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The Meeting is invited to take note of the attached UNEP Protocol for the scientific evaluation of proposals to cull marine mammals.

Report of the Scientific Advisory
Committee of the Marine Mammals
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PROTOCOL FOR THE SCIENTIFIC EVALUATION OF PROPOSALS TO CULL MARINE MAMMALS

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PROTOCOL FOR THE SCIENTIFIC EVALUATION OF PROPOSALS TO CULL MARINE MAMMALS

BACKGROUND

The Planning and Coordinating Committee (PCC) of the UNEP Marine Mammal Action Plan (MMAP) has as its members a number of inter-governmental and non-governmental organizations which share an interest in marine mammals. Among its activities is the establishment of an ad-hoc Scientific Advisory Committee (SAC) to advise on current issues as the need arises. In 1992, in response to an intensifying debate on the interactions between fisheries and marine mammals, a SAC was convened to consider the question of culling marine mammals for the purpose of protecting fisheries resources.

The task given to the SAC was twofold:

- compile a list of historical and current culling programmes and situations in which proposals have been made for culls for the intended benefit of fisheries resources, and

- draw up guidelines for the scientific evaluation of culling proposals, including a specification of the information which is needed to evaluate a cull proposal.

The SAC held two meetings to fulfill this mandate, in November 1992 (Liège, Belgium) and August 1994 (Crowborough, United Kingdom). The reports of the meetings are available from the MMAP Secretariat at UNEP. The present protocol was drafted by a sub-committee of the SAC and then sent to all members of the Committee for review. Annex 1 lists the members of the Committee who attended the two meetings and commented on the draft protocol. The final version, incorporating comments received, was then submitted to UNEP and the other member organizations of the PCC.

INTRODUCTION

Concerns are often expressed over the quantities of fish consumed by seals, dolphins and other marine mammals, and the possibility that they are affecting the size and availability of the fish stocks and thus the viability of fishing industries. Consequently, demands are made for culls to reduce the number of marine mammals, in the belief that fewer marine mammals will consume less fish, which will leave more fish available for fisheries to catch, with resulting benefits for the fishing industry and the livelihood of fishers. During this century, many control programmes aimed at reducing or limiting the numbers of seals or cetaceans have been implemented around the world. These activities have taken various forms, from bounties and culls lasting for several decades (e.g. a bounty on harbour seals *Phoca vitulina* in eastern and western Canada) to one-off hunts sponsored by governments (an open season on New Zealand fur seals *Arctocephalus forsteri* in 1946). Culls can also be implemented through existing commercial hunts, for example where the authorities subsidize a hunt to encourage it to take more animals than it otherwise would, or where a marine mammal harvest is managed with the aim of reducing, rather than merely maintaining, the marine mammal population. Table 1 lists the instances known to the SAC where culls or control programmes for marine mammals have been carried out for the apparent purpose of benefiting fisheries.

Table 1. Instances of current or historical culls or bounty programmes for marine mammals due to perceived ecological interactions with fisheries

United Kingdom	grey seals	various control programmes from 1934-1982
Ireland	grey seals	bounty until 1977
Ireland	harbour seals	bounty until 1977
Norway	grey seals	cull from 1980-1989
Norway	harbour seals	cull from 1980-1989
Norway	killer whale	expanded commercial hunt from 1978-1982
Baltic Sea states	Seals	bounties for various periods from 1889-1976
Sweden	grey seals	experimental cull 1997
Finland	grey seals	experimental cull 1997
Iceland	grey seals	bounty from 1982-??
Iceland	harbour seals	bounty from 1982-1990
Iceland	killer whales	US Naval operation in 1976
Greenland	killer whales	bounty from 1960-1975
Eastern Canada	harbour seals	bounty from 1927-1976
Eastern Canada	grey seals	cull from 1967-1984, bounty from 1976-1990
Eastern Canada	harp seals	seal hunt variously portrayed as “sustainable harvest” or population control mechanism”
Eastern Canada	beluga whales	various control programmes during 1920s and 1930s
British Columbia	Steller sea lions	various control programmes from 1912-1968
British Columbia	harbour seals	bounty from 1914-1964, recent localized culls
Alaska	harbour seals	bounty from 1920-1967
Western United States	harbour seals	various bounties from 1920s-1972
New Zealand	New Zealand fur seals	open season in 1946
Australia	Australian sea lions	open season in 1920
Australia	New Zealand fur seals	open season in 1920
Australia	Australian fur seals	open season in 1948/49
Japan	small cetaceans	various control operations until 1991
Japan	Steller sea lions	bounty
South Africa	Bottlenose dolphins	official killing in early 1900s
Namibia	Cape fur seals	fur seal hunt portrayed as “sustainable harvest” or “population control mechanism to protect fisheries”

Given the depleted status of many fish stocks and fisheries, it is not expected that demands for culling programmes will be reduced in the near future. According to a review by the Food and Agriculture Organization (FAO, 1993), one in four of the world's fish stocks for which an assessment is available is classified as over-exploited, depleted or slowly recovering from depletion. A further 44% are fully or heavily exploited, leaving fewer than one stock in three which is lightly or moderately exploited and which allows some scope for expansion. As the fishing industry attempts to maintain or increase catches from generally dwindling stocks, marine mammals are liable to be perceived increasingly as competitors to fisheries.

The limited number of cases that have been examined in depth to date reveal that interactions between marine mammals and fisheries are not always as simple as they might at first sight appear. Simplistic assumptions, such as that reductions in the abundance of a seal population will necessarily be reflected by a concomitant increase in fishery yields, can yield erroneous conclusions about the likely effects of a cull (see below on South Africa). Furthermore, experience shows that the issue of culling marine mammals can lead to emotional and polarized debates which may interfere with a rational evaluation of the potential merits and detriments of a specific proposal. For these reasons, an objective and scientific approach to the evaluation of culling proposals is important. Equally, all interested parties should have easy access to all the relevant information regarding any proposal to cull marine mammals. The SAC considered that a standard protocol for evaluation of culling proposals would assist this process, by helping to ensure that all major relevant factors are taken into account and by providing a suitable conceptual framework for making use of the available information. Use of a common protocol can also facilitate the comparison of cull proposals, which in turn can facilitate the application of experience gained in one situation to another. In addition to the essential scientific evaluation of culling proposals, there are economic and social implications of culls which should also be evaluated.

Since the last major reviews of the problems of interactions between marine mammals and fisheries (Northridge, 1984; 1991; Beddington, Beverton and Lavigne, 1985), there have been useful scientific developments relevant to the analysis of culling questions. Understanding of the properties of food webs has advanced, including methods of analysing food webs involving many species, but with only limited data on each one (Yodzis, 1989; 1994; 1998; *in press*). Other important developments include approaches to the management of marine mammal and fish stocks which involve simulation of their management under a range of scenarios (Cooke, 1995; Punt and Butterworth, 1995); this method provides a flexible means of making use of the available data and provides a consistent vertical integration of the various levels of the process from the biological through to the management levels, and is gradually becoming more widely applied.

The SAC reviewed recent scientific developments and experience relevant to the analysis of culling questions in particular and to the management of multispecies fishery situations in general, and used these to develop an evaluation protocol which aims to combine practicality in terms of the requirements for data and analysis, with a satisfactory degree of ecological and operational realism.

OVERVIEW OF THE PROTOCOL

The scientific evaluation of a proposal to cull marine mammals for the purpose of benefiting one or more commercial fisheries is not a trivial exercise, as it must consider the complexity of ecological interactions among the marine mammal population(s), the relevant fish stocks and the fishery/fisheries which catch them. The protocol developed by the SAC consists of two parts. The first (Section 2) defines in detail the information which must be provided with the culling proposal which will allow a scientific evaluation of the biological and ecological aspects, including:

i. a brief description of the components of the interaction (the marine mammal population involved, the fish species and the fishery or fisheries which take the fish and are thought to be in competition with the marine mammals) - Section 2.1;
ii. the objectives of the proposed cull and the expected benefits and risks - Section 2.2;
iii. ecological information on the marine mammals (distribution, population size, *per capita* food consumption and diet, the total food consumption of the population and their population dynamics) - Section 2.3.1;
iv. ecological information on each of the target fish species (stock assessments, the consumption of these fish by their significant predators and the principal prey species of the target fish stocks) - Section 2.3.2;
v. ecological information on other major components of the ecosystem - Section 2.3.3;
vi. information on the fisheries (total catches including, where significant, discards, and the method by which the fishery is managed) - Section 2.4.1 and 2.4.2;
vii. basic economic information such as relative prices for the commercially important species and subsidies - Section 2.4.3;
viii. details of the culling programme (number of animals to be killed, their sex and age, the target population size for the marine mammal and the methods to be used to monitor the population size) - Section 2.5;
ix. provisions for monitoring the effects of the cull in order to ascertain whether it achieves its objectives and the procedure for managing cull - Section 2.6.

Section 3 provides a description of the procedure for evaluating the likely effects of the proposed cull. The evaluation is performed using a particular type of ecological modelling known as scenario modelling. This technique has been shown to be a useful and versatile way to address fishery management problems which is able to incorporate a large amount of information while taking into account the uncertainties in our understanding of ecological relationships.

The steps involved in the evaluation exercise are:

i. summarize the available information and verify that requirements of Section 2 are fulfilled;
ii. identify those species (fish, marine mammal), fisheries and other components which must be included to create a “minimal realistic” model of the ecosystem. Increasing the number of species makes the model more realistic but also more complex and difficult to interpret. The SAC considered that a reasonable approach was to include enough species to account for most (i.e. at least 80%) of the natural predation for the commercial species of concern;
iii. construct the simulation model which includes all of the relevant components and the interactions among them;
iv. select realistic values and make realistic assumptions for the model. For instance, it is important that the model be constructed in such a way that the marine mammal population will not increase indefinitely if they are not culled. The uncertainties in either the parameter values or the model structure must be incorporated by, for example, using

a range of values or alternative plausible model structures;

v. choose the appropriate statistics which will be generated from the model to be used in assessing whether or not the cull will meet its objectives (performance measures). For instance, if increases in the catches of certain fish stocks are the objective, then the predicted catches following the cull would be a relevant performance measure. The appropriate comparison would be between catches following the cull and catches in the absence of a cull;

vi. run the model as constructed under the various scenarios;

vii. interpret the results: if the results tend to show either clear benefits or clear detriments from the proposed cull, then this would be evidence either for or against the cull, respectively. If the results are less clear cut, with some results showing gains and others suggesting disadvantages, further research may reduce the ambiguity.

An approach similar to that outlined here was used in South Africa to study the effects of a proposed cull of Cape fur seals (*A. pusillus pusillus*) on the hake fishery. A “minimal realistic” model was constructed that included the hake fishery, the fur seal population, the cull, the hake stock (in at least two age/size classes and including cannibalism) and a lumped component representing 'other predatory fish' (Anonymous, 1991). The basic model (Punt, 1994) predicted that a seal cull would benefit the fishery, although the size of the predicted effect was fairly small. A more realistic version, with two species of hake, one of which ate the other, predicted that a seal cull would have negligible benefits or a possible detrimental effect on the fishery. Subsequently, a decision was made not to proceed with the cull.

While the SAC developed this protocol using a particular modelling technique - scenario modelling - other approaches may also be valid. They would need to include the same interactions among the components (marine mammal, culling programme, fish stocks, fishery, management regime) as well as the uncertainties relating to both parameter values (fish stock abundance, catches by the fishery) and the structure of the model (ecological relationships).

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PROTOCOL FOR THE SCIENTIFIC EVALUATION OF PROPOSALS TO CULL MARINE MAMMALS

1. SCOPE

The protocol covers the case where marine mammals are perceived as ecological competitors with a fishery, and a cull of the marine mammals is proposed for the purpose of benefiting the fishery. It does not address other situations in which a marine mammal cull may be proposed, such as: (i) operational interactions (e.g. damage to fishing gear or raiding of nets by mammals); (ii) transmission of parasites from mammals to fish; (iii) actual or perceived damage to habitats by marine mammals.

The protocol focuses on the biological and ecological aspects of the evaluation of cull proposals. For this purpose, the economic objectives of the proposed cull should be noted, so that the evaluation can focus on the most relevant aspects of the expected effects of a cull, but a full evaluation of the economic consequences of a proposed cull is beyond the scope of the current protocol.

There are two main parts to the protocol:
- specification of the information required for the scientific evaluation of culling proposal
- outline of the evaluation process for cull proposals.

2. INFORMATION REQUIRED FOR THE SCIENTIFIC EVALUATION OF CULLING PROPOSALS

In order to evaluate scientifically a proposal to cull marine mammals to benefit fisheries, a certain minimum amount of information is needed. To facilitate the evaluation, it is preferable that cull proposals be made in written form, and include the information specified below, with references to the original sources of the information.

The potential amount and scope of ecological data that is relevant to the evaluation of a cull proposal is virtually unlimited. It is recognized that ecological data can be costly to collect and that long time series may be required for them to be useable. This protocol focuses on specifying the minimum set of information that is required for a scientifically meaningful evaluation of a cull proposal. It does not attempt to provide an exhaustive list of additional data, that, if available, could be used to improve the evaluation of the cull proposal.

In situations in which some of the data listed are not available, attempts should be made to obtain them. If too much information is missing, an evaluation of the proposal may not be feasible. In such cases the cull could not be justified on scientific grounds because it would not be possible to judge whether it would be likely to achieve its stated objectives or, alternatively, have detrimental and/or unexpected impacts on the target fish stocks or other species in the system. A summary list of the data required is given in Table 2.

Table 2. Data required for the scientific evaluation of cull proposals.

1. Basic information: - the marine mammal population, range and migration - the target fish species - the fisheries involved and the species they take - the geographical area of concern
2. Cull objectives: - biological - operational - economic
3. Ecological information:
(i) Marine mammal: - distribution, population size, and population structure - *per capita* food/energy consumption - diet composition, including methods of sampling and estimation - total food consumption - demographic parameters
(ii) Target fish species: - distribution and migration - demographic parameters (weight at age, age at spawning, etc) - details of current stock assessment (if any), including: - data used (e.g. catch at age, research survey abundance indices, commercial catch per unit effort) - details of assessment model and results
(iii) Other predators and prey of the target fish species: - abundance, amounts consumed, details of stock assessments if any
(iv) Other components of the ecosystem: - 2-way matrix of 'who eats whom' with estimated or guessed annual consumptions - estimated abundance by species
4. Fisheries: - catches, including bycatches, of the target and other species - management system in place, if any, including procedure, if any, for determining TAC - basic economic data, where relevant to objectives
5. Culling programme: - envisaged duration - annual numbers to be killed or details of other measures, e.g. bounties - measures to estimate the numbers killed - target population size or other reduction/control targets, if any - provisions for monitoring marine mammal population - provisions, if any, for monitoring the effects of the cull.

2.1. Basic information on the marine mammal/fishery interaction

The following should be specified:

- the marine mammal species and population(s) involved, their geographical extent and seasonal movements;
- the target fish species which are thought to be the subject of competition between marine mammals and fisheries;
- the fishery or fisheries which take the target species, their area and season of operation, gear used, and details of other species taken in significant quantities;
- the geographical area where the competition is believed to occur.

2.2. Objectives of the proposed cull

The objectives of the cull, and the expected benefits, e.g. biological or economic, need to be specified clearly, so that an evaluation can be made of the likelihood of achieving them. Any potential environmental costs and risks should also be noted.

The objectives and expected benefits of a cull could be, for example, biological (e.g. increases in the abundance of certain fish stocks), economic (e.g. increase in the profitability of a fishery) or catch-related (e.g. increases in realized or permitted catches, or realized catch rates, of certain fish species by certain fisheries).

If scientific analyses have been conducted to estimate the expected risks or benefits of the proposed cull, these should be fully documented, including a specification of the data used, the assumptions made, and the details of any models used.

2.3. Ecological Information

Certain ecological data are required for each of the marine mammal population(s), the fishery or fisheries, and the target fish stocks which are believed to be involved in the interaction. The information listed below is not an exhaustive list of all the relevant information, but represents the minimum required for a meaningful evaluation of the cull proposal.

2.3.1. The marine mammals

Estimates are needed of the total consumption by the marine mammals both of the target fish species and of all other species that form a significant component of their diet, since these other species may be involved in direct or indirect interactions with the target species. Obtaining these estimates will require the following information:

2.3.1.1. Distribution

In order to identify which marine mammals are actually involved in the interaction, information is necessary on the distribution of the population including any seasonal migrations, so that the fraction of the population in the area of interest at each time of year can be estimated. In many species, males and females or adults and juveniles are found in different areas.

2.3.1.2. Population size

An estimate is needed at least of the current size of the marine mammal population, and preferably also estimates of the population size in previous years and the current trend in abundance. All estimates should specify the component of the population to which they refer and have associated confidence limits (e.g. 525,000 ± 48,500 animals aged one year and older). The method of estimation should be specified and documented. Where possible, information on the age and sex composition of the population should be provided. The latter is especially important in species where males and females differ greatly in size.

2.3.1.3. Per capita food consumption and diet

The *per capita* food consumption of the marine mammal population, partitioned by prey type, can be estimated either by (i) direct measurements of the absolute amounts consumed, e.g. from stomach content or faecal analysis; or (ii) by converting an estimate of relative diet composition to an estimate of total consumption using estimates of the energy requirements of the mammal and the energy content of the food species. Method (i) is only feasible in some cases, and even when it can be used, method (ii) should also be applied as a cross check. Application of method (ii) requires:

- estimation of the annual energy requirements of the marine mammal;
- estimation of the composition of the marine mammal's diet;
- estimates of the energy content of each prey species.

The *per capita* energy requirement estimates should be for each age class and sex. Where specific data are not available, generic formulae for mammalian food consumption by body size and life stage may be used. They should be for the period of the year in which the marine mammal is in the area of interest.

Estimation of the composition of the diet, by food species, requires care. Diet composition can vary widely: by time of day, between seasons, from region to region, from year to year and, often, between males and females and among animals of different ages and sizes. It is necessary to ensure that dietary information is representative. Stomach contents or observed feeding behaviour of animals taken in or near fishing nets are unlikely to be representative. Likewise, the diets of animals at times and places where they can readily be seen during breeding or hauling out may not be representative of their diet through the year and their range. Since all of the techniques currently available to estimate diet composition are biassed in one way or another, the methodology used should be noted and the results interpreted cautiously.

The energy content of prey items can also vary seasonally in some species, as fish are often richer in their energy content just prior to spawning. Data on these variations, which can have a large impact on estimates of total consumption, are needed for the most important prey species. Information on the size of the fish which are consumed, especially of the target species, may also be necessary to evaluate the cull in some cases.

2.3.1.4. Total food consumption by the marine mammal population

The above information on diet, distribution and abundance can then be combined to give estimates of how much fish and other prey of each species is consumed by the marine mammal population in the area of interest.

2.3.1.5. Population dynamics of the marine mammal

An essential part of the evaluation of the ecological effects of the proposed cull is an estimate of the impact of the cull on the abundance of the marine mammal. For this purpose, estimates of basic population parameters for the marine mammal are required: fecundity, age at maturity, and natural mortality by age. Where available, data on changes in any of these parameters over time should be given. Natural mortality rates can be difficult to estimate: if assumed values are used, an explanation and brief justification should be given. Using this information, predictions should be made of the impact of the proposed cull on the marine mammal population. The assumptions and model used for this purpose should be detailed.

There will usually be considerable uncertainty about some key population processes, such as the presence and nature of density-dependent effects in the marine mammal population dynamics. In this case, a range of alternative assumptions should be made, to span a plausible reasonable range for the unknown effects. Models which imply that the marine mammal population would, in the absence of a cull, increase without limit, are not realistic.

2.3.2. The target fish species

2.3.2.1. Stock assessments

Full details of the current stock assessment of each of the target fish species should be provided. These include:

- assumed and measured values of biological parameters, including weight at age, age at first spawning, natural mortality rates;
- data used for the assessment: e.g. time series of annual catches by age or size, time series of abundance data from research surveys, if available, time series of catches per unit effort by fishery;
- details of the assessment model used and the results.

If no stock assessment has been performed, the above data should be provided to enable this to be done.

2.3.2.2. Other predators and prey of the target fish species

Estimates should be provided of the annual consumption of the target fish species by each significant predator species in the area. Although it is difficult to give firm guidelines as to what constitutes a significant predator, the following guideline has been found to provide a reasonable balance between inclusiveness and practicality: the major predators of the target species should be listed in decreasing order of estimated consumption, and enough predators included to account for most (e.g. 80% or more) of the total estimated predation mortality on each age class of the target fish species in the area. As much of the life history of the target fish species should be included as possible, but it may be necessary to ignore predation on the earliest life stages due to lack of reliable data. Estimates of predation mortality should include cannibalism (predation of larger fish on smaller fish of the same species) where this occurs.

The main prey species of the target fish species should be identified, and estimates of consumption of each prey species made. This is especially important when the target species prey upon their own species or each other, or on species which are also preyed upon by the marine mammals. In some cases it may be necessary to include one or more additional prey species which are of particular interest to managers, even though they would not normally be included on the basis of their consumption by the marine mammal in question.

2.3.3. Other components of the ecosystem

Conceivably, other species in the system, besides those already discussed in Sections 2.3.1 and

2.3.2, could play a significant role in the response to a cull. For instance, if other predators of the target species are significant, then changes in the abundance of those other predators might also be significant and the model would need to predict such changes. This might require detailed information about the predators and the prey of those other predators of the target species. By the same reasoning, one might need detailed information about the predators and prey of the predators and prey of those other predators of the target species, and so on: indeed one might need to know all the interactions in the whole system. However, full information of this kind (say, accounting for at least 80% of consumption of all species in the system) will rarely, if ever, be available. Therefore, the SAC agreed that such multispecies issues could be addressed in the following way.

All the major taxonomic groups in the ecosystem (i.e. species feeding, or being preyed upon, in the area of interest, for part or all of the year) should be identified, as well as the trophic interactions between them (who eats whom). Initially, this information should be assembled in qualitative terms: i.e. include all significant components and trophic interactions, without quantifying them. The information is best expressed as a two-way table, with rows for prey and columns for predators. When this has been done, available data should be searched for a range of estimates of abundance, in biomass, of as many components as possible. Estimates of the total food consumption, and the consumption of individual prey species, should be entered where available. Gaps in the table should then be filled with reasonable guesses, in such a way that the "books balance". The distinction between estimated and guessed values should be kept clear. For estimated values the source of data should be listed, while for guessed values a brief explanation of the rationale should be provided.

Estimation of food requirements based on general allometric relationships relating energy requirements to body size for different groups of organisms should be used to derive a plausible range of estimates where specific data are lacking.

This table will be used for deciding what species should provisionally be taken into account in an evaluation of the likely effects of the cull. Taxonomically similar species should not be lumped together if there are substantial differences in their distribution and diet, such as between species occurring inshore and offshore.

2.4. Information on the fisheries

2.4.1. Catches

For each fishery which exploits the target fish species, reliable data should be provided on total quantities of fish caught (including those which are discarded), their size distribution and the location and season of the catches. Some fisheries may need to be included on the basis of their bycatches alone if these are significant. Data are also required on the catches of other species, including both commercially valuable species and bycatches, by each of these fisheries.

2.4.2. Management

In most instances, a cull of marine mammals would be intended to increase the abundance of fish stocks, on the assumption that this would lead to greater catches and profits for the fishing industry. However, the extent to which potential increases in a fish stock are reflected in increased catches can depend on the way the fishery is managed.

In order to evaluate the possible effects of a cull on a fishery, it is necessary to specify the way in which the fishery is to be managed during and following the cull. Typically this is accomplished by setting management measures, such as effort controls or a Total Allowable Catch (TAC), on an annual basis, using an assessment of the state of the stocks at that time, which is in turn based on a series of catch and other data collected up to that point. The method by which the annual TAC is determined or calculated should be specified, so that this can be included in simulations of the effect of a cull under various scenarios.

If there is no clearly defined procedure for the determination of management measures (e.g. TACs), the main objectives of the fishery management regime should be specified.

2.4.3. Economics

A full evaluation of the economic effects of a cull is beyond the scope of this protocol. Nevertheless, the economic objectives of the cull, if any, should be stated, since these help to guide the choice of biological and technical indices (such as the predicted level of catch for a given period into the future, or the level of fishing effort required to achieve a given catch) used to summarize the predicted effects of a cull, and to ensure that they are relevant.

A full economic analysis of the effects of a cull on a fishery would require information on operating costs, capitalization, market conditions, subsidies, taxation, etc. However, even in the absence of such an analysis, certain basic economic information should be provided where appropriate. For example, if the main fishery of interest catches several species of commercial value, data on the relative prices of each should be given, so that predictions of the level of catch by species can be converted to a total catch value. This may be particularly relevant in cases where the ecological modelling analyses suggest that the marine mammal cull may increase the abundance of some commercial fish species but reduce the abundance of others.

It should be emphasized that increases in the potential yield of a fish stock do not necessarily translate into an increase in the net economic yield of the fishery. In the case of fisheries which are inadequately managed and dependent on high levels of subsidies, enhancing the potential yield of the fish stock, through a marine mammal cull or other means, can even exacerbate the net economic losses made by the fishery. However, these issues are beyond the scope of this protocol.

2.5. Details of the proposed cull or culling programme

There are several types of control programmes which can be used to reduce marine mammal populations, such as culls and bounties maintained for several years or events limited to one or two years. The effects of the control programme will depend upon its extent and the methods chosen.

The number of marine mammals to be killed each year should be specified, along with details of how this number has been determined, the predicted age and sex of the animals, where and when they would be taken and how long the culling programme is expected to continue. The proposal should also note the precise timing in relation to the annual cycle of the marine mammal population, such as a cull during or immediately after the reproductive period or an opportunistic hunt throughout the year. If the number to be killed is not fixed in advance, but is dependent on data to be collected, such as a fixed proportion of the estimated pup production in each year, then the formula for determining the number and class of animals to be culled should be specified, along with details of the data which will be used to implement the formula.

If the number to be culled is not fixed or based on a fixed formula, for example if it is based on a bounty programme to provide an incentive to people to kill the marine mammals opportunistically, then the nature of the incentives should be specified, along with a rough assessment of its likely effect in terms of expected numbers killed, plus any relevant data from past experience.

The intended effects of the cull on the marine mammal population, such as to reduce it to a specific target level, should be specified.

Details should also be given of how the cull is to be implemented and what measures are proposed to verify or estimate the numbers of animals which are actually killed, as well as the scientific information to be obtained from the animals killed and its intended use.

The intended procedures for monitoring the marine mammal population (such as annual surveys of abundance) during and after the cull period should be specified.

2.6. Provisions for monitoring the effects of the cull

The provisions, if any, for monitoring the effects of the cull, with a view to ascertaining whether it had the intended effect, should be specified. Specific monitoring provisions should be undertaken with respect to each of the major elements in the objectives of the cull and the expected effects of the cull on the fishery and the marine mammal population. Management decisions to continue, stop or modify a cull may be linked to the results of the monitoring programme.

3. EVALUATION OF CULL PROPOSALS

3.1. Introduction

This section describes the procedure for evaluating, in advance, the likely effects of a proposed cull, especially in terms of the likelihood of achieving its objectives. The specified evaluation should be completed before a cull is undertaken.

Although the focus of this protocol is on the prior evaluation of a proposed cull, the approach can in principle also be used to evaluate the effects of a cull that has already taken place. However, delaying the evaluation until after the cull has taken place is not recommended for two reasons: (i) the prior analysis might indicate that the cull has a high probability of being detrimental to the stated objectives, and hence it would disadvantageous for the cull to take place; (ii) the prior analysis might reveal that in order to enhance the reliability of the assessment of the likely effects of the cull, certain data need to be collected from the pre-cull system. Without these data, it may be considerably harder to determine whether the cull had the intended effect.

The prior evaluation should also include an evaluation of the chances that the planned means of monitoring the effects of the cull will yield reliable results.

The recommended method of evaluation involves the ecological modelling exercise detailed in the following sections. The modelling approach used - scenario modelling - has been shown to be an useful and versatile tool in addressing fishery management questions. The exercise will not necessarily yield a definite verdict as to whether the proposed cull will be beneficial or detrimental, but it may yield an indication of the relative likelihood or plausibility of the cull having positive or negative effects with respect to its objectives. The evaluation exercise may also pinpoint those key aspects of the system on which more information would enable the effect of the cull to be predicted and monitored with more confidence.

It is recognized that in some cases the available modelling expertise may not be available, or there may be features of the situation that make the modelling exercise described below unduly difficult, in which case the evaluation may be performed in a less formal way. In such cases, it is nevertheless recommended that the following sections be studied and that: (i) the data that would be required to implement a model of the type described are assembled; (ii) all the major features which are recommended for inclusion in the modelling exercise should be assessed for their relevance and taken into account in the evaluation to the extent possible. Table 3 lists the main steps involved in the evaluation process.

3.2. Structure of the evaluation

The evaluation exercise involves the following steps:

(1) Summarizing the available information, including a determination of whether the information specified above is complete and of sufficient quality to conduct an evaluation of the possible effects of the cull. In particular, the information needs to be sufficient to construct a reasonable simulation model of the system, as described below.

(2) Identification of those components of the system which need to be taken into account for at least a minimal realistic evaluation of the likely effects of the proposed cull: these will include the marine mammal population, the cull itself, the target fish stock or stocks, other major predators of the target fish stocks, and, where appropriate the fishery, the management of the fishery, and other relevant components of the ecosystem.

(3) Construction of a simulation model of the system which includes as submodels each of the components identified under (2) and all significant interactions between these components.

(4) Specification of quantitative performance measures and other model outputs which are used to summarize the predicted performance of the cull relative to its objectives, and to throw light on other relevant aspects of the predicted effects of the cull. For example, if one of the objectives is to increase catches from a given fishery, then the predicted average annual catch by this fishery over the next 10 or 20 years would be a relevant performance measure. Other relevant output statistics include the extent to which the marine mammal population is predicted to be reduced by the cull.

Table 3. Procedure for the evaluation of the cull proposal

Verify that data listed in Table 2 are complete and adequate
Identify species, fisheries and other components to be included in a minimal realistic model of the system
Specify quantitative performance measures relevant to cull objectives
Construct simulation model of the system
Specify a range of alternative scenarios, covering the range of plausible parameter values and model structures
Run multiple replicate simulations of each scenario and compute performance measures and other relevant statistics
Interpret and synthesise results
Evaluate power of indices proposed to monitor effects of cull

(5) In general the available information will be insufficient to specify uniquely the most appropriate choice of models and parameter values. Hence, a variety of different scenarios should be constructed to span the range of plausible alternatives with regard to model assumptions and parameter values.

(6) In most cases some important components of the system, such as annual recruitment to the fish stock, will be subject to unpredictable random variability. The model should explicitly include this random variability, and multiple replicate simulations (typically 100 or more) of each scenario should be run so as to indicate the range of probable outcomes.

(7) Each replicate of each scenario should be run with and without the proposed cull, so that the differential effect of the cull on the predicted outcome can be analysed. The performance measures and other relevant output statistics should be summarized in a form to assist with understanding of the results, and, if possible, to reach an overall verdict on the relative merits or demerits of the proposed cull, or, failing that, to pinpoint those aspects of the system where more data are needed to reach a conclusion.

Some of these steps are elaborated in more detail in the following sections.

3.3. Construction of the simulation model

A simulation model should be constructed which contains the following submodels to simulate the components of the system:

3.3.1. Population dynamics of the marine mammal

This submodel should normally simulate the marine mammal population by age and sex over time, and be constructed so as to make use of available information on population parameters of the marine mammal (reproduction and mortality, age at maturation, weight at age by sex, etc). The submodel should contain some density dependence, to avoid the unrealistic prediction that the population will expand indefinitely in the absence of a cull. Since density dependence is hard to measure in populations directly, it may be necessary to make a range of assumptions about density-dependent processes, such as a range of values for the carrying capacity of the environment. For mammals dependent on a highly variable environment, whose populations are liable to fluctuate even in the absence of culling, at least some of the simulated scenarios should reflect this variability; an example would be the effects of El Niño on certain pinnipeds.

If the diet of the marine mammal is sufficiently varied (within or between years), or if the fish stocks of interest constitute only a minor portion of the marine mammal’s annual diet, it is probably not necessary to model explicitly the dependence of the marine mammal on its food resources. Otherwise, a range of assumptions may have to be made relating the population carrying capacity to the available food.

3.3.2. The proposed cull

The submodel should allow the cull to be simulated by removing given numbers of marine mammals by age and sex from the simulated population.

The proposed cull may not always specify a fixed number of animals to be taken, but may involve a variable number to be taken over time depending on estimates of the remaining numbers of animals. In such cases, the formula needs to be specified for determining the number of animals to be culled, the type of data on which this calculation will be based, and the frequency and precision with which it will be collected (for example, annual pup counts with a given coefficient of variation; see also Section 3.3.7 - Data collection submodels).

3.3.3. Food consumption of the marine mammal

This submodel should allow data on the diet composition of the marine mammal, preferably broken down by population component, such as mature and immature males and females, to be used to predict the total consumption of the species of interest by the simulated mammal population as a function of the simulated numbers of mammals by age and sex at any time in the future.

For this purpose it will be necessary to make assumptions about how diet composition might vary as the availability of the various food items changes. It will not usually be realistic to assume that the diet composition is independent of the relative abundance of food items, although this assumption might be used to construct one extreme scenario to bracket one end of the range of possibilities. A suitable intermediate assumption is that the relative proportions of the different food items vary in proportion to the ambient abundance of the respective items, i.e. relative food preferences do not vary. If the food species under explicit consideration constitute only a minor part of the total diet of the mammal, this assumption can be approximated by the assumption that the mammal exerts a fixed mortality rate on the species of interest.

An alternative scenario to include as a sensitivity test could be that the mammals focus on the more abundant food items, provided that this is consistent with the available data.

3.3.4. Dynamics of the target fish stock or stocks

In the case of fish stocks subject to an existing programme of assessment and management, it is preferable that the submodel for the dynamics of the target fish stock or stocks is equivalent to that used for the routine assessment and management of the fishery. However, if the model used for the routine assessment of the fishery is purely a stock reconstruction model, without predictive power, it will be necessary to extend it accordingly.

Given the variety of fishery assessment models in current use, and the need to match the choice of model to the specific characteristics of the fish stocks or fisheries in question, it is not appropriate to prescribe the details of the model here. However, the model does need to be of a form to enable predation on the stock by the marine mammals and other predators to be modelled explicitly. Since different predators, including fishers, often focus on different sizes of fish, it will normally be necessary to use a size- or age-structured model. Prediction of the future trends in abundance of the fish stock requires assumptions about recruitment to the stock, in the form of a stock-recruitment relationship, or the assumption of stock-independent recruitment levels. Since recruitment to most fish stocks is subject to considerable unpredictable variability, the assumed recruitment function should include an appropriate level of random variation. This will necessitate simulating multiple replicates of each scenario, whose outcomes will differ according to the different random patterns of annual recruitment that occur in each.

3.3.5. Other species

If an attempt to predict the outcome of a cull were to consider only the commercial fish species and the marine mammal thought to be one of its important predators, and ignored all other species in the ecosystem, then it is almost inevitable that the analysis would conclude that a cull would lead to increases in the size of the fish stock. However, the limited experience to date in examining interactions between marine mammals and commercial fisheries suggests that restricting the scope of the analysis to only these components of the system is liable to yield misleading predictions of the effects of a cull.

It is desirable to include as many participants in the interaction as possible in models which are used to investigate the consequences of culls. However, it is recognized that increasing the number of species in the simulation model to make it more realistic also rapidly increases its complexity and decreases the ease and confidence with which the results can be interpreted. There is a trade-off to be made between these two tendencies, which makes it difficult to give a firm guideline for the minimum adequate number of components to be included in the system.

The question of whether reliable predictions can be obtained by singling out a few key species and ignoring the others is still the subject of ongoing research from which general conclusions have not yet emerged. Nevertheless, a model which contains so few components that only one kind of outcome is possible regardless of the input data, is clearly insufficient.

At a minimum it is recommended that the models include enough components so that: (i) more than one type of behaviour is possible, depending on the input data; and (ii) the species included account for most (e.g. typically 80%+) of the predation mortality (including cannibalism, where this occurs) experienced by each age class of the commercial fish species of concern (data for the earliest life stages may not be available).

Judgement also needs to be exercised as to which interactions between the species in the model need to be included. To keep the model simple, it can be assumed that if the species in the model make up only a small part of the total diet of another species in the model, then the dynamics of the latter will be independent of the species modelled. For example, if the fish species included in the model make up only a small part of the diet of the marine mammal, then the predation impact of the marine mammal on the fish needs to be included; however, the impact of prey abundance on the population dynamics of the marine mammal need not be considered explicitly.

In the early stages of model formulation, information on other species (Section 2.3.3 - Other components of the ecosystem) can be incorporated selectively in order to achieve a balance between workability and completeness of the model. Models with differing levels of inclusiveness of other species in the system may be a part of the variety of different modelling scenarios considered (Section 3.2 - Structure of the evaluation). However, care should be taken not to permit too great a difference between models in the quality of data utilized. In many cases this requirement will limit the extent to which information about other species can be included.

3.3.6. The fishery and its management

The extent to which it is appropriate or feasible to model the fishery and its management will depend on the objectives of the cull and the nature of the fishery and the arrangements for its management, if any. Three main types of situation can occur:

(i) In the case of fisheries not subject to quantitative management restrictions, the aim of the proposed cull may be to enhance the abundance of fish, and thereby provide increased catches to the fishery at the existing level of fishing effort. In this case, it may be sufficient to model the relationship between the abundance of the fish stock and the level of catch for one or more given levels of effort, on the assumption that the cull will have no effect on the level of fishing effort.

(ii) In the case of fisheries subject to quantitative management restrictions, such as TACs, these will usually be based on some form of assessment of the fish stock. A cull of marine mammals may affect the abundance of fish, and hence the data on which the assessment is based, and thereby affect future TACs, which will in turn affect the future abundance of fish, and so on. Modelling the effect of the cull on the fish stock therefore requires modelling the process of assessment of the fish stock and the calculation of TACs. This will be possible provided that the procedure for setting the TAC is sufficiently well defined. It will also involve modelling the data on which the fish stock assessments are based (Section 3.3.7 - Data collection submodels).

(iii) In the case of fish stocks subject to TACs or similar management restrictions, but where the procedures for setting TACs or other management measures are not sufficiently well defined for them to be meaningfully included in a model, it will not be possible to model the direct impacts of a marine mammal cull on fish catches. In this case, all that can be done is to model the impact of a cull under a range of reasonable assumptions about catch levels over a limited period, to ascertain the effect of the cull on the final level of the fish stock. The assumption is that the higher the level of the fish stock at the end of the period, the greater the potential future catch levels, even though the relationship between the two cannot be quantified. An assumption of this approach is that levels of TAC over this period are independent of whether the cull takes place. This assumption will tend only to be realistic for relatively short periods, say 5-10 years.

3.3.7. Data collection submodels

Some of the cases mentioned above involve simulations in which management actions are regularly taken on the basis of the data collected to date, such as the number of mammals to be culled, or the TAC to be set for the fishery. In such cases, the type of data to be collected needs to be specified, along with their precision, and the method by which they will be used to determine the management action. All such data are subject to a certain degree of random error. For each type of data, a submodel is required to specify the nature of the random error (e.g. log-normal distribution) and its extent (e.g. coefficient of variation). It is well established that the predicted performance a fishery management strategy based on data subjected to realistic levels of error can be very different from the performance that would be predicted on the basis of perfect data. This aspect of the modelling exercise can be one of the most important.

3.4. Choice of parameter values

The parameter values for each of the submodels should be chosen to be consistent with what is known about the various components. There are two main types of uncertainty in parameter values or model structure:

(i) *Uncertainty that is not readily quantifiable* - for example, a choice between alternative model structures, or the setting of a parameter value for which little or no quantitative data are available. A common example of this kind of uncertainty is the relationship between predator diet and prey availability (functional response).

(ii) *Quantified uncertainty* - for example, where an estimate, with an associated variance, is available for a parameter value. Examples of this kind of uncertainty include the current abundance of the marine mammal and the fish stocks.

Uncertainty which is not readily quantifiable can be handled by choosing a reasonable intermediate model or parameter value for the base case scenario, together with one value or model on either side of this, chosen so as to span the possible or plausible range for the parameter value or model. Uncertainty which is quantifiable can be handled in a similar way, by taking, say, the 95% upper and lower confidence limits of the parameter value as the end of the range of likely values.

The advantage of this approach is its transparency and conceptual simplicity; a disadvantage is that it requires constructing two additional scenarios for each uncertain parameter value, thus increasing the overall number of scenarios which will later have to be taken into account in reaching an overall verdict.

Uncertainty which is quantifiable can alternatively be handled by defining a probability distribution for the value of the uncertain parameter (for example, log-normally distributed about the point estimate of the parameter). For each random replicate of each scenario, a value for this parameter will be chosen randomly from the defined probability distribution.

Since it will normally be necessary to run multiple replicates of each scenario anyway (because of the presence of inherently random or unpredictable factors, such as fish stock recruitment), the second method of handling parameter uncertainty requires no additional scenarios, nor even additional replicates of each scenario. A disadvantage is that it will not be readily transparent which source of uncertainty is contributing substantially to the overall uncertainty in the final result. Hence it will normally be necessary to employ a combination of both methods.

More sophisticated approaches for handling parameter uncertainty are available, including Bayesian conditioning, which can be used provided that the required expertise is readily available and provided that this does not result in the analyses becoming bogged down in the complexities of these methods.
Plausible ranges for some unknown parameters, such as the potential growth rates of different species can be estimated from general allometric relationships where specific data are lacking.

3.5. Performance measures and other output statistics

The simulation model will generate a large number of results for each replicate of each scenario. In order to interpret and use the results, it is necessary to focus on a few well-defined output statistics.

The predicted range of possible outcomes can often be quite broad, reflecting the level of uncertainty in the model. Hence it is useful to focus on the differences between the results of the cull and no-cull variants of each scenario. Even if the overall range of outcomes is very broad, useful conclusions can nevertheless be drawn when, for example, the effects of a cull are all in a consistent direction. Three main types of output statistics need to be identified and defined:

(i) For each objective of the cull, specific, numerical performance measures need to be defined for use in quantifying the merits or demerits of the proposed cull relative to those objectives. For example, if an objective of the cull is to increase the level of catch from a given fishery, a suitable performance statistic would be the difference (between the cull and no-cull scenarios) in the mean annual level of catch from that fishery over a period of 10 or 20 years following the initiation of the proposed cull or, in the case of a single event, the year of proposed cull. The main statistic for each scenario could be the median value of this difference over the replicates, but in addition the upper and lower 5%-iles of the difference should be given, to reflect the level of uncertainty.

(ii) Performance measures should also be specified to reflect subsidiary or implied objectives of the cull, or qualifications of the main objectives. For example, if the cull is intended to reduce, but not endanger, the marine mammal population, a relevant performance statistic to reflect the latter consideration would be the lower 5%-ile of the minimum size of the marine mammal population over the cull period.

(iii) Additional output statistics are required to enhance the transparency of the results, even when they are not directly related to the objectives of the cull. For example, if an objective of the cull is to increase catches from the fishery, then, in addition to the mean level of catch from the fishery, the mean abundance of fish would be a useful supplementary performance measure. If the model predictions indicate, for example, that the cull would not appreciably improve fish catches, then it is important to see whether this result is because the model predicts that there will be little effect of the cull on the abundance of the fish stock, or whether it predicts that the fishery fails to take advantage of an enhancement of the fish stock.

3.6. Running the model

The simulation analysis will consist of a range of scenarios: multiple replicates (typically 100) of each scenario are simulated to take account of the random variation inherent in many aspects of each scenario. Each replicate of each scenario should be run with and without the proposed cull, so that the differential benefits or losses of the cull can be discerned.

In an initial analysis, it is most convenient to define a base case scenario which contains what is considered to be the set of most likely or intermediate choices of parameter values and models. Each additional scenario differs from the base case in only one aspect: one parameter takes a value near an extreme of the plausible range.

After initial analyses have identified those parameters which appear to have substantial effects, scenarios involving combinations of alternative values of the parameters can be constructed to explore interactions. In many cases it may emerge that the results are sensitive to only a few parameters and even fewer interactions. Where this is not the case, a statistically more systematic approach to the design of the simulation ‘experiment‘ may be called for.

In programming the model, the same sets of random numbers should be used for each scenario with and without the cull, so that the differences between scenarios and between the cases of a cull and no cull are not affected by the random differences between replicates.

3.7. Interpreting the results

It is important that models be structured, parameterized and conditioned in such a way as to enhance the transparency of the results. Where possible, it is important to understand why the model produces the results it does and which factors, if any, are dominant in determining the results. If no single interaction or small set of interactions is dominating the results, then it is important to recognize this. This will help to identify priorities for further data collection.

The effect of a marine mammal cull on fishery yields is the outcome of three main factors:

(i) the effect of the cull on the marine mammal population itself
(ii) the effect of fishing on the fish population
(iii) the "substitutability" of fish removed by marine mammals and fish removed by the fishery.

"Substitutability" here denotes the extent to which a given reduction in consumption of fish (whether of a given species or in total) by the marine mammals achieved by a cull can be reflected in increases in catches by a fishery without depleting the fish stock further or increasing the risk of stock collapse. The substitutability can also refer to the converse situation, in which increases in consumption by growing populations of marine mammals result in decreases in fishery catches. It can be useful to distinguish further between the pure ecological substitutability that could be achieved given perfect knowledge of the fish stocks, and the degree of substitution that is achievable in practice given the imperfections of fisheries assessment and management.

Model outputs should be presented in a way which enable these three factors to be separately discernable.

In cases where some of the parameters of the model are not input but are functions of other parameters, the values that the model gives to these parameters should be produced as output so that their biological feasibility can be assessed (in some cases there may exist more direct estimates or observations of the parameters against which the values can be compared).

Outputs should also be presented in ways which are meaningful to fishery scientists in terms of the ways in which they normally assess fish stocks. For example, the single-species dynamics for the fish stock of interest implied by a multispecies model (in essence the projection of that model onto one dimension) should be presented so that fisheries scientists can relate the behaviour of the model to that of the models which they normally use for stock assessment.

3.8. Conclusions from the modelling exercise

The conclusions to be drawn from the modelling exercise depend on the pattern of results. If the results tend to go one way, this would constitute evidence in favour or against the cull, depending on the direction of the results.

For example, if the results indicate a substantial benefit from culling, in terms of the main performance statistics, in some scenarios, while in other scenarios they indicate small benefits or detriments for culling, but indicate no substantial detriments from culling in any scenario, then this would constitute evidence in favour of the cull.

A further possibility is that even within scenarios, the range of results from individual replicate runs includes both outcomes indicating substantial benefits of culling and outcomes indicating substantial detriments from culling. This situation is more likely occur if the second method of handling parameter uncertainty described in Section 3.4 is used. In such cases the conclusions to be drawn will depend on an assessment of the relative risks of culling and not culling.

3.9. Monitoring the effects of a cull

The proposed means of monitoring the effects of a cull should be evaluated along with the cull proposal. For each scenario and replicate, the model should produce as output the simulated values of the index which has been proposed to monitor the success of the cull. The simulated values should take account of the type of data on which the index is to be based, the statistical properties of these data, and the way the index is to be calculated from them.

The results of the simulation model can then be used to estimate the probability that the proposed indices will show significant effects of the cull, and, if they do, the probability that the indicated effects will be in the same direction (i.e. beneficial or detrimental) as the true effects.

A finding that the planned means of monitoring the effects of the cull are unlikely to yield reliable results does not necessarily imply that the cull should not go ahead. There may be cases where, while it is possible to predict with reasonable confidence that a cull is likely to be beneficial, there are nevertheless inherent reasons why it will not be feasible to verify subsequently that the predicted benefits have indeed accrued. This is particularly liable to be the case in ecosystems subject to high levels of unexplained natural variability.

In some circumstances it may be desirable to develop adaptive management plans, such that subsequent management actions (e.g. to continue, stop or modify the cull) are dependent on predetermined events or effects being detected by the monitoring program.

ANNEX I: Members of the Scientific Advisory Committee

Name	Country	1992	1994	Commented on protocol
Arnoldus Schytte Blix	Norway	x		
Monica Borobia	UNEP	x	x	
Justin Cooke	Germany	x	x	x
Enrique Alberto Crespo	Argentina	x	x	x
Michael Earle	Belgium	x	x	x
John Harwood	United Kingdom	x	x	x
Sidney Holt	Italy	x	x	x
Toshio Kasuya	Japan	x		
David Lavigne	Canada	x	x	x
Andrew Read	United States	x		
Jean-Paul Roux	Namibia		x	
Keith Sainsbury	Australia	x		x
Mark Simmonds	United Kingdom	x		x
Tony Sinclair	Canada	x		x
Peter Yodzis	Canada	x	x	x

ANNEX II: Glossary

allometric relationship - mathematical relationship describing the relative increase in a part of an organism or a measure of its physiology or behaviour in relation to some other measure, usually its overall size

density dependent - those factors which influence a varying proportion of organisms in a population, depending on population density

ecological competition - use or defence of a resource by one individual that reduces the availability of that resources for other individuals, whether of the same species (intraspecific competition) or of another species (interspecific competition)

functional response - change in the rate of exploitation of prey by an individual predator as a result of a change in prey density

stock-recruitment relationship - relationship between the spawning stock biomass and the rate of recruitment of their progeny to the population