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FACTORS TO CONSIDER IN DEVELOPING MANAGEMENT MEASURES FOR KRILL

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Abstract

A brief review of the objectives of the Convention for the Conservation of Antarctic Marine Living Resources is given along with an outline of steps for the evolution of management procedures for krill fisheries. Various possible elements of procedures such as reactive, predictive, and feedback management, modelling, indicator species, pulse fishing, and the use of open and closed areas and seasons are outlined. Some interim management measures are suggested which could be implemented while a more generally applicable management is being developed.

Résumé

Une brève vue d'ensemble des objectifs de la Convention sur la conservation de la faune et la flore marines de l'Antarctique est présentée ici, avec un aperçu des stades d'évolution des procédures de gestion des pêcheries de krill. Les grandes lignes des éléments possibles des procédures telles que la gestion réactive, prédictive et en retour, la modélisation, les espèces indicatrices, la pêche par à-coups et l'utilisation de l'ouverture et de la fermeture de zones et de périodes sont tracées. Plusieurs mesures de gestion intérimaires, pouvant être mises à exécution en attendant le développement d'une politique de gestion applicable de façon plus générale sont proposées.

Резюме

Делается краткий обзор целей Конвенции по сохранению морских живых ресурсов Антарктики, а также в общих чертах описываются меры по усовершенствованию процедур управления промыслом криля. Дается описание всевозможных элементов этих процедур, таких как реагирующее, прогнозирующее управление, управление с обратной связью, а также моделирование, виды-индикаторы, пульсирующий промысел и применение режима открытых-закрытых районов и сезонов. Предлагаются некоторые меры по управлению, которые могли бы быть введены на время, пока более универсальная система управления находится на стадии разработки.

Resumen

Se presenta una reseña de los objetivos de la Convención para la Conservación de los Recursos Vivos Marinos Antárticos además de las directrices para el desarrollo de las medidas de administración para las

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pesquerías de krill. Se detallan varios posibles tipos de procedimiento tales como administración suplementaria, reactiva y pronóstica, modelado, especies indicadoras, pesca por pulso y el empleo de áreas y temporadas abiertas y de cierre. Se sugieren algunas medidas de administración interinas que podrían ponerse en práctica mientras se elabora un sistema de administración más general.

1. INTRODUCTION

If krill (*Euphausia superba*, Dana) were considered in isolation it is reasonably certain that the potential annual harvest is large; of the order of perhaps tens of millions of tonnes over Antarctic waters as a whole. This potential has been crudely guaged by considering the food consumption of baleen whales in the Antarctic (Laws, 1977). The baleen whales were the object of major fisheries, with some species being depleted to only a small fraction of their pristine abundance (IWC, 1990). This dependence of endangered and depleted whale stocks on the stocks of krill, adds the dimension of establishing the yield of krill than can be taken while ensuring that depleted resources are able to recover to at least a healthy proportion of their original abundance.

The conservation of species which are dependent on krill forms an integral part of objectives of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). This is in contrast to the situation under which most other fisheries have been managed in the past, and this raises the need for new approaches to fishery conservation. In any case, the problems that have been encountered in conserving fish stocks elsewhere point to the desirability of considering fresh approaches to fishery management in the Antarctic.

Fishery management is defined as the process whereby conservation measures are set in place to ensure that the objectives of conservation (including rational use) of fishery resources are achieved. Conservation also involves ensuring that species that are not exploited will be maintained at levels of abundance, such that their replacement rate is not seriously diminished. Rational use is defined to be the sustainable utilization of a resource in perpetuity. A rational fishery should be efficient, both in terms of the cost and investment in fishing, and the cost and investment required to ensure that the conservation objectives of the Convention are being met.

2. OBJECTIVES OF CCAMLR

The general objectives of CCAMLR are given in Article II of the Convention as follows:

"1. The objective of this Convention is the conservation of Antarctic marine living resources.

2. For the purposes of this Convention, the term 'conservation' includes rational use.

3. Any harvesting and associated activities in the area to which this Convention applies shall be conducted in accordance with the provisions of this Convention and with the following principles of conservation:

   (a) prevention of decrease in the size of any harvested population to levels below those which ensure its stable recruitment. For this purpose its size should not be allowed to fall below a level close to that which ensures the greatest net annual increment;

(b) maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations to the levels defined in sub-paragraph (a) above; and

(c) prevention of changes or minimization of the risk of changes in the marine ecosystem which are not potentially reversible over two or three decades, taking into account the state of available knowledge of the direct and indirect impact of harvesting, the effect of the introduction of alien species, the effects of associated activities on the marine ecosystem and of the effects of environmental changes with the aim of making possible the sustained conservation of Antarctic marine living resources."

A number of authors have discussed the objectives of CCAMLR, particularly how they require interpretation to render their meaning more precise (for example, Edwards and Heap, 1981; Beddington and de la Mare, 1984). De la Mare (1986a), suggests that an approach which can overcome the problem of having objectives which are in themselves too general is to develop subsidiary objectives which are designed to have a precise interpretation. An important property required for subsidiary objectives is that they are framed in terms of quantities which can be estimated robustly, thus allowing the degree to which objectives are met to be assessed. When subsidiary objectives are achieved it is assumed that the overall, general objectives of the Convention will also be achieved.

A given approach to management may lead to specific subsidiary objectives, and these may differ in detail from subsidiary objectives specified for a different management approach. Moreover, other subsidiary objectives may arise from considerations of the nature of fisheries, for example, a steady yield might be given a higher priority than maximizing catches. Thus, the formulation of subsidiary objectives is a subject which will need to be considered in the light of specific approaches to fishery management.

3. OTHER ASPECTS OF THE CONTEXT IN WHICH CONSERVATION STRATEGIES WILL BE FORMULATED

A fishery for krill around the Antarctic has been developing slowly for more than a decade, with a recent period in which the fishery contracted while various technical problems in handling the catch were investigated. These problems now appear to be largely overcome, and the krill fishery is once again expanding. It has been found in other fisheries (for example, the Peruvian anchovy fishery) that the overall size of a fishery can increase dramatically over a relatively short time. Fishery operations tend to concentrate on known fishing grounds; there is no reason for fishing fleets to search for, or to travel to new fishing grounds so long as the existing grounds remain productive.

Krill is regarded as a key species in waters around Antarctica; it forms a major part of the diet of many species, the conservation of which is included within the objectives of the Convention. However, available information about the ecology of the Antarctic marine ecosystem, the distribution and abundance of krill, along with incomplete knowledge about basic krill demography, such as mortality and longevity, mean that it is not possible to predict what level of krill harvest will be within the overall objectives of the Convention. In addition, the abundance and distribution of krill is likely to fluctuate from year to year. The various techniques used to estimate the abundance of animal populations also give results which are uncertain. Thus, management procedures have to cope with uncertainty arising from both ecological and sampling variability.

Variability is not the only consideration arising from incomplete knowledge; for various reasons, errors will be made in applying conservation measures. Two types of errors are possible: (1) applying measures such that opportunities for larger harvests are missed; and, (2) measures are not sufficient to prevent over-harvesting. An important property of a rational management procedure is that it should detect and correct both types of error. In evaluating possible management procedures, particular consideration should be given to their properties in either correcting errors, or insensitivity to the effects ot error.

3.1 Designation of Management Areas

It is widely regarded that the appropriate entity to manage in fisheries is a unit (or biological) stock. A unit stock is defined as a group of individuals of the same species whose gains by immigration and losses by emigration are negligible in relation to the rates of growth and mortality (Holden and Raitt, 1974). In general, a stock may be defined as an exploitable group of animals, of which there may be more than one per species, existing in a common spatial arrangement, but with limited genetic exchange between adjacent populations of the same species, usually designated on a geographical basis. A stock may or may not coincide with a unit stock; the lack of coincidence would not usually be intentional, but rather the product of incomplete knowledge of ecological processes.

The important point is that the designation of stocks for management is an integral part of the formulation of management procedures. It should be borne in mind whether a given procedure is intended to manage unit stocks or otherwise. Where a unit stock is assumed, it is important to examine the potential effect on achieving conservation objectives arising from failure to identify the unit stock correctly. Conversely, if stocks are arbitrary units, the properties of the conservation strategy for conserving unit stocks should be evaluated.

3.2 Decision Rules

Decision rules are a fundamental part of a rational management procedure. A decision rule designates what action, in terms of applying or varying conservation measures, is to be taken for any given assessment of the state of the stocks within a management unit or area. Assessment can be defined as the evaluation of the state of stocks within a management unit in the light of management objectives. However, the state of the stocks must be measured on some objective basis, and hence subsidiary objectives must be defined in relation to the available objective measures of stock status.

Clear-cut decision rules are important as a component for the evaluation of management procedures. It is difficult to predict the properties of a management procedure if its implementation would not be based on well specified decision rules. Moreover, well specified decision rules have a role in facilitating consensus decision-making.

3.3 Harvesting Objectives

It is not sufficient to consider only the ecological aspects of management, although the production from the Antarctic marine ecosystem is an ecological constraint which is ultimately limiting. Within the ecological constraints there is scope for adjusting management procedures so that they have differing properties, advantages and disadvantages, for the fishing industries and CCAMLR. For example, the industry may prefer catches that are relatively constant from year to year. Yet either strategy has to achieve the same conservation objectives. In general, objectives such as ensuring conservation, attaining the highest possible yield, and minimizing fluctuations in catch from year to year cannot all be fully achieved simultaneously. For example, steady catches are attained by accepting a lower average yield.

3.4 Data and Assessment Methods

Assessment of the status of stocks is usually dependent on statistical procedures for estimating the parameters which constitute the input to management procedures. Inevitably the parameter estimates will be uncertain due to both sampling variability and the possible failures of assumptions underlying the statistical methods. The desirable property of assessment methods and the management procedure is robustness, which can be defined in terms of making correct decisions even though underlying assumptions have not been satisfied.

It is important that the properties of assessment methods be examined as nearly as possible in the circumstances in which they would be used; that is, within the framework and decision rules of a given management procedure. For example, a method of assessment may be imprecise, and hence any single estimate would lead to a low probability of making a correct management decision. However, if the method were to lead to correct decisions on average, then a procedure which always took the action implied by the method would achieve the overall objectives. Conversely, using a procedure which took the imprecision into account, by reducing catches in proportion to the uncertainty, could also achieve the objectives.

Each of these procedures would have different properties, particularly in the short-term. The first procedure could be designed to maximize the average yield, but it would initially lead to erratic application of conservation measures, until sufficient data accumulated to stabilize the estimates of the decision parameters. The second procedure would tend to lead to the conservative application of measures until sufficient data accumulated to estimate the level of harvest within the overall objectives, but with the advantage of a lower degree of fluctuation in the harvest from year to year.

3.5 Time Frame for Implementation

A further element to consider in developing management procedures is the length of time required for full implementation. Different possible procedures may take different lengths of time before it becomes clear what the long-term general level of fishing might be, or until sufficient data accumulate to apply them confidently. Possible procedures should be evaluated to attempt to indicate the time scale involved in any such initial phase, and as a corollary, what steps, if any, are necessary to ensure that the objectives of the Convention are being met in any interim period before the strategy becomes fully effective. Where the information base is not yet adequate, a staged implementation may be necessary. This may involve the application of some conservation measures so as to guarantee the achievement the Convention's conservation objectives, but in a way which would allow a safe level of harvest while the data necessary for the ultimate implementation of a full management procedure are gathered.

4. SOME EXAMPLES OF POSSIBLE ELEMENTS OF MANAGEMENT PROCEDURES

In order to give more substance to the general discussion above, a few elementary management options will be examined in the context of their likely power to meet the objectives of the Convention, along with their implications for the Commission and the fishing industry.

Six examples will be examined.

(1) Reactive management.
(2) Predictive management (modelling).
(3) Open and closed areas.
(4) Indicator species.
(5) Pulse fishing.
(6) Feedback management.

The selection of these six options does not imply that the list is exhaustive, or that combinations of some of them may not also be useful approaches to explore. The intent of the discussion here is to examine some potential procedures from two points of view: (1) to discuss some initial consideration arising from concrete examples; and, (2) to use these examples to consider how to evaluate possible management procedures.

In general, it is not necessary to examine every aspect of the performance of any given procedure. The process of evaluation is in some senses also a process of elimination. The first step is to examine whether a procedure can work in ideal circumstances, using, for example, analytical mathematical methods or computer simulation studies. The evaluation of a given procedure need only proceed to the point where it becomes clear that it can fail to meet the objectives of the Convention. At this point, it has to be modified or discarded.

Candidates which survive such testing then need to be examined under more realistic circumstances, with the cycle of modification or rejection continuing until there are a few which appear to have the capacity to meet the objectives of the Convention. These final candidates then need to be analyzed in the greatest detail to determine their properties of robustness in terms of working under feasible worst-case conditions. Weight needs to be given to the economic aspects of the performance of the surviving candidates as a factor in making final choices.

4.1 Reactive Management

Reactive management is the practice of implementing conservation measures only after the need for them is apparent. In the context of CCAMLR, this would mean that catches would be unregulated until such time as stocks of either target or dependent species declined to levels below that ensuring their stable recruitment, or to below the level of maximum net annual increment, or changes occurred which were not potentially reversible over two or three decades.

In terms of formulating decision rules, it would be necessary to determine where such levels are, or what kind of changes would not be reversible over two to three decades. An approach with these general objectives has the difficulty that the criteria which would indicate whether the objectives are being met cannot be defined in measurable terms in advance.

For example, recruitment can only be shown to have become unstable (i.e., declined) well after the fact. In most fish stocks, recruitment is highly variable from year to year, and so it will take a number of years of data to determine whether there has been a true decline in recruitment rather than chance fluctuations showing a number of years of poor recruitment. The essential problem is to detect the 'signal' about recruitment from 'noisy' data. The first part of such a problem is to decide at which point that a fishery-induced decline in recruitment is more likely than the effects of chance. In essence, this question is equivalent to, what is the probability that there will be a failure to implement conservation measures when they are in fact required? The corollary is, what is the probability that conservation measures would be put in place when in fact they were not necessary?

Even when the technical difficulties in estimating recruitment are ignored, there is a high probability of failing to introduce conservation measures in a timely fashion, with the possibility that stocks may be seriously depleted. A likely consequence will be that fisheries will be unstable, going through cycles of boom and bust (for some examples see Allen and McGlade, 1986), with potentially irreversible impacts on the ecosystem as a whole.

The problems are multiplied when it is the recruitment of a dependent (consumer) species that is to be maintained. For example, for whales, it is very difficult to estimate recruitment (de la Mare, 1987 and 1989). In addition, any trend in the recruitment of consumer or prey species might be interpreted as being related to some other environmental trend rather than to the effects of harvesting. Thus, the causes of changes in an ecosystem may not be unambiguously identifiable after the event. This may lead to a delay, or even a failure, in reaching consensus that management measures are needed, and this could result in harvesting leading to an irreversible impact upon the ecosystem.

Hence, a procedure relying upon a purely reactive approach seems unsuitable for meeting the recruitment objective unless both recruitment and the estimates of it are both not subject to high levels of random variability.

4.2 Predictive Management (Modelling)

Predictive management involves predicting the levels of catch which can be taken by considering information already known about the system, or that can be determined by further studies carried out before harvesting has changed the system in such a way that there is a failure to meet the Convention's objectives. It is an approach largely based on having some form of model about the system. The model may even be so crude as to not even be identified as a model in the usual sense, for example, the idea of predicting a level of krill harvest on the basis of what was once eaten by large whales is such a crude model. However, much more sophisticated models can be built considering multiple species and energy flows and the like.

The application of multi-species models for the management of the Antarctic marine ecosystem has been discussed by Butterworth (1984), Beddington and de la Mare (1984), de la Mare (1986a) and Miller (1986). Modelling needs to be built on the more arbitrary approaches outlined above. Butterworth (1984) suggests that there should first be interim measures to delimit management areas, agree on target levels for stock size and to monitor stocks, accompanied by empirical (i.e., production) modelling rather than an analytical approach which attempts to incorporate parameters for which density-dependent changes have been measured.

Beddington and de la Mare (1984) and de la Mare (1986a) emphasize that simulation modelling can be a valuable tool in evaluating strategies for the acquisition of information about a system, in designing a regulatory framework from an ecosystem perspective, enabling potential management procedures to be tested and refined by applying them to a whole range of artificial exploited systems of increasing complexity. This approach can reduce the high overhead costs of feedback methods requiring a great deal of data, resource surveys, stock assessments, etc. As summarized by Beddington and de la Mare (1984), "modelling cannot substitute for experimentally rigorous observation. Conversely, unguided observation provides only data not insight."

While modelling has a valuable role in the development of long-term strategies for the conservation of Antarctic marine ecosystems, a well balanced strategy should begin with simple, pragmatic interim safeguards (and model-tested) empirical approach.

4.3 Open and Closed Areas and Seasons

This is defined as the declaration of a series of open and closed areas, perhaps combined with open and closed seasons, selected with the objective of ensuring sufficient protection of target species within closed areas to maintain ecosystems there, while also ensuring sufficient recruitment from both closed and open areas to maintain fishing. In theory, such an approach would require little or no regulation of fishing operations in the open areas, provided that there were limited effects on stocks in the closed areas. The critical step is the selection of boundaries between open and closed areas in a manner which ensures ecological as well as economic viability of this management regime.

One implication of this approach is that in open areas, heavy fishing upon krill might cause localized effects on some consumer species, but some small-scale regional disruption could be acceptable over the Convention Area as a whole.

In managing a single species resource, krill appear to be well suited to such an approach, having semi-discrete concentrations related to quasi-stationary cyclonic gyres, but with considerable exchange between each. However, the distribution of consumer species may not be determined solely by the concentration of krill, but may also be influenced greatly by other factors such as the distribution and condition of sea ice, or the location of suitable breeding sites. This may lead to complications in choosing the sizes and locations of open and closed areas.

Nevertheless, even arbitrarily selected open and closed areas may have practical value as an interim approach, being simple, inexpensive and not demanding very detailed prior knowledge of the components of the system (de la Mare, 1986a).

4.4 Indicator Species

One possibility for detecting deleterious effects of krill fishing on the suite of krill predators is to monitor condition factors of a small range of predators (Green-Hammond *et al*, 1983). These were termed indicator species, with the implication that changes in condition, such as body fat, or fecundity, would predict that the changes in population status of krill predators would follow. This concept has, at least in part, underlain the general approach adopted by the CCAMLR Ecosystem Monitoring Program (CEMP). There are three general problems to be addressed in applying the indicator species concept which can be summed up as coverage, calibration and extrapolation.

The existing CEMP program is concentrated on a small number of areas selected because of logistical constraints, and continuing research programs which had already acquired data. Thus, at this stage, the CEMP program has limited coverage, and so can only detect the effects of krill fishing within the foraging range of the selected predators. If the krill fishery operates substantially outside this range, the program will have little power to detect the effects of krill-fishing on krill predators. The obvious solution is to concentrate the existing fishing activity into one of the CEMP monitoring regions, and to exclude the fishery from a similar site as a kind of experimental 'control'. If none of the existing sites form a suitable replicate, then the CEMP program may have to consider augmenting the set of sites. The question of mounting what amounts to an 'experiment' along these lines warrants further serious consideration.

Calibration means identifying the relationship between krill abundance and the selected predator condition factor. In general, it would be expected that there will be a non-linear relationship between krill abundance and predator condition factors. At high levels of krill abundance, the predator condition will be saturated, that is further increases in krill will produce negligible further increase in predator condition. At lower levels of krill abundance, predator condition would still be expected do decline more slowly than krill abundance if, as is likely, predators are able to home in on krill concentrations. It may transpire that the predator condition factors will not give sufficient early warning to prevent the fishery from over-exploiting the krill stocks in terms of their optimal single-species management.

Assuming that a suitable condition factor could be identified and calibrated, it would be an article of faith that the use of the condition factor as a decision parameter in a management procedure would result in conservation of other krill-dependent predators. However, as Beddington and de la Mare (1985) point out, extrapolation to wide-ranging predators would probably be conservative where fishing is limited to the foraging range of selected shore-based predator populations.

4.5 Pulse Fishing

Pulse fishing entails harvesting intensely within a given area until the stock is reduced to a certain point, and then moving to other areas until the stock recovers in the first area. The point where fishing ceases in a given area is usually determined on economic rather than ecological grounds, but decision rules could in theory be formulated to comply with the objectives of the Convention. This would require initial surveys to estimate the size of the pulse which can be applied. A discount should be made to allow for uncertainty in this estimate. The criteria for deciding when to cease fishing should be pre-determined. Part of the costs of this approach should include surveys during the non-fishing period to monitor recovery towards a pre-determined point at which fishing is to be resumed.

In practice, pulse fishing has been applied with questionable effectiveness to the management of single or multi-species fisheries. Its application to the management of ecosystems is far more doubtful, even when the system is pristine. Intensive fishing reducing a key species to a very low level might favour certain of the consumer species more than others. For example, if the prey species has a habit of swarming, those predators feeding on swarms will be disadvantaged far more by intensive fishing than predators consuming prey individually. Hence, pulse fishing applied intensively might alter the community structure of an ecosystem very significantly.

In the case of Antarctic marine ecosystems the situation is more difficult in that the larger baleen whales are so depleted that recovery within the stipulated twenty or thirty years is uncertain. Thus, there is a danger that pulse fishing upon krill swarms may apply pressures beyond the principles specified in Article II of the Convention.

4.6 Feedback Management

The importance of basing fisheries management on feedback principles is now also being recognized (Tanaka, 1984; de la Mare, 1986a). The discussion on feedback given here is based on that of de la Mare (1986a). Properly designed feedback systems have a number of important advantages over non-feedback systems. These include improved accuracy and stability in attaining objectives and reduced sensitivity to error in the model assumed to apply to the controlled system.

The implication of applying control systems theory and feedback to living resource conservation is that it directs attention to the examination of system input and output. For a convention such as CCAMLR, the total system under discussion is the ecosystem in a given region, combined with a conservation strategy. Thus, the part of system to be controlled (at least along some partial dimension) is the ecosystem, and the management procedure forms a control system. The system input is formed from the objectives of the Convention, and hence, the system output is some set of observed attributes of the ecosystem. In control systems theory terms, the catches are not necessarily considered as part of the output of the system, but they are the principle control action which can be applied to drive the ecosystem towards a specified set of objectives.

Suppose that it was decided that the abundance of an exploited fish stock should not fall to below say $\mathbf{X}_{\min}$ (to ensure stable recruitment) and that the optimal level of the stock was somewhat higher at $\mathbf{X}_{\mathrm{opt}}$. Similarly, suppose that some predator is to be maintained at a level above $\mathbf{Y}_{\min}$ and to have a desirable level of $\mathbf{Y}_{\mathrm{opt}}$. Thus the input to the system is $\mathbf{X}_{\mathrm{opt}}$ and $\mathbf{Y}_{\mathrm{opt}}$ and its output is the observed values of **X** and **Y**. Feedback control would lead to catches being increased, if the observed values of **X** and **Y** were above their target levels, but some reduction in catches would be required if either **X** or **Y** were below target. The changes in catches would be governed by some form of decision rule, which could be rather complex, but which would include some element of proportionality in that small differences between the observed and target values for X and Y lead to smaller adjustments in catches than do large discrepancies between the observed values and their targets. If the observed values of X or Y were to be found below the minimum levels then catching would cease until the stocks had recovered towards the target level.

Simulation studies of such a regulatory system, in a single species context, have shown that the probabilities of erroneously curtailing exploitation on a stock or inadvertently reducing it to below the minimum level can both be controlled (de la Mare, 1986b and 1989). However, it has also been shown that the time to detect and correct errors can be relatively long because of the effects of variability in estimates of absolute or relative abundance (de la Mare, 1984 and 1986a).

The example outlined above is not intended to be definitive, but to illustrate how feedback regulation might work, and in particular to highlight three important principles. The first principle is that the initial rate of exploitation should be basically feasible in terms of a likely level of sustainable yield. This requires that an estimate of abundance is available for each exploited stock in advance of the substantial development of its fishery, or that other basic safeguards are put in place such as closed areas and seasons as suggested earlier. This is important for two reasons: (1) that it helps to avoid over-capacity in the fishery; and (2) it helps to ensure that the reduction in the biomass of the stock occurs over a sufficiently long time span to allow sufficient data to accumulate so that errors in the predicted yield can be identified and corrected, before the consequences become serious for the fishery. The second principle requires that the objectives for the regulatory system should be framed in terms of aspects of the status of the controlled system which can be estimated robustly. The third principle is that the regulatory framework specifies what actions are required given the observed values of status of the controlled system. These principles are also an important factor in creating an environment in which scientific consensus is more readily obtained.

5. TOWARDS AN OVERALL STRATEGY

A management procedure for krill should favour steady fisheries which are ecologically sustainable as well as economically efficient. It is essential that the management procedure should limit the risk of accidental failure to achieve the objectives of the Convention. Moreover, the costs of management should be commensurate with the value of the fisheries. Within these general constraints, management is ultimately an empirical process, and to determine the highest levels of harvest of krill which will be compatible with the objectives of CCAMLR requires monitoring of the effects of fishing. However, in the short to medium term, approaches should be sought which will ensure that the objectives of the Convention are met without requiring commitments to research and monitoring activities which are excessive in comparison with the importance of the fisheries.

The strategy approaches outlined in this document all have various advantages and disadvantages. Choosing suitable long-term strategies may be a process which will require a number of years for evaluation and implementation. Thus, there is a need for interim procedures to ensure that the development of fisheries does not outstrip the basis on which they can be managed. Therefore, it might be useful to consider a procedure which can be implemented in stages, which may include elements drawn from (a) Open and Closed Areas and Seasons; (b) Feedback Management; and, (c) Predictive Management. The emphasis on particular elements will depend on the subsidiary objectives for harvesting, as well as a weighing of the costs incurred to collect the data and undertake other associated activities of particular management strategies. It is premature to indicate the detailed form that a long-term strategy for krill conservation might take. However, it is possible to indicate a basic structure, with emphasis on the elements which are appropriate to implement in the interim as part of the first stages of setting up an overall management procedure. The framework might then contain the following elements:

(i) Selection and designation of open and closed sectors for krill harvesting. In the present state of knowledge of the dynamics of the Antarctic marine ecosystem, it would be prudent to designate several (say six) sectors, and open some of these (say three) to krill fishing.

(ii) In each of the sectors open to the fishery, a number of subareas are designated which are open for fishing, the remaining subareas to remain closed as an interim measure to ensure sufficient stock escapes the fishery each year to maintain recruitment and essential ecological processes. Alternatively, separate interim catch limits be set at modest levels for each sector open for fishing. Some or all of the subareas may be involved in the CEMP program.

(iii) Interim measures for krill fishing should apply until replaced by improved management procedures as they develop. The time frame envisaged for the interim measures would be that required to evaluate and choose the next stage of the overall strategy. This time scale could be of the order of five years or more.

(iv) During the interim period, as full a data collection as possible should be made on fishing operations, target and selected consumer species, and on the physical environment. Only those data necessary for the implementation of agreed management procedures would ultimately be required to be submitted to CCAMLR. However, since it is not possible to specify the ultimate data requirements in advance, extensive data of all types should be collected and archived by Members.

(v) CCAMLR should facilitate cooperation in the collection and analysis of these data.

(vi) Eventual phasing-in of feedback management if and when increases in yields are sought, or if data collected in the course of monitoring indicated that recruitment was failing in exploited or dependent species.

6. OUTLINE OF A WORKPLAN FOR DEVELOPING A MANAGEMENT PROCEDURE

Developing a management procedure will be a complex task which involves the selection of criteria to examine the potential performance of procedures to provide the ultimate basis for making choices. The aim is not to develop the best possible management procedure to last for all time, but to approach the problem pragmatically to ensure that the Commission at any stage has a management procedure sufficient for its current needs, but that it is also anticipating what kind of procedure will be needed in the short to medium term. Failure to plan actively ahead may well leave the Commission reacting to unnecessary surprises which could have been avoided with the application of some forethought. An outline of the steps involved in the initial phases of such a tentative workplan is as follows:

1. Refine the objectives of conservation and formulate any subsidiary objectives.

2. Choose initial candidate strategies.

3. Identify and initiate interim conservation measures to ensure objectives are met while longer-term procedures are under development.

4. Undertake the first round of examination of candidate procedures, and any refinements or additions necessary to objectives.

5. Conduct a major review of progress. Select candidate procedures for intensive analysis. Refine objectives and procedures if necessary.

6. Undertake intensive analysis of final candidates, similar to step (4), but with additional particular attention costs and benefits to fisheries and the Commission.

7. Conduct the next major review of progress. If suitable procedures have been identified then proceed to formal adoption of the decision rules and conservation measures by the Commission. Otherwise, refine objectives and procedures; repeat steps (6) and (7).

The time scale involved overall depends partly on the priority and resources assigned to the process by the Commission and its Members. However, assuming basic progress is tied to the annual meeting of the Commission, the time scale could be five to six years. That does not mean that the procedure existing after that time would be perfect, but that it would be adequate for meeting the basic objectives. A cycle of improving the procedures would continue in the face of new developments in the fisheries and to take into account improvements in assessment methodology.

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