposes of this summary they have been combined.

CCAMLR (the Commission for the Conservation of Antarctic Marine Living Resources) approached the management of the Antarctic Krill fishery with many of the same concerns as are now being demonstrated for other fisheries. Krill is an intermediate food web species, and is the principal food for many species of birds, seals and whales and fish (which are themselves the subject of some Antarctic fisheries). At the time that CCAMLR came into force (1982) there was already a substantial krill fishery in the Antarctic - 500,000 tonnes were taken in 1982 (Agnew & Nicol 1996). CCAMLR's Article II sets out the objectives of the Convention, which is (1) to manage fisheries so that harvested populations do not drop below levels which ensure stable recruitment, while (2) maintaining the ecological relationships between harvested and dependent species, and (3) preventing changes which are not reversible in 20-30 years.

Recognising that this sort of ecosystem-based management would be extremely difficult to implement, CCAMLR approached the problem from a number of angles. Firstly, single species methods were used to assess the potential yield available from krill stocks which have lowest risks to the stocks themselves - parts 1 and 2 of Article II. Secondly, predator demands were taken into account in the development of decision rules for defining an acceptable long-term catch from these calculations. Thirdly, an Ecosystem Monitoring Program was implemented to both monitor the predator species involved and to use that monitoring to differentiate between changes due to fishing krill and natural environmental changes.

The krill yield model is well described in Butterworth et al (1991, 1994). The model uses the approach of Beddington & Cooke (1983) to project the dynamics of a krill population over a period of time with random recruitment to establish the probability distribution of risk of population decline for a number of fixed harvesting strategies. The approach actually calculates the value of γ in yield = γ Bo, where Bo is the pre-exploitation biomass of the krill population. The modelling exercise can proceed in the absence of an estimate of Bo, since this is taken to be 1, and will yield a γ value. However, in order to be applied in management, so that a precautionary catch (TAC) can be set, an estimate of Bo is required. This is usually acquired from an acoustic survey (e.g. Trathan et al 1992) but can be estimated from predator requirements. It does not need to be reassessed on a regular basis, because the model is strictly applicable only to the pre-exploitation biomass.

The model runs a population projection 1000 times for each of a number of γ values. For each run natural mortality, length at 50% selectivity, length at 50% maturity, recruitment variability and survey error and bias are selected from random uniform, normal or log-normal distributions. Thus these parameters need not be known exactly, so long as there is some knowledge about their distributions or bounds. Although recruitment variability was originally estimated within some expected bounds, later developments used net surveys of krill from around the Antarctic to estimate observed recruitment variability as an input for the model (de la Mare 1994 a, b). Serial correlation in recruitment could also be incorporated. A deterministic equilibrium age-structure (8 ages) is generated for year 1, and the population is projected with random recruitment for 10 years (until all history of the deterministic year 1 has left the system). A 'survey' is taken of the biomass at this point (taking appropriate random survey error and bias) and the constant catch to be taken throughout the life of the fishery is determined from catch = gBo. The population is then projected for a further 20 years (in accordance with the time scales identified in Article II) under condition of this constant catch - although F has an upper limit of 1.5. Growth and catch is seasonal. Statistics about the spawning stock biomass of the population during this time are acquired over the 1000 models runs.

Two statistics are used by CCAMLR to determine an acceptable level of harvest proportion (g). The first is the probability that the minimum spawning stock biomass over the 20 year period drops to less than 20% of its median unexploited level, which would be of concern in a single-species context. The second is the probability that the spawning stock biomass at the end of the 20 year period is less than 75% of its unexploited median. CCAMLR arrived at this statistic through consideration of predator demands, considering that predators would begin to be affected if the median biomass under exploitation dropped to less than 75% of its unexploited level. Three decision rules arose from these statistics (SC-CCAMLR 1994):

- Rule 1: choose γ1 where probability of spawning stock biomass dropping below 20% of its median level in the absence of fishing, over a 20 year simulation, is 10%. This currently yields $\gamma = 0.149$.

- Rule 2: choose γ2 where the median spawning stock biomass after 20 years is 75% of its median level in the absence of fishing. This currently yields $\gamma = 0.116$.

- Rule 3: select the lower of γ1 and γ2 for the calculation of krill yield.

The krill yield model and its decision rules therefore offer a method of setting precautionary catch limits which consider both the harvested species and its predators, when there is some uncertainty in the assessment of the stock. In general, γ will increase as uncertainty decreases. The choice of limits, especially the limit of 75% of unexploited biomass of Rule 2, is somewhat arbitrary. However, the Rule 1 limits are becoming accepted internationally as appropriate for a precautionary approach, and the Rule 2 limits are considered by CCAMLR to be a pragmatic interim solution to the problem of estimating the escapement from the fishery required to maintain predator populations. There are a number of other modelling initiatives in CCAMLR which attempt to define this limit using empirical predator data (e.g. Butterworth & Thomson 1995) of which the CCAMLR Ecosystem Monitoring Program is an essential component.

The CCAMLR Ecosystem Monitoring Program (CEMP) was set up in 1984 as a response to part 2 of Article II, (SC-CAMLR-IV para 7.2):

- to detect and record significant changes in critical components of the ecosystem, to serve as a basis for the Conservation of Antarctic Marine Living Resources;
- to distinguish between changes due to the harvesting of commercial species and changes due to environmental variability, both physical and biological.

A detailed description of CEMP is given by Everson (this document). The program is a large collaborative international scientific effort - data on 13 predator parameters (such as penguin chick weight at fledging), from 6 predator species, are collected from 12 sites around the Antarctic by 7 CCAMLR Member nations. Data on non-predator parameters are also collected - krill abundance and distribution, sea ice extent and sea surface temperature being among them. Trends and anomalies in what are now about 80 time series of data extending for up to 20 years can be analysed and compared. In addition to being a watchdog for signs of stress to both predators and krill, the result is a very powerful tool for modelling the ecosystem and the way it might respond to changes in krill biomass effected by fishing. Preliminary analyses of some of the datasets have indicated that a significant amount of the variability in predator parameters can be explained by environmental variation. The krill catch is currently so low in comparison the estimated unexploited biomass that it is not altogether unexpected that no effects of fishing on predators have yet been demonstrated. (for instance in the Atlantic sector krill catch is 100,000 tonnes, less than 0.5% of the Bo of 35 million tonnes).

The CCAMLR approach to managing the Antarctic krill, taking into account single species and dependent species requirements, uncertainty and the precautionary approach can therefore be summarised as:

1. set up a program for monitoring the effects of harvesting on critical ecosystem components. Review this program frequently and use it to define items 4-5 as appropriate.

2. define a general production model for krill which allows the setting of long-term, low risk fixed catch allowances and requires a minimum survey effort.

3. run this model with all parameters defined, however uncertainly, by probability distributions;

4. define decision rules for calculation of precautionary catch based on consideration of both harvested species and their predators;

5. refine the model, its inputs and the decision rules as more data become available, but use the 'best available' data to set catch limits.

One of the strengths of this approach is that despite the scientific complexity of satisfying Article II it has been possible to arrive at real management decisions (e.g. catch limits), even when data were limited. The approach is so 'sensible', and the decision rules so simple, that explaining the model and approaches to managers has been relatively straightforward.

Ecosystem Monitoring in the Southern Ocean

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Central to the CCAMLR strategy towards management is the ecosystem approach. This evolved from the BIOMASS programme when Antarctic Treaty Members recognized the potential for ecological disaster if large scale harvesting of krill took place in the absence of rational control. In establishing an ecosystem monitoring programme , CCAMLR was aware that there are a very large number of potential interactions which might be of relevance in providing advice for management. However, in view of the need to establish a coherent and practical programme within a reasonable time frame, the programme needed to be closely focused.

The following thoughts have been behind the identification of components in the CCAMLR Ecosystem Monitoring Programme, CEMP. The species need to have the following characteristics: they should be accessible; they should have some demonstrable ecological interaction and the interaction should be relevant to ecosystem management. This relevance is assessed in terms of the closeness of the links in the food web between the harvested species and the monitored species. A second criterion also applies with regard to the relevance of the monitored species and that is that of those species which are directly affected by commercial activity; this has come to the fore in recent years with the recognition of the high incidental mortality of seabirds which attack baits set by commercial longliners for toothfish and tuna. The final point regarding the choice of species and monitoring parameters has been the one of practicality, the ease of access to sampling sites and the ease with which individuals can be sampled.

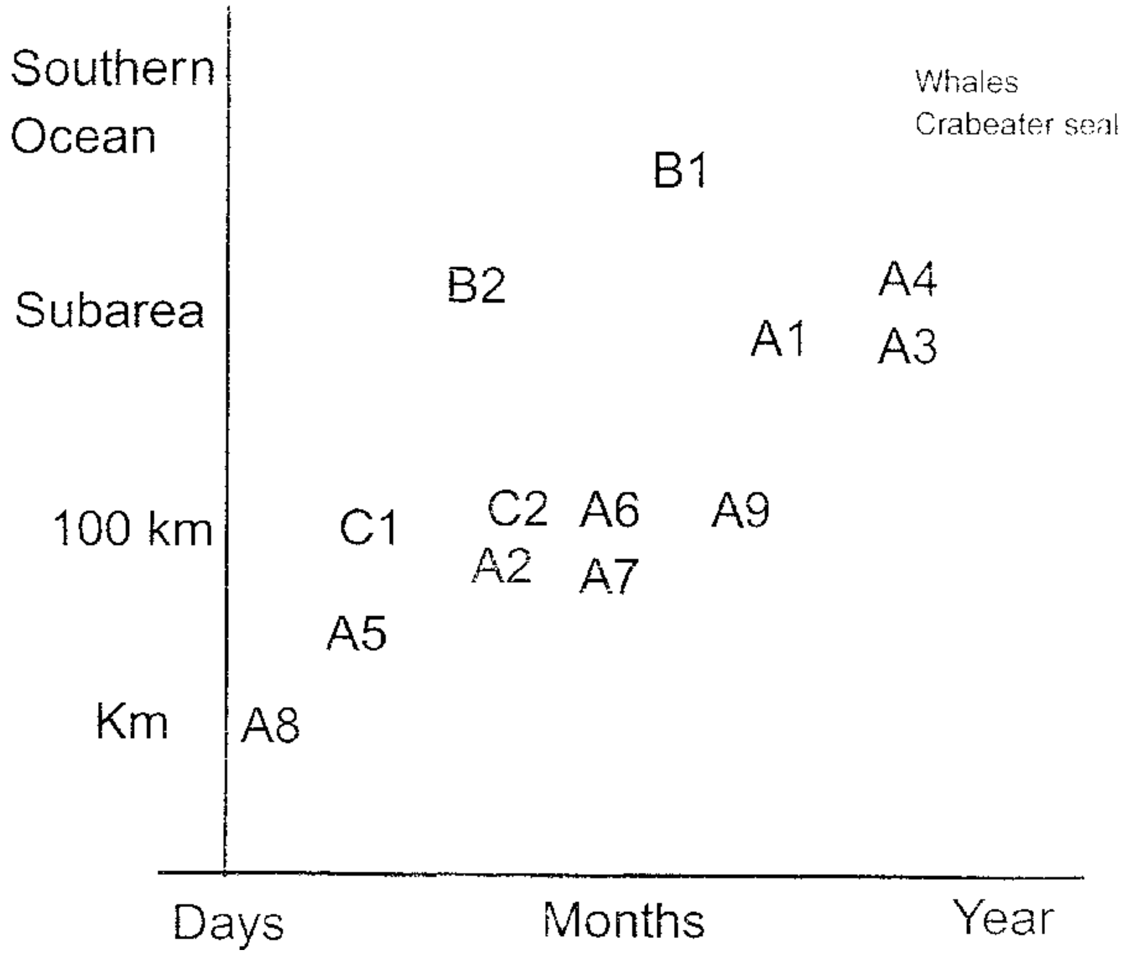
The underlying aim has been to establish a programme which monitored changes in dependent species and allowed a reasoned and objective debate to decide whether any changes were likely to be due to natural causes or else induced by commercial activity. Consequently, the parameters have been chosen so as to provide information over a wide range of time and space scales. Currently the following standard methods are used:

- Adelie, Chinstrap and Macaroni Penguins: (Al) adult weight on arrival at the breeding colony, (A2) duration of first incubation shift, (A3) breeding colony size, (A4) Age-specific annual survival, (A5) duration of foraging trips, (A6) breeding success. (A7) chick weight at fledging, (A8) chick diet, and (A9) breeding chronology.
- Black-browed albatross: (B 1) breeding population size, (B2) breeding success, (B3) age specific annual survival and recruitment.
- Fur seal: (C1) duration of cow foraging/ attendance cycle, (C2) pup growth.

Further parameters associated with baleen whales and crabeater, both of which are widespread over the Southern Ocean have been considered although specific parameters have not been incorporated into CEMP. An indication of the spatial and temporal scale of interactions with krill, the key harvested species, is shown below. The environment is monitored through (Fl) sea ice cover as viewed from the colony, (F2) seaice within the study region, (F3) local weather and (F4) snow cover in the colony. Additional information is derived from national oceanographic programmes and satellite information on sea surface temperature and sea ice distributions.

Krill are monitored directly through the commercial fishery and also through individual studies on krill distribution (vertically and horizontally) and abundance through the national programmes of CCAMLR Members.

Subjective time and space scales for CEMP dependent species parameters.



Importance of krill in the Bering Sea

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Large scale, intensive harvesting of fish and whales occurred during the 1950s, 1960s, and early 1970s in the Bering Sea and Gulf of Alaska. The stocks of large whales, flatfishes, herring, and slope rockfishes were severely reduced during this period (National Research Council 1996). Although, quantitative estimates are not available, this reduction in major consumers of krill and zooplankton is thought to have generated food for other species. This increased availability of krill and zooplankton, coupled with environmental changes, are though to have led to the eastern Bering Sea fish assemblage becoming dominated by one species, the walleye pollock (Theragra chalcogramma). In the 1970s and 1980s, although some finfish populations grew rapidly, a number of forage species appear to have declined. In the face of these changes, both harbor seals and Steller sea lions have declined dramatically over the past several decades. These declines appear to be related to a lack of food, with juvenile pinnipeds likely affected most severely. A likely explanation of these events is that a combination of environmental change and human exploitation of krill and zooplankton predators (both whales and fish) resulted in changes to the ecosystem that have been detrimental to pinnipeds (National Research Council 1996).

NRC. 1996. The Bering Sea Ecosystem. National Academy Press, Washington, D.C. 307 pp.

Approaches to setting quotas when actual data is limited

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Traditional population models were grouped into four categories depending on model structure and data requirements. The first category is age structured models with knowledge of biological and ecological dynamics. The second category was also age structured but the underlying dynamics are less well specified. Assessments of major exploited marine resources (cod, herring, scallops) would fall into this category. The third category is production models which do not require data on age structure and thus is used for many invertebrate and tropical stocks. The final category, which requires the least data, were called depletion model; they require less biological information than the production models and again are often used for invertebrate stocks. Depending on the amount of data available for krill, or other forage species, a class of models can be developed. The major krill fishery in Antarctic waters would be classed as a production model. However there may not be enough information on Scotian Shelf krill to support such a model at this time.

The B.C. Krill Fishery

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The euphausiid fishery in British Columbia began in 1970. Catches were small but a quota of 500 tons was imposed in 1976 because the importance of euphausiids as food for commercially important fin fish was recognized. Catches have increased substantially In recent years and industry is pursuing an increase in the quota. Fisheries and Oceans Canada has rejected requests to increase the quota because of the importance of euphausiids as prey It seems that any quota increase would depend on knowing how productive euphausiids are and what the annual euphausiid ration is for commercially or socially important fish, bird or mammal species. This information gap applies to the proposed fishery on the Scotian Shelf as well.

There is quantitative information on importance of euphausiids to pelagic fish species along the southwest coast of Vancouver Island. Data from the Laperouse Project. which began in 1985, show that euphausiids account for about 90, 100 and 60% of the prey consumed by Pacific Hake *(Merluccius productus),* Pacific herring *(Clupea pallasi)* and spiny dogfish (Squalus *acanthias)* respectively. On average, it is estimated that these species consume 400.000 tonnes of euphausiids annually.

There is also information on interannual variability of euphausiid productivity in the same region. Results of a S-year study of euphausiid population biology and productivity in Barkley Sound, part of the Laperouse study area, show that euphausiid productivity has dropped by 90% after the 1992 and 1993 warm water years. Pacific hake and herring appear to have been affected by this change in productivity. There is anedoctal evidence that hake fisheries are more difficult to prosecute because fish are less aggregated. Adult herring distributions have changed. Preliminary results suggest poor growth conditions for herring as of 1993.

The results of the work off Vancouver Island were presented to illustrate how data deficiencies for the euphausiid fishery in B. C. and the proposed one on the Scotian Shelf can he addressed. What is ultimately required is a sense of how productive a euphausiid stock is, where in the range of variation current productivity levels are at, and how important euphausiids are to other species. The requested quota seems to be a very small fraction of the estimated biomass. Stipulations for any euphausiid fishery should include monitoring euphausiid productivity and the predator species that depend on it.

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DFO Atlantic Fisheries Research Document 96/99

MPO Pêches de l'Atlantique Document de recherche 96/99

ECOLOGICAL FACTORS TO BE CONSIDERED IN ESTABLISHING A NEW KRILL FISHERY IN THE MARITIMES REGION

by

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[1]This series documents the scientific basis for the evaluation of fisheries resources in Atlantic Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the secretariat.

[1]La présente série documente les bases scientifiques des évaluations des ressources halieutiques sur la côte atlantique du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les Documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au secrétariat.

TABLE OF CONTENTS

ABSTRACT

An attempt is made to try .to consider all possible ecological side effects of establishing a new fishery for krill on the Scotian Shelf and environs. First, an estimate of abundance is attempted in the proposed fishing area from published estimates of krill densities and adult habitat . preference. Then, the requested harvest and a calculated exploitation rate are presented. The issue of whether krill harvesting could remove a major food source from other commercial fisheries or other ecologically important species is considered. The same concern is introduced for planktivorous sea birds and certain endangered marine mammals. The issue of by-catch being a potential problem for a krill fishery also is considered. Finally, the Sheldon Size Spectrum Approach is used in an attempt to rationalize and evaluate undercutting the traditional cod- haddock-hake fishery of the region.

RÉSUMÉ

On tente de cemer toutes les répercussions écologiques de l'ouverture d'une nouvelle pêche du krill sur le plateau néo-écossais et clans les eaux environnantes. On fait en premier lieu une estimation de l'abondance du krill dans la région concemée à partir d'estimations publiées des densités de krill et des habitats préférés par les adultes, puis on détermine les prises requises et un taux d'exploitation. On étudie ensuite la question à savoir si la récolte de krill pourrait priver d'autres espèces d'intérêt commercial ou écologique d'une importante source de nourriture. La même idée est appliquée aux oiseaux marins planctivores et certaines espèces de mammiteres marins en voie de disparition. La question des prises accessoires comme un problème potentiel de la pêche du krill est aussi considérée. En dernier lieu, on utilise l'approche Sheldon par spectre de tailles pour essayer de rationaliser et d'evaluer comment la pêche du krill nuira à la pêche traditionnelle de la morue, de l'aiglefm et de la merluche dans la région.

INTRODUCTION

A couple of proposals have been received by the Maritimes Regional Office, Fisheries and Oceans Canada, over the past year seeking permission to fish commercially for species of euphausiids, commonly known as krill. The market for this fishery is in the manufacture of aquaculture feed where krill is used in a processed form as a nutritional additive in pellets. Krill is known to contain a high protein content (60- 70% dry weight), essential fatty acids, and flesh- pigmenting carotenoids which are more than adequate for salmonid aquaculture (Storebakken 1988).

Canada has authorized two previous krill and/or plankton fisheries. An experimental fishery existed on the west coast as early as the 1970s (Heath 1977), and this has developed into a regulated fishery since 1990, with the assistance of annual acoustic assessments of the Strait of Georgia krill populations (Mackas et al. 1996). The annual British Columbia coast-wide quota of 500 t has infrequently been reached in the intervening years, ranging from 53 t to 530 t, up to 1994. Most of these landings come from a small area near Iervis Inlet (Strait of Georgia).

On the east coast, Fisheries and Oceans Canada first issued a scientific permit to harvest zooplankton (both krill and copepods) in the Gulf of St. Lawrence in 1991. An exploratory fishery proceeded for copepods and krill in November 1993 in the St. Lawrence Estuary off Ste-Anne-des-Monts (Runge and Joly 1995). This permit was renewed with a preventative Total Allowable Catch (TAC) of 100 t ofkri1l.and 50 t of Clanusf n 1994, but only 6.3 t and 0.4 t were harvested, respectively. The TAC was increased in 1995 to 300 t of kill and 2000 t of Calanus, but landings were low at 2 t and 1 t, respectively. It was felt that the designated late-fall harvest period was too restrictive to reach the quotas set due to inclement weather at this time of year (J. Runge, pers. comm.).

It is the purpose of this report to best evaluate the potential effect of a new krill fishery in the Maritimes Region, on the shelf ecosystem with the knowledge presently available.

KRILL POPULATION ESTIMATES

There really is not a good measure of euphausiid abundance in the Scotian Shelf (Bay of Fundy Region). There is plenty of information on tow net catch of euphausiids in the region (Lewis and Sameoto 1988a,b,c; 1989a,b; 1990); however, interpretation of these data is fraught with problems. Euphausiid avoidance behaviour of towed nets results in order-of-magnitude lower abundance estimates compared to acoustic estimates (Sameoto et al. 1993). There are also problems associated with surface acoustic measures of euphausiid abundance (Cochrane et al. 1994). It appears that the best abundance estimates that we have are from the bottom-mounted acoustic Doppler current profiler, which overcomes acoustic interference problems in the near-surface waters, and enables an integrated temporal estimate of abundance. Cochrane et al. (1994) used this instrument in the LaHave Basin, in 192 m of water over a 49-day period in late fall, when the two generations of Meganyctiphanes would be present, and calculated that on average over this time period 81.2 g/m2 or 81.2 tJkm2 existed. This is not very different from Cochrane's and Sameoto's (1991) earlier estimate of 79.2 g/m2 obtained in the LaHave Basin with surface .acoustic techniques. They also estimated an euphausiid density of 102 g/m2 for the neighbouring , Emerald Basin (Cochrane and Sameoto 1991).

If we use these values for LaHave and Emerald Basins, and assume a similar density of euphausiids in the Fundian Channel (ignoring the shelf break population indicated in Sameoto's and Cochrane's [1996] shaded-in chart), we arrive at:

	Area (km2. within 100 fathoms)	Density (t)
LaHave Basin	3578	290,549
Emerald Basin	4108	419,031
Fundian Channel	9629	781,923
Total		1,491,503

If this estimate is realistic, the initial proposal received by DFO to harvest 1,000 t represents 0.06% of the standing stock.

ALLOWABLE EXPLOITATION LEVEL

The author has spoken to Dr. Robert Mohn (DFO, Dartmouth, N.S.) about the request contained in the initial proposal of allowing 2% of the euphausiid biomass to be harvested. Dr. Mohn assured that this level of exploitation was extremely low for an animal with a ~2-year life span and that 20% of an exploited species or 40% of a virgin population is frequently allowed in a commercial fishery. The present rough calculation of 0.06% is many orders-of-magnitude below the so-called safe level of exploitation.

ADULT AND JUVENlLE COMMERCIAL FISH SPECIES

The next issue of concern is whether the removal of euphausiids will have a detrimental effect on existing fisheries. As a start, the summer distribution and abundance trends of species caught on the Scotian Shelf(1970 to 1992) by the research vessel groundfish survey (Simon and Comeau 1994) was used to obtain average abundances of juvenile and adult fishes which are likely to utilize krill and exhibit an overlapping geographic distribution to the proposed harvesting areas (Table 1).

Table 1. Abundance of groundfish and pelagics on the Scotian Shelf and its basins.

	Species	No./tow*
Redfish	Sebastes sp.	1-2500***
Silver hake	Merluccius bilinearis	1-2500***
Spiny dogfish	Squalus acanthias	1-500**
Pollock	Pollachius virens	1-00***
Longfin hake	Urophycis chesteri	1-500
Argentines	Argentina silus	1-500**
Shortfin squid	Illex illebruscus	1-500
Atlantic mackerel	Scomber scombrus	1-250**
Red hake	Urophycis chuss	1-100
White hake	Urophycis tenuis	1-100***
Offshore hake	Merluccius albidus	1-50
Cusk	Brosme brosme	1-20

*Standardized bottom trawl to 1.75 nautical miles;
**Pelagic species such as mackerel, herring, gaspereau, etc., are underrepresented in the catch due to near bottom sampling;
***Some of the demersal fishes spend part of the time in the water column at night feeding, which means that they also would be underrepresented in the trawls, though not as much as the pelagic fishes.

Of this list of species, three are harvested by our fisheries: pollock 4VWX' silver hake 4VWX' and redfish 4WX (DFO Atlantic Fisheries Stock Status Rep. 95/6). Together they comprise 18% of the total catch in metric tons for the Scotian Shelf area in 1994. Historically, before the most recent groundfish collapse, they represented a higher percentage of the catch, e.g. 43% n 1986.

Almost all of the fish species which overlap geographically with euphausiid concentrations feed on crustaceans with small fish making up a greater proportion of the diet as they grow in size (Scott and Scott 1988; Maurer and Bowman 1985) (Table 2).

Table 2. Scotian Shelf (including basins) fish species and diet.

Species	Diet
Redfish	Amphipods, copepods, and euphausiids are primary food
Silver hake	Euphausiids are an important food source (up to 28%)
Spiny dogfish	Feeds chiefly on fish, but will feed on whatever present
Pollock	50% of diet crustacean with euphausiids an important component
Longfin hake	Feeds on crustaceans, euphausiids, shrimps, and amphipods
Argentines	Food primarily euphausiids and amphipods
Shortfin squid	Fish, squid, and crustaceans, including euphausiids
Atlantic mackerel	Feeds on crustaceans and small fishes
Red hake	Crustaceans major prey
White hake	Crustaceans 17% of diet
Offshore hake	Not known, but probably similar to silver hake

Thus, it can be seen that the diet of the dominant fish species in Emerald Basin and LaHave Basin, and the Fundian Channel, not surprisingly is composed of euphausiids; and in most species this makes up a considerable portion of their diet.

The next question is whether the removal of euphausiids would effect the productivity of other fisheries in the neighborhood. It is notable that neither Atlantic cod nor haddock overlap in distribution with the bulk of the adult euphausiid populations from the summer groundfish survey (Simon and Comeau 1994), preferring to frequent waters shallower than 100 m deep, chiefly on the offshore banks. However, cod are known to inhabit the deeper waters of the basins on the Scotian Shelf during the winter months (L. Paul Fanning, pers. comm., DFO, Dartmouth, N.S.). This is not to imply that cod and haddock do not eat euphausiids during the summer, because juvenile euphausiids are carried onto the shoaler areas; but they would comprise less of the diet than fish species habitating the deeper waters year-round where the euphausiids are more dense. In fact, one coastal study of the Passamaquoddy Bay area proposes that Meganyctiphanes, particularly the juvenile stages, are widespread in shallower waters during the summer months and somehow migrate, or are carried by residual flow to deeper waters of the Grand Manan Basin for overwintering (Hollingshead and Corey 1974; Kulka et al. 1982).

Evaluating the importance of krill as a direct (food) or indirect (food of prey) source of ,energy which fuels the higher trophic levels represented by the above fishes is more difficult. One would need to know the individual energy requirements not only of each mature fish species, but a continuum of all their developmental sizes above say twice the biomass of their krill prey (see Sheldon Size Spectrum Approach below).

MARINE MAMMAL INTERACTIONS

A number of marine mammals also depend on plankton and nekton for food. Some of these species are considered endangered, such as the humpback, blue, and right whales. In particular, the right whale which used to number in the tens of thousands in the North Atlantic, is reduced to hundreds in sp. e of a total hunting ban since 1935. There are presently estimated to be only 350 individual left in the North Atlantic (M. Brown , East Coast Ecosystems Research, Nova Scotia, pers. c mm.). Right whales are baleen plankton feeders believed to feed primarily on copepods but so consume euphausiids (Dr. Paul Brodie, Halifax, N.S., pers. comm.). Their northern migration brings them to the Bay of Fundy and Scotian Shelf region, together with their young, presumably for food (Kraus et al. 1986; Winn et al. 1986; Mate et al. 1992). Their centres of abundance, .the Canadian leg of their annual migrations, occur at the mouth of the Bay of Fundy and Roseway Basin (north of Browns Bank). The Bay of Fundy appears to be the sole feeding ground for calves and their mothers in Canadian waters (Kraus et al. 1986). Both these areas should b excluded from any krill fishery. The whale-watching portion of local tourism is worth tens of thousands of dollars each year off southern Nova Scotia and New Brunswick. At last count there are 24 boats equipped and ready to take tourists whale watching this summer (i.e. 1996) along the east and west coasts of the Bay of Fundy (Moira Brown, pers. comm.).

MARINE BIRD INTERACTIONS

There are a number of pelagic bird species which inhabit the Scotian Shelf and the waters off , the Bay of Fundy and southwestern Nova Scotia, at least part of the year (Lock, et al. 1994). However, the number of species which feed primarily on plankton and macroplankton can be reduced to four main types. Dovekies are concentrated along the Shelf break and off southwestern ova Scotia during the winter months, particularly in February. Black-legged kittiwakes are resent in the same area between October and February. On the other hand, greater shearwaters frequent the deeper waters off southwestern Nova Scotia between May and October, with greatest abundance from June to August. Shearwaters are know to concentrate in late summer o Brier Island, N.S., feeding primarily on the large krill (Meganyctiphanes novegica), which concentrate at the sea surface (Barker 1976; Brown et al.; 1979; and Nichol 1984). Leach's storm petrels are also very abundant during the summer months off southwestern Nova Scotia, with one of the biggest breeding concentrations in the Maritimes of 50,000 pairs occurring on nearby Bon Portage Island (A.R. Lock, Canadian Wildlife Service, Environment Canada, Dartmouth, N.S., pers. comm.). Storm petrels nesting on Pearl Island and feeding on the Scotian Shelf feed mainly on euphausiids; however, on a volumetric basis fish larval remains predominant over crustacean (Linton 1978).

It is also important to consider whether the proposed krill fishery would interfere with either a spawning ground or nursery area for important species in the area. Larval lobsters are present in the waters proposed for this fishery, but they originate either from the offshore banks, notably Browns and Georges Banks, or inshore of the 15 fathom depth! off southwest Nova Scotia (Stasko and Gordon 1983; Harding and Trites 1988). Only the fourth and final planktonic-pelagic stage occurs in the proposed fishing areas; and these are dispersed enough, yet restricted to the near-surface waters, not to represent a significant by-catch.

Silver hake are much like the offshore lobster in that they migrate from deeper waters off the continental slope and shelf basins onto the offshore banks to spawn (Waldron 1988). The larval and juvenile hake remain over the offshore banks, so there is little likelihood of their being removed by a krill fishery.

Pollock are also bank spawners and are known to use Browns Bank in the spring and Emerald and Western Banks in the fall; but, it is uncertain whether the larvae are maintained in these areas (Neilson and Perley 1996). The young-of-the-year migrate to the coast and reside in the estuaries and embayments along Nova Scotia. Juvenile pollock (Ages 0-2) have a distribution which matches the predicted and observed distribution of Meganyctiphanes with high catches in the summer groundfish surveys of 1970-1995 in The Gully, Emerald, and LaHave Basins, Crowell Basin, and the mouth of the Bay of Fundy (Black 1996).

Cod, haddock, and flatfish spawn over the offshore banks, and lesser spawnings occur close to shore, with most of the larvae remaining near the banks (Hurley and Campana 1989; Brander and Hurley 1992) but with some documented leakage from the Browns Bank area (Suthers et al. 1989). Juvenile cod and haddock (Ages 0-2 years) caught during the summer groundfish surveys (1970-1995) tended to be highly associated with the offshore banks (Black 1996). However, the cod may move into the deeper waters of the basins during the winter months like the adults.

Redfish young are released as egg-yolk larvae by the females in deep water (>350 m) in July and settle to the bottom by October; however, they are quite broadly dispersed over the Scotian Shelf (Kenchington 1984).

Most other meroplanktonic larvae of bottom-living organisms (e.g. scallops) and planktonic organisms would simply pass through the coarse mesh (1/4 inch) planned for the krill fishery, with the exception of decapod shrimps, amphipods, and mysiids. Major concentrations of shrimp occur on the northeastern sections of the Scotian Shelf which are outside the currently proposed krill fishery .

It does not appear that by-catch of other key species of the Shelf ecosystem presents a problem, though this concern should probably be monitored if a krill fishery is allowed.

Information from the Scotian Shelf lchthyoplankton Program (SSIP), conducted in the late 1970s and early 1980s, could be examined in any future reviews of this nature.

THE SHELDON SIZE SPECTRUM APPROACH

Another approach to the problem is to determine whether short-circuiting the food web will have detrimental effects on the entire ecosystem. Sheldon et al. (1972;1982) advocated that the biomass (per-unit volume or area) of a marine pelagic food web was constant or flat when plotted against the logarithm of body size. With this assumption they predicted that the fishable standing stock of cod, haddock, and silver hake on the Scotian Shelf (Northwest Atlantic Fisheries Organization [NAFO] Areas 4VS and W) was 6.8 g/m2 based on a measured phytoplankton standing stock of 1.7 g/m2 and with four logarithmic size units representing the fishable stocks. Over the past 10 years it has been generally agreed that the marine size spectra has secondary structure with rather regular predictable peaks and troughs (Schwinghamer 1985) and that overall a slight negative slope occurs (Boudreau and Dickie 1992). If we use Boudreau's and Dickie's (1992) equation for the size spectra of Browns Bank (NAFO Area X) as representative of the Scotian Shelf, the fishable standing stock of groundfish would again be 1.72 x 4 or 6.8 g wet weightlm2, but the standing stock of nekton-macroplankton in the size range of adult euphausiids would be 8.7 g wet weightlm2. Sheldon et al. (1982) calculated that 2.6 9 wet weightlm2 per logarithmic size interval were produced in a fish population from the northern section of the Scotian Shelf in the 1954-1962 era before exploitation became excessive (mid 1960s). The euphausiid estimate given by Cochrane et al. (1994) for the LaHave Basin of 81.2 g/m2 is an order-of-magnitude greater than needed to support historic groundfish population levels in the 1950s and 1960s. However, the associated Regional Assessment Process document by Sameoto and Cochrane (1996) guestimates the euphausiid biomass on the Scotian Shelf basins at 10 g wet weight/m2, which nicely matches predictions based on the Size Spectrum Approach. In the present case, the groundfish stocks are so low that the production of euphausiids is bound to be excessive for the needs of the current fish population. It would be fair to summarize that production removed from one trophic level is bound to reduce the yield from higher trophic levels in a reasonably stable ecosystem and that economics and good ecological management should ultimately determine which product (krill or fish) is harvested and in what quantities.

CONCLUDING REMARKS

Caution should definitely be the overriding principle when we harvest lower and lower in the marine food web. If we apply the logic and advice of Ken Frank (DFO), as contained in DFO Atlantic Fisheries Stock Status Report (95/6, p. 133-134) concerning sandlance exploitation, we would not recommend a fishery for krill because it has a prominent position in the middle of the food web of the deeper regions of the Scotian Shelf and Gulf of Maine. Furthermore, the author of this paper has documented above that almost all commercially important species in the area utilize euphausiids as a primary food source. However, given the present modest request to harvest 1,000 t of krill, it is considered that this could be allowable as an exploratory venture providing that a better estimate of their abundance be obtained in the future. DFO might consider deploying several bottom-mounted acoustic Doppler current profilers (Cochrane et al. 1994) at different times of the year, particularly in regions where we presently have no information, i.e. Fundian Channel and the Scotian Shelf break. Sameoto's recommendation (unpubl. document) that the inshore area of southwestern Nova Scotia and the mouth of the Bay of Fundy be excluded from the possible krill fishery is supported here because of the presence of a lucrative herring fishery, the largest concentration of breeding petrels in the Maritimes, and the fact that these areas are also the feeding areas for the endangered right whale, not to mention the commercial whale-watching enterprises in the area. Finally, an ecological-economic study should be done to evaluate the relative potentials of fish and krill fisheries given the carrying capacity of the environment and the dependence offish on krill for food.

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APPENDIX V. Remarks from the Ecology Action Centre

ECOLOGY ACTION CENTRE

1568 Argyle Street, Suite 31
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4 June, 1997

Dear Dr. Head:

We have read the Draft Proceedings of the Krill Workshop and commend you and the committee on producing a well written and useful document. We welcome the discussion on how fisheries for forage species should proceed and the application of models, such as CCAMLR, to all forage species, including those already being fished.

That said, we perceive that the krill workshop was designed more to answer the question of how a krill fishery should proceed rather than the more basic and crucial question of whether it should proceed at all. (We are glad this concern was noted on page 15.) We feel that this maybe the result of the professional training of stock assessment scientists who are trained to ask and answer the questions of how much is there and how much can we take. Perhaps, we need more ecologists involved in this discussion.

We are concerned by recommendation 6 of the Executive Summary which suggests to us that proposals to fish krill will be allowed if they involve some science. The first proposal to fish krill that we were aware of requested a catch of 1000 mt. which is double the 1997 quota of the West Coast fishery and many times more than the Gulf fishery. Would this proposal be considered a scientific monitoring exercise? Again we are concerned that scientific fisheries will be designed to answer the question of how much more krill can be fished, rather than whether we should fish krill.

At present the Marine Issues Committee remains opposed to any krill fishery on the Scotian Shelf for the following reasons:

1. All major forage species are either being exploited or being targeted for exploitation. What will the cumulative impact be on dependent species?

2. Most dependent fish species, e.g. cod and herring, have been over-exploited and hopefully are now in the process of recovering.

3. Once a fishery is initiated it is more difficult to stop or limit as companies invest in the fishery.

4. The majority of commercially exploited species on Canada's East Coast are either fully or over-exploited.

5. Krill will be harvested to feed captive fish and as the aquaculture industry grows so will demand.

6. In this era of budget cuts the Department of Fisheries and Oceans has limited resources. Even if the costs are covered by the proponent, the fishery will divert resources away from more economically important fisheries which have yet to be "fixed".

7. There is strong opposition to this fishery from both the fishing and environmental community.

With respect to the CCAMLR model we have contacted NGOs active in the Antarctic who have outlined some concerns they have with the model as it is applied to krill. Briefly, these are some of the concerns:

1. The estimate of the krill biomass used in the model is out of date and there is a need for a new survey.

2. The model has not been able to accurately account for the amount of krill predators need.

3. The model doesn't factor in where and when the krill will be taken, leading to disproportionate impacts on predators.

We have not been able to adequately evaluate these criticisms, but it appears that NGOs already familiar with the model have concerns about it.

We do not have all the answers. For example, we would like to participate in a considered discussion of the ecological value of not harvesting some "key" species, and indeed trying to determine if there are key forage species on the Scotian Shelf.

As mentioned by Inigo Everson at the Workshop, when some individual or group in CCAMLR is uncomfortable with a report they are able to contribute a dissenting view. Please could you consider this letter as such and include it as an appendix in the proceedings.

Thank-you.

Sincerely,

Mark Butler
Chair, Marine Issues Committee,
Ecology Action Centre