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ANTARCTIC ECOSYSTEM MANAGEMENT

Abstract

This document describes a framework within which an initial strategy could be developed for managing commercial exploitation of the marine living resources of the Southern Ocean. More particularly, practical approaches are suggested for managing the exploitation of krill and fish in accordance with the objectives and requirements of Article II of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). Quantitative predictions, and hence multi-species models, are necessary for assessing any indirect impact that might arise through the exploitation of either krill or fish, and they are necessary also if management is to be aimed at restoring depleted populations. The knowledge for these models is not available at present. Consequently, the report makes recommendations for (1) the type of research that is needed to improve the situation, and (2) interim management action that is regarded as practicable. The research includes (a) identifying those components (species) of the ecosystem that most significantly influence the dynamics of the system, (b) estimating their demographic status in subsystems, and (c) conducting perturbation experiments in certain of these subsystems. With regard to interim management action, it is recommended that (a) management areas should be delimited, (b) target levels for stock-size should be agreed and (c) both direct and indirect methods should be employed to monitor these stocks. In particular, early attempts should be made to model the fishing operation.

PLAN D'AMENAGEMENT DE L'ECOSYSTEME DE L'ANTARCTIQUE (GESTION/EXPLOITATION)

Résumé

Ce document décrit les éléments de base à partir desquels une stratégie initiale pour le contrôle de l' exploitation commerciale des ressources marines vivantes de l'océan Austral pourrait être développée. Plus particulièrement, des suggestions sont offertes sur la manière d'aborder la question du contrôle de l'exploitation du krill et des poissons conformément aux objectifs et aux dispositions de l'Article II de la Convention sur la Conservation de la Faune et la Flore Marines de l'Antarctique (CCAMLR). Des prévisions quantitatives, et donc des modèles à espèces multiples, sont nécessaires pour évaluer les répercussions indirectes éventuelles de l'exploitation du krill ou des poissons; nécessaires également si le but du contrôle est de repeupler les populations décimées. Ces modèles n'existent pas encore. Par conséquent, des recommandations sont faites sur (1) le genre d'études nécessaires pour améliorer la situation, et (2) un plan intérimaire d'action possible. Les études viseraient (a) à identifier les éléments (les espèces) de l'écosystème qui influent le plus (de façon significative) sur la dynamique du système, (b) à estimer leur état démographique en sous-systèmes, et (c) à conduire des études expérimentales sur les perturbations dans certains de ces sous-systèmes. En ce qui concerne le plan intérimaire d'action, l'Afrique du Sud recommande (a) de délimiter les zones de contrôle, (b) de se concerter sur les objectifs des niveaux de la biomasse et (c) d'utiliser des méthodes directes et indirectes pour contrôler ces réserves. Notamment, des essais préliminaires de modèle d'opérations de pêche devraient être tentés.

УПРАВЛЕНИЕ ЭКОСИСТЕМОЙ АНТАРКТИКИ

Резюме

Настоящий документ дает описание работ, внутри которых можно было бы разработать начальную стратегию управления коммерческой эксплуатацией морских живых ресурсов Южного океана. Более того, предлагаются практические подходы к управлению эксплуатацией криля и рыбы в соответствии с целями и требованиями Статьи II Конвенции о сохранении морских живых ресурсов Антарктики (CCAMLR). Количественные прогнозы и, следовательно, многовидовые модели необходимы при оценке какого-либо косвенного воздействия, являющегося результатом эксплуатации криля или рыбы, и они также необходимы, если целью управления является восстановление истощенных популяций. Еще не имеется данных, требующихся для создания этих моделей. Исходя из этого, в настоящем докладе делаются рекомендации относительно (1) вида исследования, требующегося для исправления положения и (2) временных действий в области управления, которые считаются реальными. Исследование включает в себя:
(a) определение тех составных частей (видов) экосистемы, которые в наибольшей мере влияют на динамику системы, (b) оценку их демографи-

ческого положения в подсистемах и (c) проведение экспериментов по возмущению в отдельных районах этих подсистем. Что касается временных действий в области управления, рекомендуется, чтобы (a) районы управления были делимитированы, (b) целевые уровни размеров запасов были согласованы и (c) для мониторинга этих запасов применялись как прямые, так и косвенные методы. В особенности, должны быть сделаны без отлагательства попытки моделирования промысловых операций.

ADMINISTRACION DEL ECOSISTEMA ANTARTICO

Resumen

Este documento describe una estructura por medio de la cual se podría desarrollar una estrategia inicial para administrar la explotación comercial de los recursos vivos marinos del Océano Austral. En particular, se sugieren medidas prácticas para administrar la explotación de krill y peces de conformidad con los objetivos y requisitos del Artículo II de la Convención sobre la Conservación de los Recursos Vivos Marinos Antárticos (CCAMLR). Se necesitan pronósticos cuantitativos y por consiguiente modelos de multiespecíficos para evaluar cualquier impacto indirecto que pueda surgir debido a la explotación ya sea de krill o peces, siendo asimismo necesarios si la meta de la administración es restaurar las poblaciones disminuídas. En la actualidad no se dispone de conocimiento sobre estos modelos. Por lo tanto, el informe formula recomendaciones para (1) el tipo de investigación que se necesita para mejorar la situación, y (2) la acción administrativa interina que se considera factible. La investigación incluye (a) la identificación de los componentes (especies) del ecosistema que ejercen una influencia significativa en la dinámica del sistema, (b) las estimaciones de su estado demográgico en los subsistemas, y (c) la conducción de experimentos sobre la perturbación en algunos de estos subsistemas. Con respecto a la acción administrativa interina, se recomienda que (a) se deberían delimitar áreas administrativas, (b) se deberían acordar niveles objetivo con respecto al tamaño de las existencias y (c) se deberían emplear métodos tanto directos como indirectos para controlar estas existencias. En particular, se debería tratar de modelar la operación pesquera con la debida anticipación.

PREAMBLE

At a meeting of the Scientific Committee for the Conservation of Antarctic Marine Living Resources (CCAMLR), held at Hobart during the period 30 August - 8 September, 1983, it was agreed that: national representatives be requested to draw up papers commenting and raising questions on ecosystem management in the Antarctic; and, that in some situations it would be appropriate for national representatives to co-ordinate views that may be held on these matters in their countries, before transmitting them to the Secretariat at least three months preceding the next Scientific Committee meeting.

This report sets out the South African response to these requests. It represents a consensus of the opinions and advice of a group of scientists who met for discussions under the chairmanship of G.H. Stander. The group consisted of: D.S. Butterworth (Author), P.R. Condy, J.G. Field, I. Hampton, P.B. Hulley, D.G.M. Miller, W.R. Siegfried, G.H. Stander and O.A. van der Westhuysen.

CONTENTS

1. THE ECOSYSTEM APPROACH OF CCAMLR ARTICLE II

1.1 Introduction

The essence of the ecosystem approach implicit in CCAMLR Article II (as distinct from the single-species approach implicit in most operative marine conservation, and rational use, strategies) is encapsulated in two extracts from the Article:

(i) "taking into account ..... indirect impact of harvesting" [3(c)] and

(ii) "restoration of depleted populations..." [(3(b)].

Achievement of CCAMLR Article II objectives necessitates consideration of the practical implications of these two requirements. This is examined in the following sections. The line of argument used is illustrated schematically in Fig. 1.

1.2 The Indirect Impact of Harvesting

The simplest single- species management approach tacitly assumes that the effect of harvesting is adequately described by a "man-species" interaction term, where the species exists in an "invariant" environment. The relationship between the species and its environment is represented in an empirical manner, with the effects of harvesting of the species on other species ("the indirect impact") assumed to be either inconsequential or effectively absorbed in the empirical parameters. Except perhaps in an implicit and extremely general sense, such models provide no answer to the question: "If species A is harvested, what will happen to species B?"

An ability to manage rationally implies an ability to predict the effect of perturbing the system. Inevitably, quantitative prediction will be necessary (e.g. consideration of practical implementation of the hypothetical strategies of Chittleborough (1983), would be meaningless without quantitative specification of the "high", "low" and "sustainable" harvest rates to which he refers).

Such quantitative predictions require the construction of a model in which "species-species" as well as "man-species" interactions are taken into account explicitly rather than implicitly (i.e. a "multi-species model"). The greater complexity of such models (compared to single-species models) brings with it the need for additional parameters, in particular those that can quantify "species-species" interaction effects. The ability of such models to provide realistic predictions will, in all likelihood, depend crucially on the ability to determine such parameters with adequate precision (assuming also that realistic representations can be achieved for the functional forms needed to describe these interactions).

1.3 The Restoration of Depleted Populations

While this objective could be viewed entirely in a single-species context (in terms of which the only, and the most speedily effective, requirement for achieving the objective would be suspension of harvesting each population concerned until it grows back to the desired level), the implication in Article II is that species-species interactions may play a significant role, so that the manner in which present-day non-depleted stocks are harvested may influence the rate (or even the possibility) of recovery of depleted populations.

There are two possible approaches to achieving this objective. The "passive" approach would be to curtail all harvesting (of any species). The associated hypothesis would then be that, after a time (and probably a long time, of the order of centuries rather than decades), the various species in the system would return to their pre-exploitation levels (compatible with section 3(a) of Article II). An alternative hypothesis would be that more than one stable state exists for the unexploited system[1], and the system would not necessarily therefore return to its original unexploited state if undisturbed in the future. There would seem to be no firm evidence at present that would allow these two hypotheses to be distinguished. In particular the first cannot be discounted, and curtailment of all harvesting would stand (in principle) as a means of achieving the objective. Information that a species previously depleted

[1]This argument assumes that the system still contains all species originally present, i.e. that none have become extinct.

and now protected was decreasing in size might, however, constitute a basis from which to reject the single stable-state hypothesis.

The other possible approach is the "active" one, where other species (in some sense competitors of the depleted species) are harvested to reduce their size or to prevent their further growth. This approach would be intended to render possible or to enhance the speed of recovery of depleted species. A rational basis for such an approach again requires an ability to predict quantitatively the effect on some species of changing the stock-size of others. Again this implies the availability of an acceptable multi-species model.

1.4 What is Practical at the Present Time?

The arguments given indicate that, ideally, achievement of the objectives of Article II requires the availability of an acceptable multi-species model for the Antarctic ecosystem (or at least for some geographic components of the system).

1.4.1 Why is no multi-species model possible at present?

The predictive capability of a multi-species model depends upon the accuracy with which its parameters can be estimated from existing data. Input information on current population sizes, and the manner in which these sizes have changed and are now changing with time, is essential.

Such information is not available. Consider, for example, two arguable "major" components of the system: crab-eater seals and minke whales. From available evidence for crab-eater seals in one area (Bengston and Laws, 1984), it is not clear whether the population is still expanding or has levelled off. For minke whales there is no consensus on the rate of population expansion, nor indeed on whether any expansion at all has in fact occurred (IWC, 1984a).

Such a wide range of possibilities would have to be narrowed considerably before there was any chance whatsoever of extracting values of parameters to be used in a multi-species model capable of predictions without enormous standard errors.

1.4.2 How can this situation be improved?

If it is indeed impossible to construct a suitable model at the present time, efforts should be made to assemble the information necessary to change this situation. Three lines of investigation seem appropriate.

(i) Selecting the major components of the system
An initial multi-species model for the system cannot hope to include every species, nor indeed would it be possible to assemble the requisite data for every species. It would seem advisable to first reach agreement on the likely major components of the ecosystem (i.e. those species having the most significant effect on the ecosystem dynamics), on the basis of currently available data. Following this, attention could be focussed on obtaining the information needed to incorporate these species only into a multi-species model.

(ii) Population size and growth rates
This information is probably that most necessary for production of a multi-species model (incorporating the "major" species). For most species, estimates of population size can probably only be obtained through surveys, but as the variances are likely to be large, rates of change will be difficult to determine precisely from repeated surveys. Inferences may therefore have to be drawn from measured changes in biological parameters.

(iii) Perturbation experiments
Carefully regulated experimental programmes reducing certain predator populations in a few selected areas could merit consideration. Without such perturbations to subsystems, the dynamic parameters required for workable multi-species models can be determined only with great difficulty and after considerable time.

Ideally such suggested perturbation experiments should take place on subsystems effectively closed (i.e. with no substantial emigration or immigration) during the period required to obtain results.

Do subsystems satisfying such criteria in fact exist? This needs to be studied (possibly by means of simulation models) prior to embarking on any experimental programme. Estimates of immigration and emigration rates would be vital for such exercises. For whales, available tag-recapture information may provide a basis for estimating these rates.

1.4.3 What management considerations may become relevant in the meantime?

An acceptable multi-species model seems unlikely to be available in the near future, but practical decisions will almost certainly have to be made in the interim. What precautionary approaches could be taken now, to prevent the possibility of the model arriving in time only to assist in a post-mortem analysis?

(i) "Active" predator harvesting

In the absence of an accepted multi-species model, there is no basis for an operational procedure to this end. Accordingly, reduction of predator stocks where the objective is only to enhance recovery of previously depleted stocks of other predators, or to increase the proportion of prey production available for human harvest, is not a mechanism that should be considered for the Antarctic as a whole at this stage. (This is not to exclude the possibility of such a scheme on an experimental basis in selected small areas).

This standpoint would need review if positive evidence for the existence of more than one stable state for the system was forthcoming - e.g. evidence that a previously depleted and now protected species was decreasing in size.

(ii) Krill[2]

Whereas agreement on the likely effects of perturbations in higher trophic levels of the ecosystem would be difficult to obtain on the basis of available evidence, there appears to be consensus that many species in these levels are predominantly dependent (directly or indirectly) on krill as a food source. Accordingly, even in the absence of an agreed multi-species model, it seems safe to conclude that substantial depletion of the krill standing stock would result in widespread deleterious effects upon at least some of the predator species, contrary to the requirements of Article II.

Avoidance of such a substantial reduction should therefore be a particular priority, at the local level as well as for the whole Antarctic. Whereas it is unlikely that the present krill-harvesting level involves any risk of such deleterious effects on predators, the opportunity must be taken to establish a basis for early detection of, and timeous remedial reaction to, such a situation should it occur. This must be done before the krill harvest, together with the associated economic pressures occasioned by capital investment in large fleets, grows to levels that make effective remedial action impossible. Possible approaches to this problem are discussed in a following section.

(iii) Fish stocks

Since there are indications that some currently harvested populations have already been depleted (Gulland, 1983), immediate management initiatives are necessary. This situation is discussed later.

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[2]Krill in this document is taken to be euphausiid Euphausia superba Dana. Due to its ice and near ice-edge habitat, substantial exploitation of Euphausia crystallarophias Holt and Tattersall does not seem likely in the near future.

2. KRILL

2.1 Introduction

It is suggested that a priority task would be the development of a capability to prevent substantial depletion of the krill standing stock by human exploitation.

More specifically, the inherent objective might be expressed as follows:

"The standing stock of krill in each designated management area must not be permitted to fall to less than an agreed proportion of its current level."

To develop a management plan to effect this objective (or first and more fundamentally to determine whether such an objective is appropriate and realistic), certain aspects should be considered. Some of these aspects (considered to be the more pressing ones) are discussed below.

2.2 What are appropriate "Management Areas"?

In principle the different stocks (if there are distinct stocks) of krill in the Antarctic should be managed separately. Stock boundaries should be delineated on the basis of available biological and oceanographic knowledge, together with historic whaling and other records (e.g. Mackintosh, 1972). In practice such information will probably not prove definitive.

Nevertheless a practical set of boundaries should be agreed upon for the time being. Even if not entirely based on the above criteria, they should at least be chosen with a view to spreading the krill harvest to reduce the possibility of overexploitation of what might prove to be a localized stock. Accordingly "management areas" would seem an appropriate term for such divisions, because they may not necessarily define separate krill stocks.

2.3 How can the Krill Stock-Size be Monitored?

Attainment of the objective suggested in 2.1 will require an ability to monitor the size of the krill "standing stock" (i.e. a representative value of biomass at a specific time of the year chosen by convention). The term "standing stock" has been used in the context of deterministic population dynamics models, in part for economy of expression.

The krill biomass is likely to be a function of the time of year; also it may be sensitive to the large recruitment fluctuations typical of many short-lived marine species. Such effects, combined with sampling errors, may introduce such large fluctuations in estimates of stock-size that detection of underlying trends (which is an implicit requirement of the objective suggested in 2.1) becomes impractical.

In any event, advice based on trends should incorporate the standard error of the estimates in some way (see for example the approach suggested in IWC, 1984b). If the estimate of a downward trend is unbiased, there is an approximately 50% chance that the real trend is no worse than that estimated. Instead of basing the management algorithm on this estimate, it could be based on a more conservative estimate, obtained by increasing the estimated downward trend by some fraction of the associated standard error. The fraction should be such that the probability of the real trend being no worse than the new estimate exceeds 50% by an agreed amount. This procedure provides an operational means of allowing for uncertainties in estimates.

A large variance is likely in any index of the size of the krill population; for example, different krill behaviour markedly affects catchability[3], and hence indices of catch rate. Accordingly, monitoring of as many indices as possible is desirable. Monitoring can be achieved either by "assessing" (in the broad sense of the word) the krill itself

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[3]Catchability is defined as the ratio of catch per unit effort (CPUE) to biomass. Models that assume CPUE and biomass to be porportional effectively take catchability to be constant (i.e. independent of biomass). In general catchability may be a function of biomass; for example when the biomass drops but the catch rate does not fall to the same extent, the situation is one where catchability is a decreasing function of biomass.

(direct methods), or by indirect methods in which krill predators (including the krill fishery) are assessed. It is important to appreciate that indirect methods involve two components: the "assessment" of the predator and knowledge of the manner in which the predator index thus obtained relates to krill abundance. While lower coefficients of variation may be possible for some predator indices compared to those for direct krill assessments, the usefulness of these indices still depends critically on the form of their relationship with krill abundance. The relationship is usually assumed to be linear, but this functional form may be by no means well established. The possibility of convex relationships (the index responding noticeably only after substantial reduction of the krill population) would be particularly problematic.

2.3.1 Direct methods

Hydroacoustic surveys are the only method now available for estimating krill abundance directly. Their practical application in the context of likely coefficients of variation for estimates merits attention.

The most concerted attempt to date to estimate krill abundance acoustically was the FIBEX survey in 1981, when 11 ships surveyed krill quasi-synoptically in four sectors constituting about 15% of the krill's geographic range. The coefficient of variation caused by random sampling error (i.e. the precision) was estimated at about 25% (Hampton, 1983). Systematic errors (e.g. from uncertainties in the target strength/length relationship for krill, and calibration errors), were potentially far greater than this. Such findings show that absolute acoustic estimates of total (i.e. circumpolar) krill standing stock are unlikely to be sufficiently accurate for management purposes at present, although the potential for improving accuracy by better calibration techniques and target strength information, for example, certainly exists.

More success may be achieved in monitoring changes in standing stock acoustically, because the precision will not be affected by systematic errors provided that they remain reasonably constant from one survey to the next. Even so, the imprecision of the FIBEX estimate indicates that acoustic surveys on an unprecedented scale in terms of area, number of ships and cost, would be needed to monitor global changes in the krill population, unless a vastly more efficient survey strategy can be devised.

Acoustic monitoring of changes in standing stock within some of the defined management areas could be more successful, provided that these areas are not too large. For such monitoring to be useful for management, the areas would either have to a) contain most of the population, or b) be such that changes in standing stock within them reflect changes in the population at large, or c) contain local stocks which can be managed separately. Acoustic data on krill distribution, collected from research ships and ships of opportunity over a long period, would be useful for refining and possibly re-defining the management areas according to all or some of these criteria. Long-term inter-disciplinary acoustic, hydrological and biological studies should help in discovering the reasons for the observed distributions, and thereby assist in the definition of the management areas.

Acoustic surveys could also be useful for selecting small areas for perturbation experiments and acoustic methodology studies.

2.3.2 Indirect methods

Of the predator indices of krill abundance potentially available, that from fishing operations - CPUE (Catch per unit effort) merits the most immediate attention.

The aspect needing special investigation is the relationship between CPUE and krill biomass, particularly the quantification of possible non-linear effects such as catchability increasing as biomass decreases. In a species such as krill, which shows marked swarming behaviour, this effect may well be substantial.

Empirical determination of the non-linear effects does not seem to be an appropriate strategy. Probably only the substantial biomass decline that the primary objective (of 2.1) aims to avoid would provide the necessary data for such analysis. Instead, attempts should be made to develop a model of the fishing operation that provides quantitative prediction of the non-linear effects (compare for example the approaches of Paloheimo and Dickie, 1964, Cooke and Christensen, 1983 and Cooke, 1985). It is important to construct the basis for such a model at an early stage, because collection of non-standard items among the effort statistics may be necessitated for its utilisation.

Efforts should also be made to improve knowledge of the form of the relationship between krill abundance and other readily obtainable predator indices.

2.4 What would be an appropriate "Proportion" of the Current Stock-Size (Target level)?

An empirical (i.e. production model) rather than an analytical approach (incorporating biological parameters for which density-dependent changes have been measured or may be measurable) would seem the most practical procedure at this stage.

Possible approaches are those of May *et al.* (1979) and Caddy and Csirke (1983). The former utilize simple predator-prey models. The latter consider a production curve for the fishery and natural predators combined, rather than for the fishery alone; they suggest a management criterion of maximum biological production which will occur at a stock-size greater than that providing MSY for the fishery alone.

For either approach an important parameter to determine is the ratio of the stock-size providing maximal biological production to the unexploited stock-size (the level at which natural predators hold the stock in the absence of fishing). In principle this ratio could be greater than or less than unity. The larger the ratio is, the greater the indirect effects of harvesting are likely to be. A review of data from other systems may provide values useful for comparative purposes.

The anticipated reduction of the krill standing stock by human exploitation must have a deleterious effect on at least some of the krill predators. Accordingly an initially conservative selection of the proportion concerned would be appropriate. For example, in the context of the Schaefer/logistic model a value of say 80% might be preferred compared to the single species MSY at 50% which the model implies.

If krill predator stocks are (still) increasing in response to depletion of many of the baleen whale populations, the krill standing stock would be expected to decrease from its present level. In this context the objective level suggested in 2.1 is on the conservative side because it would then limit fishing intensity on krill more than if krill predator stocks remained at present levels. The objective could be reviewed if quantitative assessment of such an effect becomes available.

2.5 Operational Management Criteria

A vital consideration in the management of short-lived species subject to recruitment fluctuations (as seems likely to be the case for krill) is the ability timeously to detect and react to poor recruitment periods by decreasing the TAC (Total Allowable Catch) or whatever other major limiting mechanism, such as effort, might be adopted. Frequently, opposition to such necessary action arises from over-capitalization in the developmental phase of a fishery, with consequent pressure to maintain catch levels to cover the costs of such capitalization. For krill, the production/biomass (P/B) ratio is likely to be high, so the problem of over-optimism induced by the initial bonus provided the fishery through reduction of the standing stock to the agreed level, should not be too serious. However a high P/B ratio also implies a possible lack of resilience - whereas catches up to "MSY"[4] are readily sustainable, catches in excess of this level (estimation of which will in any case be problematic) for even a short period could substantially reduce the stock.

Placing a ceiling on the rate at which fishing effort (or correspondingly TACs) is allowed to increase in these initial stages of the krill fishery is a strategy that could ameliorate some of the problems mentioned above. Knowledge of the krill production function would permit ready determination of an appropriate value for such a ceiling. However, given the likely difficulties in determining this function accurately in the short term, it may be necessary to semi-arbitrarily adopt a value considered appropriately conservative.

A further point to consider is the formula for TAC (say) reduction which would apply should a decrease in standing stock below the "agreed proportion" be detected. Whereas such circumstances are probably (hopefully) unlikely to arise in the short term, their consideration should

[4]This argument ignores the effect of fluctuations for the purpose of simple illustration of the point in question.

not be overly delayed as it is most important that the formula be pre-specified, not left to be debated concurrently with detection of the effect.

3. FISH STOCKS

3.1 Introduction

Past trends in Antarctic demersal fisheries[5] lead to the conclusion that stocks are already heavily exploited, with past catches representing mainly the depletion of accumulated stocks rather than the harvesting of surplus production (Gulland, 1983). It is probable that many of these stocks have fallen below the level advocated by Article II [3(a)]. A particular concern must be the prevention of further deterioration of such stocks, and urgent management response to this effect may well be necessary. In addition the basis should be laid for regulating potential future exploitation of pelagic species[6].

An interim operational objective (similar to that suggested for krill) for the exploited (or potentially exploitable) fish stocks might be expressed as follows:

> "The stock-size of the species concerned must not be permitted to fall below, or must be allowed to recover to, an agreed fraction of its estimated pre-exploitation level in each designated management area."

Inherent in any management plan to achieve such an objective are the same general aspects as discussed in the section on krill. The following will not re-elaborate on common features, but will be devoted to discussion on points of difference only.

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[5] Target species are predominantly bottom (benthic) dwelling. Important species exploited to date include *Raja georgiana*, *Notothenia gibberifrons*, *Notothenia coriiceps*, *Notothenia rossii rossii*, *Notothenia rossii marmorata*, *Champsocephalus gunnari*, *Chaenocephalus aceratus* and *Channichthys rhinoceratus* to name a few.

[6] The species *Pleuragramma antarcticum* may be very abundant and could assume considerable commercial importance. "Pelagic" species currently exploited include *Notothenia magellanica*, *Micromesistius australis*, *Dissostichus mawsoni* and *Dissotichus eleginoides*.

3.2 What are appropriate "management areas"?

Commercial exploitation of demersal stocks is confined to a few localized shallow-water areas (e.g. the environs of South Georgia, the Antarctic Peninsula, and the Kerguelen-Heard Plateau), which constitute a small fraction of the CCAMLR area. It seems reasonable to assume that the populations in these areas are isolated because of the large expanses of deep water that separate them. Such knowledge should serve as a basis for delimiting stock boundaries, or at least "management areas".

3.3 How can population size be monitored?

An ability to monitor the population size of exploited stocks (and also those conceivably protected to allow recovery after exploitation) is a practical necessity for management in terms of the objective stated in 3.1.

If stocks are truly confined to localized areas, as suggested by commercial catches, accoustic surveys could be very effective in defining the boundaries more accurately and in monitoring changes in standing stock. The problem of low target strength in species lacking swim-bladders can be overcome by deep-towing echo-sounder transducers to improve signal/noise ratios. Recent advances in the determination of fish target strength *in situ* may even permit useful absolute estimates of abundance.

Trawl surveys also merit consideration, and might be able to provide absolute estimates as well as relative indices of abundance.

CPUE is the most readily available indirect index. Care should be taken, however, to determine whether CPUE is biased as an index of fish abundance either by limitations in on-board processing and storage capabilities, or by catchability increasing as the population decreases.

3.4 What would be an appropriate fraction of the Pre-Exploitation Stock-Size (Target level)?

It seems doubtful that existing catch-effort data for any of the Antarctic fish stocks is sufficiently accurate or reliable to allow precise estimation of a ratio such as the stock-size producing MSY (single-species model) to the unexploited stock-size. Any fraction agreed upon would probably have to be based on comparisons with convention or model evaluation of this fraction for fish stocks elsewhere in the world. To allow at least qualitatively for the Article II requirement to take into account the indirect impact of harvesting, this fraction should be set conservatively (i.e. at a larger than a smaller value). A possible example of such an indirect effect is the decrease in Southern Elephant Seals at Marion Island, for which a postulated cause is competition for fish between the seals and the fishing fleets (Skinner and Van Aarde, 1983).

An appropriate fraction might be 50%.

3.5 Operational Management Criteria

If surplus production to biomass ratios for Antarctic demersal stocks are as low as they seem (Gulland 1983), "pulse fishing" may prove the only economically viable long-term harvesting strategy (i.e. rather than fishing every year, fishing should be carried out intensely over a short period once every number of years).

The associated regulatory procedures should nevertheless be set in accordance with Article II [3(a)], i.e. the TAC for pulse-fishing should be set to ensure that the stock-size does not decrease below the level inidicated by the objective. The pulse-fishing strategy assumes that the population can always increase after such harvesting. This ability may be prejudiced if the stock-size falls below the agreed level.

The fastest method to restore heavily depleted stocks to desired levels is to prohibit fishing the stocks until these levels are reached. However, such restrictive measures may be impractical, and would also lead to loss of much of the data on which monitoring of stock recovery could be based. Nevertheless if exploitation of such stocks continues, either on a steady basis or by pulse-fishing, TAC's should be set at levels that constitute removal of not more than an agreed proportion (perhaps 50%) of the appropriate surplus production estimate.

Such recommendations presuppose an ability to estimate surplus production. Again there may be insufficient data to allow this to be done to any great accuracy, and input from comparisons with better-studied stocks elsewhere in the world may prove useful. (In making such comparisons, it should be noted that surplus productions to biomass ratios for Antarctic fish may be lower than ratios for similar species in lower latitudes because of the comparatively slower rates of growth of Antarctic species - Everson, 1977). Experimental programmes setting different (even zero) catch levels in selected areas could enhance estimation. The success of this would depend on the extent to which stocks are in fact localized in the areas selected.

4. SUMMARY OF RECOMMENDATIONS

4.1 The Ecosystem Approach

1. Taking into account the indirect impact of harvesting, including any effect that this may have on the restoration of depleted populations, requires an ability to predict quantitatively; for this, multi-species models need to be developed.

2. Research required to develop such models includes:
   a) identifying those components (species) of the ecosystem that have the most significant influence on the dynamics of the system.

   b) estimating the population sizes and growth rates of these species in subsystems.

   c) conducting perturbation experiments in certain subsystems to enhance determination of model parameters (provided prior studies indicate little likelihood of substantial imigration into or emigration out of any chosen subsystem while the experiment is in progress).

3. Reduction of currently abundant krill predator stocks for the sole purpose of enhancing recovery rates of other previously depleted krill

predator stocks, or of increasing the proportion of krill production available for human harvest, is not a mechanism that should be considered for the Antarctic as a whole at this stage. (This is not to exclude the possibility of such a scheme being applied experimentally in selected subsystems.)

4. Interim management strategies for krill and fish stocks must be devised.

4.2 Krill

1. A suggested interim objective is:

   "The standing stock of krill in each management area must not be permitted to fall to less than an agreed proportion of its current level."

2. Stock boundaries, or management areas, must be delimited.

3. Hydroacoustic calibration techniques and target strength information should be improved.

4. Attempts should be made to model fishing operation, to allow quantitative prediction of possible non-linear effects in the CPUE-stock-size relationship for krill.

5. Knowledge of the form of the relationship between predator indices and krill stock-size should be improved.

6. The proportion of krill stock-size (or target level) referred to in the suggested objective (perhaps 80%) must be agreed.

7. A ceiling should be placed on the rate at which fishing effort or TACs for krill may increase.

8. Agreement must be reached on management action to be taken should the krill stock-size drop below the level indicated in the objective.

4.3 Fish Stocks

1. A suggested interim objective is:

   "The stock-size of exploited (or potentially exploitable) fish stocks must not be permitted to fall below, or must be allowed to recover to, an agreed fraction of their estimated pre-exploitation levels in each designated management area".

2. Stock boundaries, or management areas, must be delimited for such fish species.

3. The possibilities of hydroacoustically monitoring trends in stock-size and delineating stock boundaries should be investigated.

4. Agreement must be reached on the fraction of pre-exploitation stock-size (or target level) referred to in the suggested objective (perhaps 50%).

5. Regulation pertaining to possible "pulse-fishing" should respect the requirement of the suggested objective that stock-size not fall below the agreed target level.

6. For stocks already below agreed target levels, TACs for any continued harvesting should be set at values constituting not more than an agreed proportion (perhaps 50%) of the estimated surplus production.

7. Experimental programmes in selected subsystems should be considered to facilitate and enhance determination of surplus production functions.

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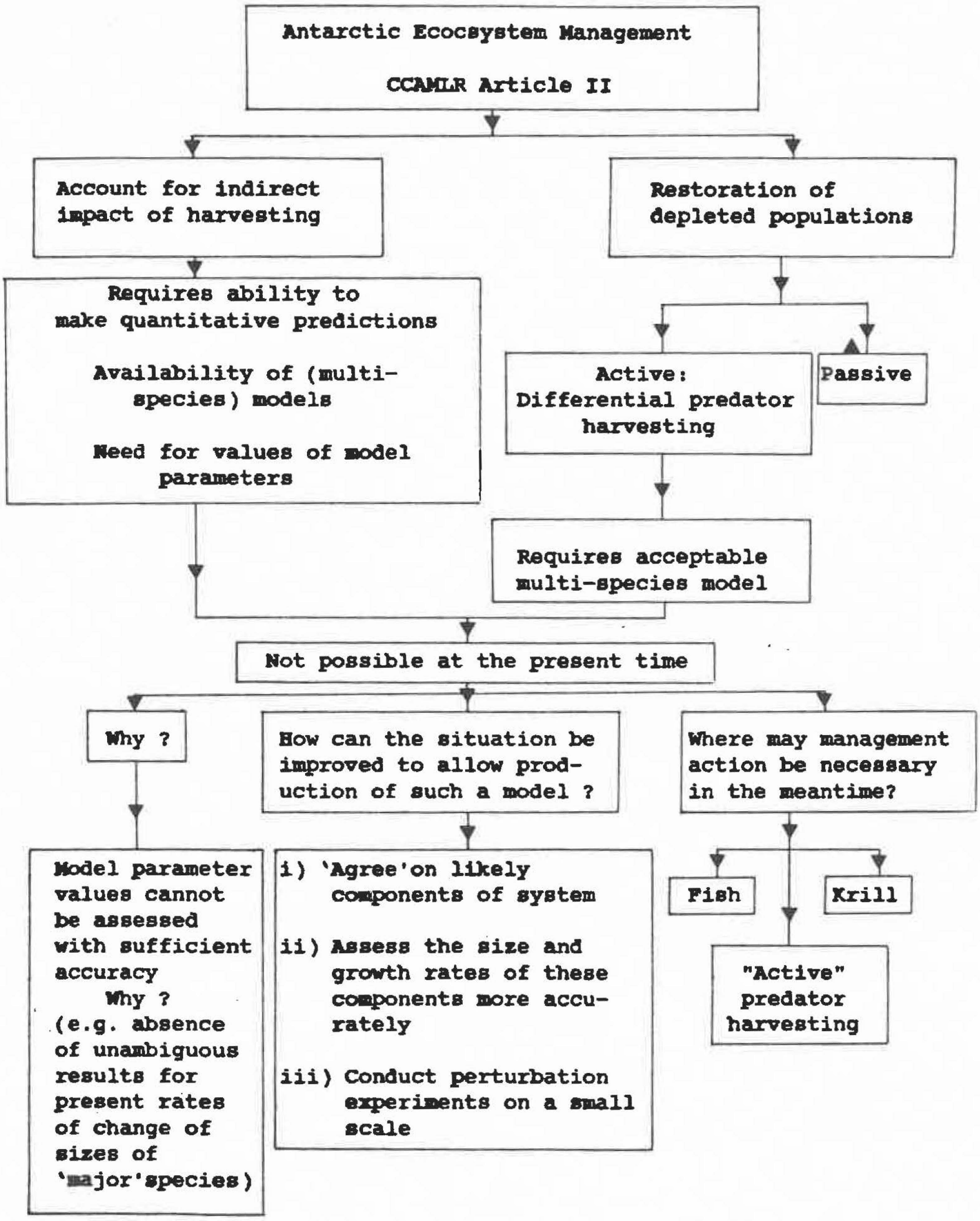

Figure 1. Antarctic ecosystem management
CCAMLR Article II

Figure 1. Plan d'aménagement de l'écosystème de l'Antarctique
Article II de la CCAMLR

Рисуно 1. Управление экосистемой Антарктики
Статья II Конвенции

Ilustración 1. Administración del ecosistema Antártico
Artículo II de CCAMLR