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AN APPROACH TO A MANAGEMENT STRATEGY FOR THE ANTARCTIC MARINE ECOSYSTEM

Abstract

A number of options for a management strategy ranging from total protection to harvesting at specific levels are discussed. These options are based on certain assumptions on the state of the system and consideration of past exploitation and present condition of stocks. Experimental fishing is suggested to obtain necessary information on responses within the ecosystem. Three areas of research priority are indicated and the design of experiments to assist management are proposed.

APPROCHE D'UNE STRATEGIE D'AMENAGEMENT DE L'ECOSYSTEME MARIN DE L'ANTARCTIQUE

Résumé

Plusieurs options sont discutées quant au choix d'une stratégie d'aménagement, allant de la protection totale jusqu'à l'exploitation à des niveaux déterminés. Ces options sont fondées sur certaines hypothèses concernant l'état du système et tiennent compte de l'exploitation passée et de la condition présente des stocks. Des opérations de pêche expérimentales sont suggérées afin d'obtenir les informations nécessaires en ce qui concerne les réactions au sein de l'écosystème. Trois domaines de recherches prioritaires sont indiqués et le format d'expériences destinées à faciliter l'aménagement est proposé.

ПОДХОД К СТРАТЕГИИ УПРАВЛЕНИЯ МОРСКОЙ ЭКОСИСТЕМОЙ АНТАРКТИКИ

Резюме

Обсуждается несколько возможных стратегий управления: от полной охраны до эксплуатации в определенной степени. Основой этих предложений послужили определенные предположения о состоянии системы и сведения о промысле в прошлом и современном состоянии запасов. Для того, чтобы получить необходимую информацию о реакциях в экосистеме, предлагается применить метод экспериментального промысла. Указаны три сферы первоочередных исследований и предлагаются схемы экспериментов в помощь осуществлению управления.

ENFOQUE DE UNA ESTRATEGIA DE ADMINISTRACION DEL ECOSISTEMA MARINO ANTARTICO

Resumen

Se estudian varias opciones con respecto a una estrategia de administración que varían desde una protección total hasta la recolección a niveles específicos. Estas opciones se basan sobre ciertas suposiciones sobre el estado del sistema y toman en cuenta la explotación pasada y el estado actual de las existencias. Se menciona la pesca experimental como medio para obtener la información necesaria sobre las respuestas dentro del ecosistema. Se da prioridad a tres áreas de investigación y se propone el diseño de experimentos para asistir a la administración.

INTRODUCTION

During informal discussions of the Scientific Committee for the Conservation of Antarctic Marine Living Resources, held at Hobart from 7-10 June 1982, participants were asked to prepare their views on management goals, for discussion at the second meeting of Scientific Committee. Subsequently, a panel of scientists in Australia discussed possible approaches to a management strategy and this was assembled as a basis for further discussion.

Several alternative approaches are set out and the likely consequences of each are assessed on the basis of our present limited understanding of relationships within this ecosystem. Although necessarily simplistic at this stage, the process is aimed at helping to clarify management goals, as well as to highlight some research priorities.

For the present purposes of a "thought-starter" aimed at stimulating discussion, any other commitments, resolutions or prejudices for or against the harvesting of particular species or groups of species are placed to one side in order to enable the Scientific Committee to consider objectively the most effective means of achieving the aims of the Convention for the Conservation of Antarctic Marine Living Resources.

In the interests of brevity, no attempt has been made to review the literature on the state of individual stocks, nor to discuss in detail the evidence available to support each assumption. Instead, we have drawn upon recent reviews such as those by the BIOMASS group (El-Sayed 1977, 1981), by Everson (1977), Laws (1977), Lubimova et al. (1980), May et al. (1979) and Knox (1982).

OBJECTIVES

In expanding on the primary objective of the Convention, which is the conservation of Antarctic marine living resources, Article II makes five points:-

(a) Conservation includes rational use:

(b) The ecosystem is to be managed in a manner which maintains the ecological relationships between harvested, dependent and competing populations:

(c) Management of the ecosystem will include the restoration of depleted populations (to a level as defined in (d)):

(d) Management should prevent any harvested population from falling below a level close to that which ensures the greatest net annual increment:

(e) Management of the marine ecosystem should not only be concerned with the effects of harvesting, but also with the effects of introduction of alien species and also the impacts of other activities likely to effect environmental changes which are not potentially reversible over two or three decades.

These agreed approaches set the objectives around which a management strategy must be framed.

THE ECOSYSTEM CONCEPT

The Convention does not specify that each population be returned to, and maintained at, the size which may have existed in the undisturbed state (some 150 years ago). Instead, there is a commitment to manage the ecosystem as a whole, re-establishing and maintaining relationships between members of the community. Since all the elements of an ecosystem are interlinked, management within the context of the ecosystem implies an understanding of how the various linkages operate. The most effective way to reach an understanding of how those linkages operate is to identify the major forces which drive them.

It is generally accepted that a major limiting mechanism is the availability of food; that is, important links in the ecosystem are trophic links. The consequences of this proposition that food has been limiting in the Antarctic ecosystem are of major significance. They enable the rate of increase or decrease in resource abundance to be predicted under a variety of alternative management regimes.

There is evidence that Euphausia superba, the major species of Antarctic krill, is the staple food of key resource species in the Antarctic ecosystem including baleen whales, crabeater seals, fur seals and Adelie penguins. E. superba may also be an important food for Antarctic fish and cephalopods, upon which other species of seals, penguins and other seabirds depend. Therefore, variations in krill abundance will have a direct impact on the major consumers in the Antarctic and vice versa.

Some populations of penguins, in contrast to baleen whales, may have limited areas in which to breed; there are limited ice-free areas of coast close enough to a supply of krill adequate to feed themselves and their young. Thus penguins may be limited both by food and by breeding space. Certain seals may also be limited by available breeding sites on sub-Antarctic islands. Such populations although limited to some extent by food abundance will show a uniquely different population response to changes in the numbers of other competing species and to alternative management strategies.

Before the advent of man, a balance had apparently been achieved between the competing species of consumers (and their predators) within the undisturbed ecosystem, such that each population remains at or near its asymptote for the natural environmental pressures to which it was exposed. In that situation the recruitment coefficient (r) approximated the natural mortality coefficient (M) so that a population fluctuated about a stable level.

If there was a long term trend changing the environmental pressures, those populations under greater pressure would be exposed to higher mortality and/or lower recruitment such that r-M being negative would bring that population into decline, while a population under reduced pressure would have a positive value for r-M, resulting in a rise in that population. Thus there would be an adjustment until the competing populations achieved a fresh balance, possibly in different proportions to that existing previously.

PAST EXPLOITATION AND PRESENT CONDITION OF STOCKS

Exploitation of resources from the Antarctic marine ecosystem commenced over 150 years ago, first upon fur seals, then on elephant seals and penguins on sub-Antarctic islands. Hunting of right whales peaked about 1840 but had totally collapsed by 1845 due to overfishing. Catching of the larger and/or faster swimming baleen whales in the Antarctic ecosystem was largely delayed until the beginning of the present century with the introduction of the harpoon gun and steam vessels. Progressive depletion of blue whales, humpback whales, fin whales and sei whales followed.

As these populations of consumers were reduced, competition for food was eased, the improved nutrition resulting in faster growth, earlier maturity, higher reproductive rates (Laws 1977), and the potential for better survival of young. In this situation the difference between recruitment (r) and natural mortality (M) became positive, enabling those populations not being hunted to increase exponentially in the form:

$$N_t = N_o e^{(r-M)t}$$

In minke whales, r-M is apparently considered to be maximal at present, the catch quota of 7020 minke whales permitted by the IWC in 1982-83 being aimed to hold southern stocks at a level where net annual increment is greatest.

With the lessened competition for food, krill consuming penguins may have peaked quickly then stabilised as the easing of the food limitation was replaced by the limitation of available breeding space.

For crabeater seals however, the release of the limitation of food may have enabled r-M to maximise and population growth to continue to rise towards a new plateau whose limits are not yet determined.

On the above hypotheses, the relative positions today of some of the major consumers in the Antarctic ecosystem on the sigmoid population growth curve are indicated in Figure 1. In absolute terms the vertical scale will be different for each species, but Figure 1 illustrates the relative condition of populations at present. Certain populations of elephant seals and fur seals have recovered well from earlier exploitation and may be approaching a limit (where r=M) of breeding space rather than food supply.

ALTERNATIVE MANAGEMENT APPROACHES

If the objectives of Article II of the Convention are to be achieved, Figure 1 clearly shows that right, blue, fin, humpback and sei whales need to be given every opportunity to recover. Not only should they be fully protected from any further hunting

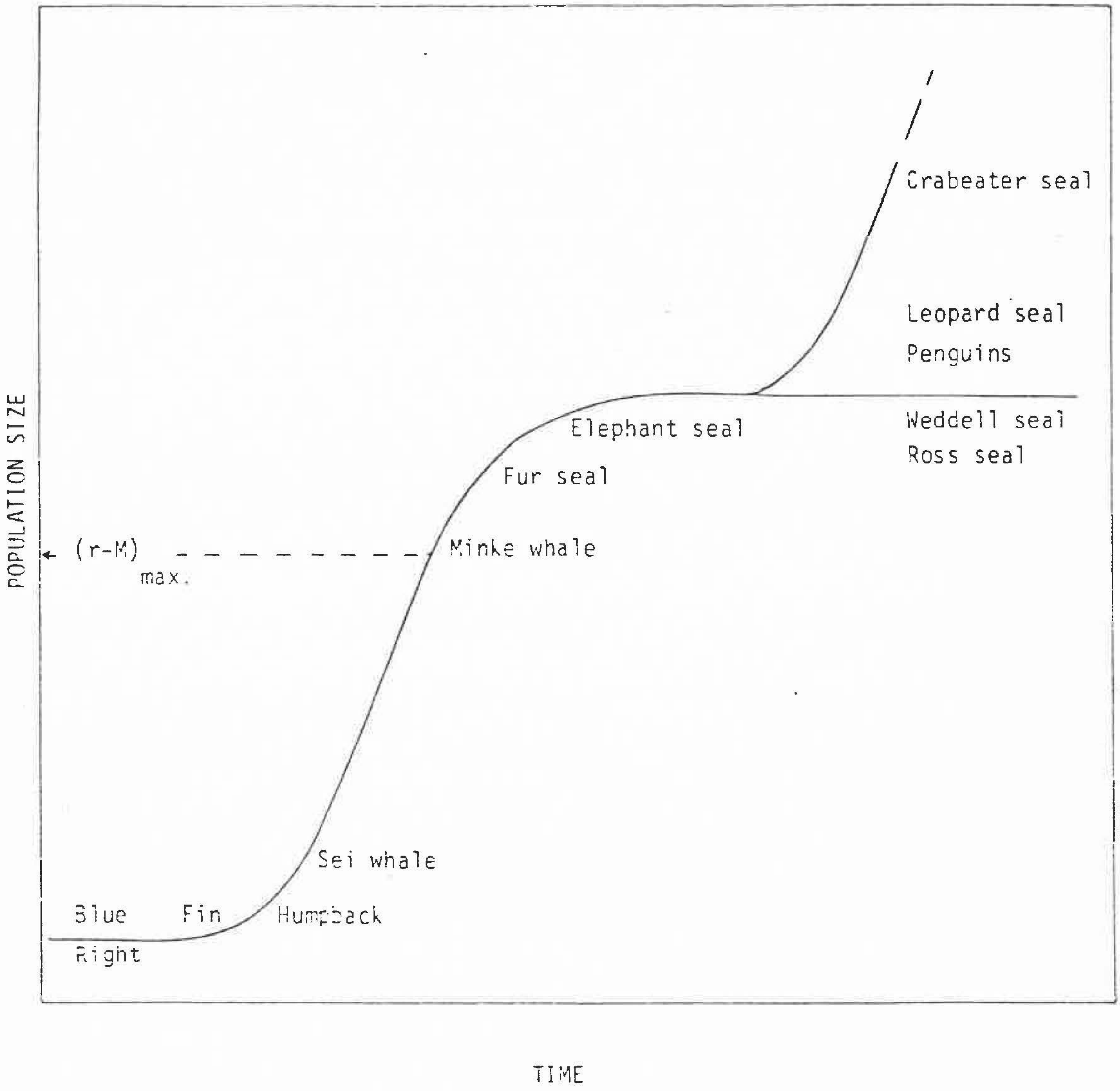

Figure 1. Present relative positions of major consumers in the Antarctic marine ecosystem on a population growth curve.

at this stage, but also management of other sectors of the ecosystem should be designed to ensure that food supply in the form of krill swarms is sustained at levels which do not inhibit the recovery of the depleted whale stocks.

In the case of minke whales, if the Scientific Committee of the International Whaling Commission is convinced that there are sufficient data to conclude that Antarctic stocks are presently held at a level where net annual increment is maximal, then on the basis of Article II of the Convention, a carefully selected level of catching might be sustained. (However, at the 34th annual meeting of the IWC a schedule amendment was passed specifying a cessation of commercial whaling by 1986.)

Crabeater seals, on the other hand, present an anomaly; they appear to be benefiting from maximal net annual increment and so satisfying Article II of the Convention, but possibly at the expense of the depleted baleen whales.

If breeding space is limiting further increase of penguins and other birds, elephant seals and fur seals, then these groups of consumers are unlikely to retard the recovery of depleted whale species through increasing competition for food.

Then setting aside fish and cephalopods for the time being (for reasons discussed later), a limited number of options remain for consideration as management strategies. Some of these are listed as follows:

A. Total protection: no harvest of any species.

B. Low harvest of krill only.

C. High harvest of krill only.

D. Low (or zero) harvest of krill + sustainable catch of crabeater seals.

E. High harvest of krill + sustainable catch of crabeater seals.

F. Low (or zero) harvest of krill + sustainable catch of crabeater seals + sustainable catch of minke whales.

HYPOTHETICAL CONSEQUENCES

Subject to the assumptions outlined above, the likely consequences upon the ecosystem arising from each of the management options can now be considered.

A. Total protection: no harvest of any species:

With key populations in the relative positions as indicated in Figure 1, crabeater seals are best placed to move ahead even further by exponential growth at maximal rate. Some other seals and penguins might soon reach the limit set by available breeding space (if not already so limited). Minke whales, if already at a level where net annual increment is maximal, would increase much more rapidly than other baleen whales, and so have the potential to achieve a greater population size than ever before.

When the overall food supply ceiling was again reached, the krill consumers in this ecosystem may well be dominated by crabeater seals and minke whales while the larger baleen whales may be insignificant.

Thus a management strategy where there was an immediate and complete closure of any further exploitation of resources within the Antarctic ecosystem would not automatically result in recovery of all stocks to the same community structure as that which existed 150 years ago.

B. Low harvest of krill only:

A low harvest of krill which left a large proportion of the present "surplus" would have much the same result as option A, except that the food supply ceiling would be reached somewhat earlier, halting the widening gaps between the krill consumers.

C. High harvest of krill only:

Similar effect as option B. However, with an early cessation of recovery, certain of the severely depleted stocks of some baleen whales might fail to maximise net annual increment and in the face of declining recruitment, one or two species might disappear altogether.

D. Low (or zero) harvest of krill + sustainable catch of crabeater seals:

Crabeater seals would be held near their present level; baleen whales would increase but minke whales would outstrip other species. When the food ceiling was reached, crabeater seals and minke whales might be relatively more abundant than in the ecosystem of 150 years ago, but the larger whales should be far better represented than at present.

E. High harvest of krill + sustainable catch of crabeater seals:

Slightly better prospects than option C for some partial recovery of presently depleted baleen whale populations, but again the available food could be limiting well before net annual increment was maximal.

F. Low (or zero) harvest of krill + sustainable catch of crabeater seals + sustainable catch of minke whales:

With crabeater seal and minke whale populations remaining static, other baleen whales would move as fast as possible towards levels where net annual increments were greatest.

While this by no means exhausts the options which might be available, these examples serve to illustrate the point that in the present state of the Antarctic ecosystem, if Article II of the Convention is to be put into effect, the ecosystem cannot be managed adequately by taking only krill. In order to ensure that depleted stocks have an early opportunity to maximise net annual increment, option F would appear to be the most effective, at least in the short term. As the larger baleen whale species recovered to the point where net annual increment became maximal, minke whaling and sealing could cease, or alternatively, a whole new management strategy might be devised for this ecosystem.

The probable impact of each option outlined above is a generalisation only. Much would depend on a more precise definition of "low" and "high" levels of exploitation of krill. The assumption that penguins (and certain species of seals) are limited by breeding space needs to be checked. If incorrect (i.e., not presently limited by either breeding space or by food), then a higher complexity of options is possible, and unless culling of penguins was applied, these might dominate the system in time. However, the rationale leading towards option F is considered to be reasonably based for a first approach to a management strategy.

In this approach to management strategies, fish and cephalopods were not included amongst the major consumers. Although fish have some importance within the ecosystem, it was initially considered that they might not be in such direct competition as the other major consumers because the larger stocks of demersal fish occurred on banks on the outer edge of the ecosystem (e.g. around Kerguelen/Heard Islands, and South Georgia), where exploitation had already been severe. For example, fish catches around Kerguelen Islands peaked in 1971-72 with a total catch of 120,000 tonnes, thereafter declining, while fish catches in the South Atlantic sector peaked in 1977-78 with a total catch of 202,000 tonnes and then declining sharply (FAO Yearbook of Fishery Statistics 1981, vol. 52). Thus it was thought that fish might be considered separately for management purposes.

However, recent examination of fish larvae within Australian zooplankton samples showed increasing proportions of larvae of demersal fish approaching the coast of Antarctica, possibly indicating significant stocks of demersal fish on the continental shelf of the mainland itself. One further aspect requiring consideration is the potential impact on fish resources of the relatively high by-catch take of fish larvae during commercial krill fishing.

Much less is known of cephalopod resources of Antarctic waters, but these might well be located towards the outer edge of the ecosystem (nearer to the Antarctic Convergence), as Australian zooplankton samples taken towards the Antarctic continent rarely contained any squid larvae. Also it is possible that cephalopods might be part of a slightly different food chain not so dependent upon Euphausia superba. Hence it appears unlikely that squid need to be considered in management strategies in the first instance, though they warrant research attention in the longer term.

QUANTITATIVE MODELLING

The relatively simple conceptual models developed above might well be tested further by simulations based upon those data which are available. While the limitations of the data may mean that the initial output will lack precision, such exercises will give further guidance in selecting options for closer investigation. Examples of this approach are given by May et al. (1979).

EXPERIMENTAL FISHING AS A MANAGEMENT TOOL

Linked with the modelling suggested above, the assumptions inherent in certain of the options outlined earlier might be tested in very practical terms by relatively large scale experiments carried out in different geographic sectors of the Antarctic ecosystem. Gyres maintained within the circumpolar water circulation concentrate krill into semi-discrete systems (Lubimova et al. 1980), and at least in the case of the baleen whales there are indications (Mackintosh 1942) that these consumers tend to feed each year on the same food concentration rather than to range freely around Antarctic waters. Hence it is highly probable that different experimental fishing regimes tested in separate (well chosen) sectors of Antarctic waters would yield meaningful results.

Three options which could be anticipated to produce quite different impacts are A, C and F. If these were applied to separate geographic sectors of Antarctic waters, then Sector A might be closed to fishing (a sanctuary), Sector C might be fished heavily for krill every season, while Sector F might be exposed to low (or zero) harvest of krill plus sustainable catches of minke whales and crabeater seals.

In all three sectors, considerable base-line data would be required, including population parameters for both crabeater seals and minke whales (population size; age at first breeding; birth rate, growth rate, natural mortality), and if possible some sighting rates for other species of baleen whales. Each management regime would need to be maintained continuously for a number of years (at least six years), and the same base-line data again measured.

If it was practical to mount controlled experiments on such a scale, a number of ancillary projects could be incorporated to study the roles of other consumers such as birds or other seal species.

Selected hypotheses might be tested by more localised experiments. For example, the hypothesis that breeding space is now limiting population growth of penguins might be tested by a controlled experiment using two separate colonies of the same species. In the first colony a high proportion of the adults would be banded but the population otherwise undisturbed. In the second colony a significant proportion of the adults (e.g. one third) would be culled and a high proportion of the remainder banded. Knowing that there is little exchange between colonies, in subsequent years the decline in the percentage of adults carrying bands will reflect recruitment plus band losses. Assuming equal rates of band loss in members of both colonies, a more rapid dilution of bands in the culled population will indicate an increased rate of recruitment to the adult population. Comparison of growth rates of chicks from year to year and between the two colonies could be used as an index of nutritional state within the colonies (i.e., whether food is becoming limiting), while regular censuses would indicate whether one or both populations had ceased to increase (indicating a limitation of breeding space, if nutrition was still optimal).

The hypothesis that populations of elephant seals and fur seals may now be approaching equilibrium (determined by limited breeding space) might be tested similarly. However, as population parameters can be measured more effectively in these mammals than is possible for penguins, such gross culling may not be required.

CONCLUSIONS

This initial approach to a management strategy for the Antarctic marine ecosystem is based upon the state of knowledge presently available. Certain assumptions had to be made, i.e.;

(a) that krill supply had been the main determinant of population size for the major consumers within the undisturbed ecosystem;

(b) that for certain penguins and seals, breeding space was also limiting (and continues to limit population growth);

(c) that for crabeater seals, breeding space has not been a limiting factor, and that with the reduction in competition for food, crabeater seals are now increasing exponentially;

(d) that the southern population of minke whales is presently held (by fishing) at a level where net annual increment is close to maximal.

The framework of approach using these assumptions has enabled a strategy of modelling linked with experimental fishing to be proposed, and has also focussed upon some research priorities needed to check certain of the basic assumptions.

Proposals for experimental fishing are based on applying quite different management strategies to each of several geographic sectors within the Antarctic ecosystem and by carefully monitoring the responses of harvested, dependent and competing species, learn more of the relationships between key members of this community. The results can then be applied in refining models. The magnitude of such an undertaking to apply well designed experimental fishing as a means of testing hypotheses and in determining relationships between species within this ecosystem is recognised. However, a management strategy based on carefully planned experimental fishing with concurrent research data taken on other competitors or consumers may be the most practical approach to managing the ecosystem successfully. Management research on this scale will be expensive, but there are opportunities for defraying the research costs by careful utilisation of the resources taken during the process.

An important research priority which stands out in developing this approach to management is the need for information on crabeater seal population size, age structure, breeding and mortality rates, etc. It is also necessary to verify (or refute) the hypothesis that crabeater seals are increasing to some higher plateau as a result of increasing food availability because of reduction of baleen whales.

Another research priority which has been identified is the need to assess whether certain species of penguins, fur seals and elephant seals may be limited by breeding space rather than solely by food supply.

A third research priority is a closer examination of the by-catch take of larval fish within krill fishing operations and an assessment of the impact of this upon fish resources.

A management strategy should not be regarded as a rigid framework but rather as an iterative process, with reviews as warranted by the gaining of fresh information. The next review and re-assessment should be carried out as soon as the Scientific Committee of CCAMLR has carried out a review of all available data upon the condition of each major species within this ecosystem. Then if experimental fishing and research on the lines outlined above were carried out, management strategy could be reviewed and refined in the light of these findings.

One important conclusion which is evident from this first approach is that a strategy of immediate and full protection of all resources within this ecosystem is very unlikely to result in the recovery of all species to the community structure which existed over 150 years ago. For that objective to be achieved, some difficult (even unpalatable) management actions will be necessary.

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Fig. 1. Present relative positions of major consumers in the Antarctic marine ecosystem on a population growth curve.

Fig. 1. Positions relatives actuelles des prédateurs principaux dans l'écosystème marin antarctique sur une courbe d'accroissement de la population.

Рис. 1. Существующее относительное положение основных хищников морской экосистемы Антарктики на кривой роста популяции.

Figura 1. Posiciones actuales relativas de los mayores consumidores en el ecosistema marino antártico en una curva de crecimiento de población.