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Application of the Precautionary Approach and Conservation Reference Point to the Management of Atlantic Seals: A Discussion Paper.

Application de l'approche de précaution et de points de référence pour la conservation à la gestion des phoques de l'Atlantique : Document de travail.

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Abstract

Resource management usually involves a tradeoff between conservation, economic and political concerns in establishing harvest levels. Often, decisions fail to consider the uncertainty associated with the available information on the resource, with negative consequences.

The Precautionary Approach (PA) brings scientists, resource managers and stakeholders together to identify clear management objectives, to establish specific benchmark or reference levels, to enable the status of the resource to be evaluated and to identify specific management actions that would be triggered when a population approaches or falls below the benchmark(s). Canada has subscribed to the Precautionary Principle outline in the Rio convention. Within this framework, Conservation, Precautionary and Target reference points can be identified and linked to specific actions to aid in managing the resource. The PA also recognizes that the amount of information concerning the status of a resource may vary and that a lack of information is not sufficient to delay taking a management decision.

Harp seals, hooded seals and grey seals are commercially exploited to varying levels throughout Atlantic Canada. The availability of scientific information concerning the status of these resources (abundance, reproductive and mortality rates) also varies between the three species. A conceptual framework for applying the PA to Atlantic seal management is outlined. For a Data Rich species, two precautionary and a conservation reference level are proposed. A precautionary reference level could be established at 70% (N_{70}) of the pristine population size or a proxy of the pristine population (e.g. maximum population size). When populations fall below N_{70}, conservation objectives assumes a greater role in the setting of harvest levels, and measures are put in place to allow the population to increase above the precautionary reference level. A second precautionary level is established at 50% of the estimated pristine population size, while a conservation limit resulting in closure of commercial harvesting is established at 30% of the estimated maximum population size.

Species with no recent population data are considered Data Poor and require a more risk adverse approach to their management. This could be accomplished by identifying the maximum allowable removals that will ensure that the acceptable risk of the population falling below this reference point is only 5%. This level has been referred to as the Potential Biological Removal (PBR) and is easily calculated using default values and an estimate of abundance. Since the only data required is an estimate of population size, it or a similar approach is appropriate for data poor species. The PBR approach has the added advantage that the simulation trials used to establish the appropriate population size (N_{Min}) ensured that the formulation was robust when the model assumptions were relaxed and plausible uncertainties were included.

Résumé

La gestion des ressources établit habituellement les limites de prélèvement à partir d'un compromis entre les besoins de conservation, les enjeux économiques et les enjeux politiques. L'incertitude liée à l'information disponible sur la ressource est souvent négligée lors de la prise de décisions, avec pour résultat des conséquences fâcheuses.

Dans le cadre de l'approche de précaution (AP), les scientifiques, les gestionnaires de ressources et les parties intéressées s'unissent pour fixer des objectifs clairs en matière de gestion et des points ou niveaux de référence précis qui permettent d'évaluer l'état de la ressource et de déterminer des mesures de gestion précises à prendre lorsque la taille d'une population s'approche d'un point de référence ou devient inférieure à celui-ci. Le Canada s'est engagé à respecter le principe de précaution tel qu'énoncé dans la Déclaration de Rio. Dans ce cadre de travail, il est possible d'établir des points de référence (cibles, de précaution et pour la conservation) et de les lier à certaines mesures de gestion de la ressource. L'AP reconnaît également que la quantité de données disponibles sur l'état d'une ressource peut varier, et qu'un manque de données ne peut servir de prétexte pour remettre à plus tard la prise de décisions de gestion.

Le phoque du Groenland, le phoque à capuchon et le phoque gris font l'objet de chasses commerciales d'intensité différente dans l'ensemble du Canada atlantique. La disponibilité de données scientifiques sur l'état de ces ressources (abondance, taux de reproduction et taux de mortalité) varie également selon l'espèce. Nous présentons un cadre conceptuel d'application de l'AP à la gestion des phoques de l'Atlantique. Pour les espèces bien documentées, nous proposons deux points de référence de précaution et un pour la conservation. Le premier point de référence de précaution pourrait être fixé à 70 % (N_{70}) de la taille de la population à l'état originel ou d'une mesure indirecte de cette population (p. ex. taille maximale de la population). Lorsque la taille d'une population passe sous N_{70}, il faut davantage tenir compte des objectifs de conservation lors de l'établissement des limites de prélèvement, et des mesures sont mises en œuvre afin de permettre à cette population d'accroître son effectif au-dessus de N_{70}. Le deuxième point de référence de précaution est fixé à 50 % de la taille estimée de la population à l'état originel, tandis que la limite pour la conservation, sous laquelle la chasse commerciale est fermée, est fixée à 30 % de la taille maximale estimée de la population.

Les espèces pour lesquelles nous ne possédons pas de données récentes sont considérées comme peu documentées et elles doivent faire l'objet de mesures de gestion plus prudentes. Par exemple, il est possible de déterminer le prélèvement maximal qui permet de réduire à 5 % les chances que la population passe sous le point de référence. Cette limite a été désignée « prélèvement biologique potentiel » et elle est facilement calculable à l'aide de valeurs par défaut et d'une estimation de l'abondance. Puisqu'une estimation de la taille de la

population est la seule donnée nécessaire, cette méthode ou une méthode semblable convient aux espèces peu documentées. De plus, les simulations effectuées dans le cadre de cette méthode pour déterminer la taille appropriée de la population (N_{Min}) ont permis de vérifier la robustesse de la procédure lorsque les postulats du modèle sont assouplis et que les incertitudes possibles sont prises en compte.

Introduction

Scientists provide regular advice to managers based on biological assessments of the exploited resource. These assessments normally attempt to predict future changes in the state of the resource by incorporating information on the age structure of past catches, estimates of recruitment and indices of abundance into an assessment model (Cooke 1999). Because the information is often incomplete, and model parameters are subject to natural variability, the resulting advice is also associated with considerable uncertainty. In the past, failure to recognize the importance of this uncertainty has lead managers to require proof that populations or resources were in difficulty before actions were taken (Taylor et al. 2000). Unfortunately, by the time serious damage to resources has been identified, they have often collapsed. Northwest Atlantic cod stocks and many large whale populations are examples of species for which traditional management approaches have resulted in large declines.

An alternative to the reductionist or mechanistic approach used in the past, is the precautionary principle. The Precautionary Principle articulates a basis for taking action in cases with insufficient scientific understanding, including extreme complexity, especially when outcomes are irreversible and/or widespread (deFur 2000). The precautionary approach attempts to incorporate a broader perspective, which is more consistent with the complexity of marine ecosystems. Within the context of fisheries management, the precautionary approach strives to be more cautious when information is less certain, does not use the absence of information as a reason to postpone or fail to implement conservation and management measures, defines and implements limit and target reference points and defines, in advance, decision rules for stock management (Punt and Smith 2001).

Canada supports Principle 15 of the “1992 Rio Declaration on Environment and Development” which states that: “In order to protect the environment, the precautionary approach shall widely be applied by States according to their capability. Where there are threats of serious or irreversible damage, lack of scientific uncertainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation” (Anon 2001a). Thus as outlined above, the Precautionary Approach (PA) is a distinctive approach within natural resource management that primarily affects the development of options and decisions based on values and priorities (Anon 2001a). The Precautionary Approach also requires that follow up research and monitoring be undertaken to minimize uncertainty and to improve decision making in the future, provides mechanisms for re-evaluating the basis for decisions and provides a transparent process for further consultation (Anon 2001).

A key component of this approach is that at certain stages or levels of the population, specific management actions will be established, to aid managers in managing the resource. These levels can be referred to as Conservation, Precautionary and Target reference points. A conservation reference point is the value of a property of a resource that, if violated, is taken as *prima facie* evidence of a conservation concern. A conservation concern exists when there is an unacceptable risk of serious or irreversible harm to the resource (Anon. 2001b) and as such, conservation or limit reference points are provided as point estimates to be avoided with high probability. However, given that there is uncertainty in the data, model formulations and parameters used to estimate both the current status of a resource and the conservation reference point, conservation reference points should also be associated with Precautionary reference points. A Precautionary reference point is an indicator of the level of a resource at which harvesting or fishing levels must change in order to reduce the risk that the resource will decline. To avoid such a decline, management actions should increase the chance that the resource will attain or exceed the Precautionary reference point. The intent is that if there is a high probability of complying with the Precautionary reference point, then we are confident that the conservation or limit reference point will not be violated. Ideally, advice should be framed in terms of complying with precautionary reference points, rather than avoiding conservation (limit) reference points.

Conservation and Precautionary reference points are intended to constrain removals within safe biological limits for both the target species and other components within the ecosystem. A third reference point, called the Target reference, is the level of the resource that the species should be kept at. Target reference points are identified by managers and stakeholders (with the assistance of scientists) and are intended to meet management objectives (ICES 2001). Within this context, fishery management strategies identify specific management actions, taking into account the uncertainties related to the status of the resource, that will maintain or restore populations to levels consistent with previously agreed target reference points.

One of the basic principles of the precautionary approach to which Canada has subscribed is the need to account for the uncertainty associated with estimates and to develop a basis for taking action in cases with insufficient scientific understanding. Thus, protocols are needed for situations where considerable data are available (‘data rich’) as well as for situations where the available data are limited (‘data poor’). In order to determine sustainable levels of removals of seals, current estimates of fecundity, mortality and abundance are needed. If these data are available the species could be considered ‘Data Rich’. In contrast, if they are not available the uncertainty associated with any management action will increase significantly. In these situations, the species should be considered ‘data poor’. Here, we attempt to provide a possible framework for the development of reference points that can be applied to exploited seal populations in the Northwest Atlantic. In doing so, we hope to develop a conceptual approach that might also be used in the development of reference points for other marine species.

In most fisheries, reference points have been linked to estimates of biomass or fishing mortality. However, neither of these measures is routinely used when discussing marine mammal populations. Instead, estimates of total population size are used as indicators of the status of a population.

Total abundance is not measured directly for the three seal species commercially harvested in Atlantic Canada (harp, hooded and grey seals) but rather, is estimated from a model that incorporates data on reproductive rates, age structure of the catch and independent estimates of pup production. In their review of seals and sealing in Canada, the Panel of Eminent Persons (McLaren 2001) suggested that reference points based on direct observational information (e.g. pup production, reproductive rates or condition) may be more effective than those that rely on parameter estimates derived from these observations. They also suggested that several variables be examined to make up a basket of Limit Reference Points. However, until sufficient information on how different data respond to changes in numbers, the use of estimates of total population provides a single parameter which facilitates discussions with managers, and stakeholders, but at the same time incorporates estimates of pup production, and reproductive parameters.

Data Rich Species

In cases, where sufficient harvest and population information for a species are available, we can identify reference points that can be used as a guide for fisheries management. With this in mind we suggest establishing a conservation reference point based upon abundance, called $N_{Critical}$. Associated with this limit reference point will be two Precautionary Reference Points, which for now we refer to as N_{Buf1} and $N_{Buf2.}$ These reference points identify 'buffer' population ranges within which different management control rules would apply. The first reference point would be $N_{Buf1.}$ In situations where a population is abundant and above the first reference point (N_{Buf1}) , managers could establish a target reference point based upon any number of considerations such as ecosystem impacts and/or socio-economic benefits. As long as the population remained above N_{Buf1} higher risk strategies for removing animals from the population (e.g. harvesting, incidental catch) could be adopted. These may include the management strategy that has been used in the past, that was based upon a replacement yield reference point (where there is a 50% chance that the population would decline or increase) or, alternatively, managers could opt for a specific target population that is either lower or higher than the current level. For example, if harp seals were considered to be above N_{Buf1} then management considerations could include consideration of the impact of seal consumption on the recovery of Atlantic cod stocks and if seals were found to be impeding the recovery, they may decide to lower the population. On the other hand, harp seals off northeast Newfoundland are preyed upon by polar bears. Reductions in the size of the harp seal population could have a negative impact on polar bears. Since polar bears are culturally and economically important to First Nations peoples and are involved in provincial and international management agreements, changes in harp seal management objectives should take these issues into consideration. Similarly, management objectives could be based on one of the scenarios identified by the Ministers Panel of Eminent Persons (McLaren 2001) such as maximizing economic returns to the industry or stabilizing harvest or prey consumption levels.

For populations falling between the range of N_{Buf1} and N_{Buf2} conservation concerns become a higher priority and the primary management strategy would be to return the population to a state above N_{Buf1} within a specified period of time (e.g. 10 years or less). Although harvesting and other human induced removals could continue, these strategies would adopt a higher probability (e.g. 80% vs. 50% for replacement yield) that a population would increase or conversely a lower risk that the population would continue to decline (e.g. 20%).

For populations below N_{Buf2} , conservation becomes a very high priority, such that significant conservation measures are required. Harvest strategies should ensure that there is a very high (e.g. 95%) chance that the population will increase and exceed N_{Buf1} within a specified time period.

If a population is estimated to be below $N_{Critical}$, the population would be considered to be a conservation concern and that there is an unacceptable risk of serious or irreversible harm. Under this situation, management actions would be taken to ensure that all human induced mortality was eliminated.

Specific management strategies would be developed depending on where the current estimate of the population size lies with respect to the reference points. The choice of any specific management action should be firmly based on a risk analysis approach. Before it can be implemented, its impact on the population and likelihood of reaching the intended objective must be evaluated in a manner that incorporates the uncertainties associated with the population estimates and predicated removals (McLaren 2001).

The greatest difficulty is to determine the population levels at which the reference points should be set. A number of different approaches have been used previously. We describe some general approaches for setting reference points, including general models discussed within the Fisheries (ICES\NAFO) literature based on the principle of Maximum Sustainable Yield (MSY), an approach developed within the COSEWIC/IUCN framework, reference points identified under the US Marine Mammal Protection Act, and the Revised Management Plan of the International Whaling Commission.

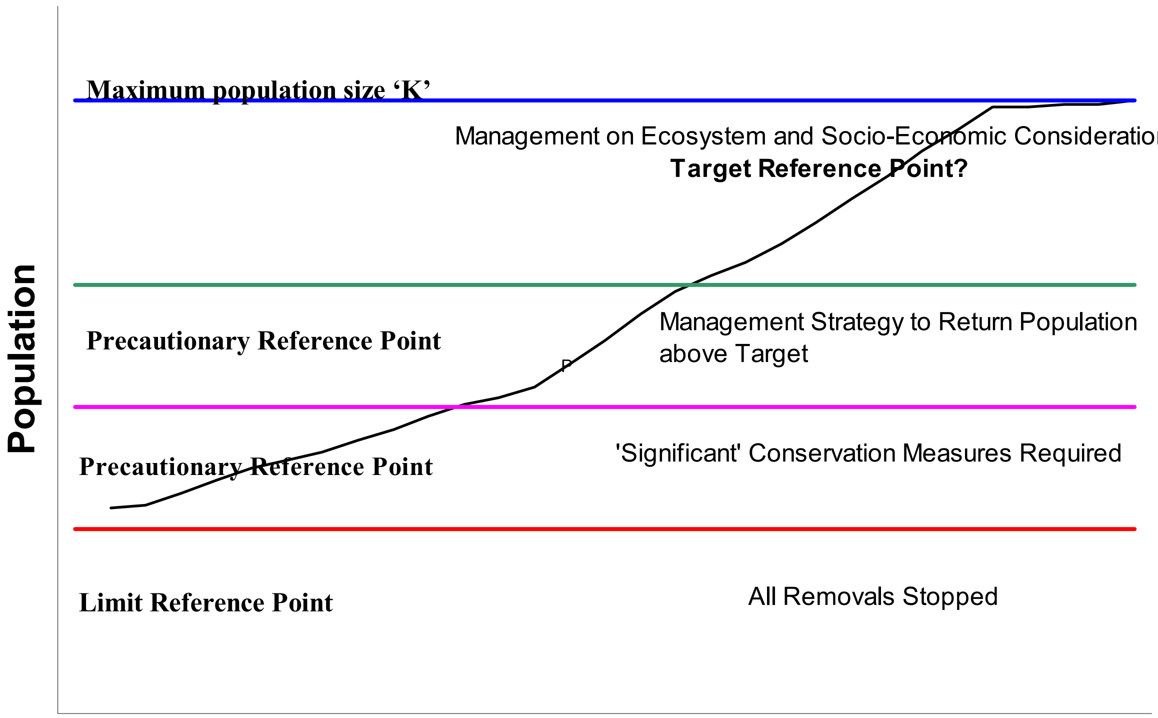

Figure 1. Reference points and control rules for implementing Objective Based Fisheries Management and the Precautionary Approach into management of seals in Atlantic Canada.

ICES/NAFO reference levels

The International Council for the Exploration of the Sea (ICES) and North Atlantic Fisheries Organization (NAFO) are responsible for providing scientific advise on the status of commercial fish species in the North Atlantic. In recent years, both organizations have worked hard at incorporating the principles of the precautionary approach into their advice. Within ICES and NAFO, different terminologies have been suggested for outlining a precautionary approach, but both groups have linked reference points to the concept of Maximum Sustainable Yield (MSY) (Caddy 1998). The concept of MSY is based upon the principle that environmental carrying capacity ('K') does not change and that population dynamics parameters are linked to changes in populations size relative to environmental carrying capacity (i.e. density dependent responses). It has a long history as a management objective, but has been discarded by most fisheries managers owing to difficulties in reliably estimating MSY, the appropriateness of MSY given other priorities (e.g. full employment) and the ability to implement effectively a harvest strategy based on MSY (Punt and Smith 2001). More recently the concept of MSY has been reincarnated, not as a management target, but as an upper limit point which harvest rates should not exceed (F_{msy}) or as a minimum biomass (B_{msy}) that a population should not fall below (Punt and Smith 2001). The objective of MSY is to harvest the maximum number of animals that can be sustained in the population over time and therefore it has also been identified as a potential target reference point (Shelton and Rice 2002).

Based upon the Fisheries literature, MSY can be used to set a reference point N_{Buf1} at 50-60% of equilibrium population size. However, since we are not able to estimate 'K' and because ecosystem carrying capacity may vary over time, the maximum observed or estimates of pristine population size could serve as proxies (Table 1). Unfortunately, pristine population sizes are difficult to determine in species that have been exploited for long periods and we do not know how the maximum population size we can estimate relates to 'K'. For Atlantic seals, however, the continued increase in populations in the absence of hunting suggests that using maximum population size will likely underestimate K.

The lowest observed population size from which a 'secure and rapid' recovery has been observed, referred to as B_{loss}, has been proposed as a limit reference point for fish stocks (Shelton and Rice 2002). However, the use of the lowest observed population size as a reference point requires information over a wide range of populations and assumes that the ecological conditions present at the time of the historical recovery (e.g. reproductive rates, food availability, etc) have remained the same. The different response of NW Atlantic groundfish stocks to high levels of fishing in the 1960s and the 1980s illustrates the potential problem with this assumption.

Seals have recovered from levels much lower than their current populations even the presence of continued hunting. For example, Healey and Stenson (2000) estimated that during the 1970s the Northwest Atlantic harp seal population increased at approximately four percent per year in the presence of annual removals in the order of 200,000. Therefore, even considering the caveats above, it may possible to consider B_{loss} as a candidate for N_{Buf2} for this species. An appropriate value for $N_{Critical}$, the lowest reference point below which no removals would be allowed, is not known but we have used 50% of N_{Buf} for discussion. A more appropriate level could be identified through extensive modelling of simulated populations.

As outlined above, the concept of MSY is based upon the principle that environmental carrying capacity ('K') does not change or varies on some predictable manner and that demographic parameters are linked to changes in population size relative to environmental carrying capacity. To describe this functional relationship, data on the equilibrium population size and the density-dependent relationship between population size, fecundity and mortality are needed. Although we do not dispute that density-dependent changes can occur, the necessary information to evaluate this phenomenon is unfortunately extremely difficult to obtain, particularly within the short-term framework of many management applications. Also, environmental changes do occur, but the response of marine mammal populations to these changes are often difficult to predict owing to inadequate information. For example the Northwest Atlantic harp seal population has more than doubled from less than 2 million in the 1970s to over 5 million today (Healey and Stenson 2002). Various attempts have been made to estimate MSY for harp seals (Lett and Benjaminsen 1977, Winters and Miller 1998), but they have not been generally accepted. Overall, the expected density dependent changes in population parameters for this population are not as convincing as has been suggested (McLaren 2001). Although the harp seal population has increased to higher levels than have been observed for several decades reproductive rates have not declined to the extremely low levels observed in other populations (Kjellqwist et al. 1998), suggesting that either harp seals do not show strong density dependent change or important changes in environmental conditions may have occurred. These changes could include an increase in environmental carrying capacity, changes in distribution to take advantage of a larger area or occupation of niches formerly occupied by other predators. Increases in strandings of seals in Atlantic Canada and along the New England states (Stevik and Fernald 1998, McAlpine 1999), and increased reports of harp seals in northern Greenland and the Canadian Arctic suggest that some expansion in range may have occurred. It has even been suggested that reduced consumption of capelin by Atlantic cod may have in fact increased the amount of food available for harp seals in the area. As a result, it is very difficult to determine what the current carrying capacity for harp seals in the Northwest Atlantic may be.

Table 1: Precautionary reference points obtained from the fisheries (NAFO/ICES) and endangered species (COSEWIC/IUCN) literature.

	NAFO/ICES	COSEWIC/IUCN
N max ('K')	Virginal or largest seen (or inferred)	
N_{Buf1}	MSY (50-60%)	70%
N_{Buf2}	Lowest level observed	50%
$N_{Critical}$	½ N_{Buf2}	30%

COSEWIC/IUCN Criteria

The point at which MSY occurs may be possible to calculate in a retrospective analysis, but there is uncertainty, on whether an MSY estimated under a set of environmental conditions during time period 1 could be applied to a population living under a different set of environmental conditions during time period 2. An alternative approach may be to use the framework developed within the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the International Union for the Conservation of Nature (IUCN) for assessing the status of populations. Within this structure, species are assigned to particular categories of concern based on percentage change in abundance in population size. Based upon the COSEWIC criteria, a species could be considered

‘Threatened’ if, over three generations, the population declined by 30% if the causes may be continuing or are not understood, or 50% if they were understood and stopped. The species could be classified as ‘Endangered’ if the declines were 50% in the case continuing declines and 70% if the decline has been halted.

Using the criteria based upon the COSEWIC/IUCN framework, the first ‘warning’ reference point, N_{Buf1}, could be set at 70% of the maximum observed (or inferred) population size, i.e. a decline of 30% (Table 1). N_{Buf2} could be 50% of the maximum observed population size and $N_{Critical}$ could lie at 30% of the maximum. Although this approach lacks a strong mathematical basis for its structure, it moves the debate away from a concept that is in itself controversial (i.e. MSY), and instead shifts the focus towards benchmarks that are clearly defined, and are in keeping with magnitudes of change in species abundance (30%, 50% and 70%) that are considered important enough to be of concern. Under this approach we are suggesting that reference points be established with respect to a pristine or maximum observed population size. This approach differs from the COSEWIC/IUCN approach in that we are only concerned with the magnitude of the population decline, and not concerned with the rate of decline in a population. In theory the rate of decline could be incorporated into this process but this requires long time series and information on generation times which are often lacking.

US MMPA and IWC RMP

Other jurisdictions have attempted to address the issue of incorporating uncertainty into marine mammal management. Under the Marine Mammal Protection Act (MMPA) the United States has identified the ‘Optimum Sustainable Population’ (OSP) as a Conservation (Limit) Reference Point. The OSP is defined as the population level at which maximum net productivity occurs (similar to the level for maximum sustainable yield in some fisheries models). For practical purposes this is defined as 50-80% of the carrying capacity (‘K’) (Wade 1998). Central to the goals of the MMPA is the objective to ensure that there will be a high probability (95%) that a reduced population will increase to the OSP level and that those at or above OSP will be unlikely (≤ 5% probability) to fall below. For species below OSP, the management conservation requirements are similar to those that we have identified above for populations that are below N_{Buf2}. Above OSP the MMPA requires that removals not exceed a level that ensures a 95% chance that the population remains above OSP. If a population falls below OSP, then the population is initially considered depleted or threatened under the American Endangered Species Act and a ‘Take reduction team’ comprised of scientists, and stakeholders is put in place to implement measures to reduce removals. If the population declines then it could be classified as ‘Endangered’ and more rigid conservations would be put in place. This process is somewhat similar to the management zones of increasing conservation that we have proposed.

The International Whaling Commission (IWC) has also proposed a management scheme that incorporates uncertainty and ensures sustainability of baleen whale populations. In developing their 'Revised Management Plan' (RMP), the IWC identified a limit reference point below which the population should not be allowed to go (i.e. $N_{critical}$) of 54% of the estimated carrying capacity (IWC 1994). If a population is above this level, catches would be allowed based upon a 'Catch Limit Algorithm' (CLA) that was developed to ensure that catches would be as stable as possible and that the highest possible yield was obtained while ensuring that the population did not decline below the limit reference point. Developed using extensive simulations that covered a wide range of plausible scenarios, the CLA was designed to be robust to past, present and future uncertainties in abundance and harvest estimates, stock identity and population dynamics (Palka 2002).

The CLA requires a time series of annual data on catches and absolute abundance estimates. In a review of various control laws considered by IWC, Cooke (1995) concluded that regular direct surveys to estimate absolute abundance were required for any satisfactory management procedure. Also, safe management could only be achieved by limiting catches to a small proportion of the absolute abundance. In most cases calculated catches are in the order of 2% of the estimated abundance. However, as new estimates of abundance are added to the time series the uncertainty associated with the population status is reduced and catch limits increase (Palka 2002).

<u>Data Poor Species</u>

In the absence of current abundance information and data on fecundity or mortality rates, the uncertainty associated with the resource's status and the impact of a particular management action increases and as a result, more caution is required. One approach could be to 'discount' acceptable removals with increasing time since the last estimate. For example, in the United States, the maximum allowable removals is decreased by 20% annually for each year greater than 5 since the last survey. By 10 years after last survey, the acceptable removal limit falls to 0. Similarly, under the IWC's RMP the acceptable catch limit is reduced if recent estimates of absolute abundance are not available. The catch limit is reduced by 20% in each year beyond the eighth year for which there is no population estimate (Palka 2002).

Another option that could be adopted if several abundance indices do exist, but are all old (e.g. > 5 years), may be for the population to automatically fall to the next lower management category, with appropriate harvest control rules. After another five years, and in the absence of new data, the status of the stock could drop another level. For example, in the absence of recent estimates a population starting out with abundance estimates greater than N_{Buf1} would automatically drop into the next lower category between N_{Buf1} and N_{Buf2} and instead of a harvest strategy that involved higher-risk, the new rule would establish that human induced mortality must be limited to allow a greater probability (e.g. 80%) chance that the population will increase. After a further 5 years, in the absence of an updated abundance estimate, the population would fall below N_{Buf2} and harvesting levels would be established with a higher likelihood (e.g. 95%) that the population would increase. However, this requires enough information to identify reference point levels for the species in the first place. A third option may be to consider the species 'data poor' and apply the conservation rules applied to these species (see below) even for species for which we have historical, but no current data.

There are no recent estimates of abundance for hooded and grey seals in Atlantic Canada and therefore, they could be considered as 'Data Poor' species. As such, when deciding upon an allowable level of removals for these species, the degree of uncertainty associated with any estimate is very large and a conservative approach should be taken. The current implementation of the US Marine Mammal Protection Act (MMPA) described above is an example of this approach. This is accomplished by identifying the maximum allowable removals that will ensure that the acceptable risk of the population falling below this reference point is 5%. By using extensive simulation modelling, the level of acceptable removals, referred to as the Potential Biological Removal (PBR) has been defined as:

$$PBR=0.5 \cdot R_{Max} \cdot F \cdot N_{Min},$$

where R_{Max} is the maximum rate of increase for the population , F is a recovery factor with values between 0.1 and 1 and N_{Min} is the estimated population size using 20th percentile of the log-normal distribution (Wade and Angliss 1997; Wade 1998). R_{Max} is set at a default of 0.04 for cetaceans and 0.12 for pinnipeds unless there is evidence for other more appropriate rates. The recovery factor (F) is set at 0.1 in the case of endangered species, 0.5 for depleted or threatened species and 1 for populations at OSP.

The only data required to calculate PBR is an estimate of population size, making it appropriate for data poor species. It also has the added advantage that the simulation trials used to establish the appropriate population size (N_{Min}) ensured that the formulation was robust when the model assumptions were relaxed and plausible uncertainties were included (Palka 2002). As stated earlier, to ensure caution in the presence of increased uncertainty the PBR level is reduced if recent estimates of abundance are not available. It is decreased by 20% annually after 5 years from the last survey and by 10 years after last survey, no harvest would be permitted because the PBR would have fallen to 0. As such, the PBR is a very conservative, risk-adverse approach and populations should on average increase over time (McLaren 2002).

Comparison of Management Schemes

Historically, in most situations management actions have not been decided on the basis of a fixed rule, but through a less well-defined process in which a variety of factors of biological, economic, operational and political concerns are taken into account during a process of brokerage and negotiation (Cooke 1999). A major feature of the Precautionary Approach that is often highlighted is that management actions should not result in serious harm. However, other aspects which are often overlooked, but which are perhaps more important is that a lack of scientific proof is not sufficient to postpone implementing conservation measures and that the Precautionary Approach requires pre-defined management actions that would be implemented if certain reference points or benchmarks are exceeded. Under the MMPA of the United States a minimum population size termed the OSP is incorporated into the Act. Removals are permitted as long as they do not exceed a level that ensures that there is a 95% chance that the population will return to levels above OSP or will remain above OSP. A population falling below OSP is initially designated as threatened under the Endangered Species Act and a take reduction team is struck to reduce removals to allow the population to move towards OSP. The number of permissible removals is identified as the PBR. The benefit of the PBR approach is that it is easy to estimate, requires little data and ensures that, as long as catches remain below PBR, that the risk of a further decline in the population is very low (Palka 2002). On the other hand, the PBR approach does not make use of all available data (e.g. age structure of the harvest), and for populations that are above OSP levels, catches are constrained to very low levels in situations where higher risks could be tolerated. An alternative system developed by the IWC was established with the specific management objective of maintaining a population above a limit reference point of 54% of the estimated carrying capacity. If a population is above this level, then the CLA ensures that catches remain as stable as possible, and that the highest possible yield would be obtained without the population declining below the limit reference point. In developing the CLA approach, the IWC allowed for changes in harvest levels to occur as population size changes with respect to the reference limit. At the same time the CLA is relatively complex, makes the very explicit assumption that density dependence occurs and can be described and has large data requirements.

In Canada, marine mammal management is governed by the Marine Mammal regulations under the Fisheries Act (R.S.C., 1985, c. F-14). Within this legislation, there is no requirement to maintain specific population levels. Instead, the Canadian government has adopted an approach that requires the establishment of a limit reference point only at a point of serious or irreversible harm. Within this context the approach that incorporates a combination of limit (conservation) and precautionary reference points for Data Rich species is consistent with Canadian policy. Although the limit reference point is quite low within this framework, compared to other jurisdictions, the addition of precautionary reference points identifies to managers population levels where conservation objectives become more important. Within the policy objectives of the Precautionary Approach a population will not approach the limit reference point as long as advice is framed in terms of complying with precautionary reference points, rather than avoiding conservation (limit) reference points.

One of the goals of a management process that uses precautionary reference points is to ensure that a species does not decline to a level where it may be considered threatened or endangered. In Canada, an independent committee (Committee on the Status of Endangered Species in Canada – COSEWIC) evaluates the status of the species based upon a series of criteria and makes a recommendation for designation under the Canadian Species at Risk Act. If this is accepted, legal protection is provided that will direct the management of the species to ensure that a recovery occurs.

When abundance information can be obtained, resulting in 3 or more surveys with the last survey being a recent one (≤5 years), along with fecundity and quantitative estimates of mortality (e.g. in the case of harp seals), the Data Rich type model could be adopted. Of the two general approaches outlined (ICES/NAFO vs COSEWIC/IUCN) for 'Data Rich situations, we recommend the framework adapted from the IUCN/COSEWIC. Although this approach could include N_{target}, a point where Management would like to see the population, we have not addressed this issue here. Instead, our main concern is the establishment of reference points or warning flags to managers that result in changes in harvesting strategies to protect the resource when reference points are exceeded. This approach relies on a previously established 'conservation' framework and avoids the potential difficulties of trying to establish MSY and the critical assumption that MSY will not change. The first precautionary point outlined above as $N_{Buf1,}$ would be set at 70% of the maximum population size and we suggest defining this point as N_{70}. The second precautionary point (N_{Buf2}) would be set at 50% of the maximum population size and could be referred to as N_{Buf} or N_{50}. The conservation reference point, referred to as $N_{critical,}$ would be set at 30% of the maximum population size. Under the criteria identified above, the NW Atlantic harp seal population could be considered as Data Rich. Population modelling suggested that the population increased to 5.5 million (Hammill and Stenson 2003), before a combination of high pup mortality from poor ice conditions and high harvest levels resulted in a decline of the population. For this population then the maximum population size seen would be 5.5 million, N_{70} would be set at 3.85 million, N_{50}=2.75 million and $N_{critical}$=1.65 million (Fig. 3).

A key component within the precautionary framework is the establishment of reference points that, if attained, will result in specific conservation actions by managers to reduce conservation concerns. The choice of any specific management action should be firmly based on a risk analysis approach. Ideally, before the above approach can be implemented, its impact on the population and likelihood of reaching the intended objective should be evaluated in a manner that incorporates the uncertainties associated with the population estimates and predicated removals (McLaren 2001). However, development of the precautionary approach requires an exchange of information between stakeholders, managers and scientists. In other jurisdictions, reaching a consensus on the modeling framework and the types of simulations that are necessary has taken several years (e.g. IWC). Because some information is already available concerning impacts on marine mammal populations from the IWC and MMPA experience, in cases where harvesting already occurs, we suggest that it is important to first develop and implement a basic framework incorporating the Precautionary approach, which can be refined as simulation results become available, rather than waiting for all simulations to be completed before trying to implement a precautionary management approach.

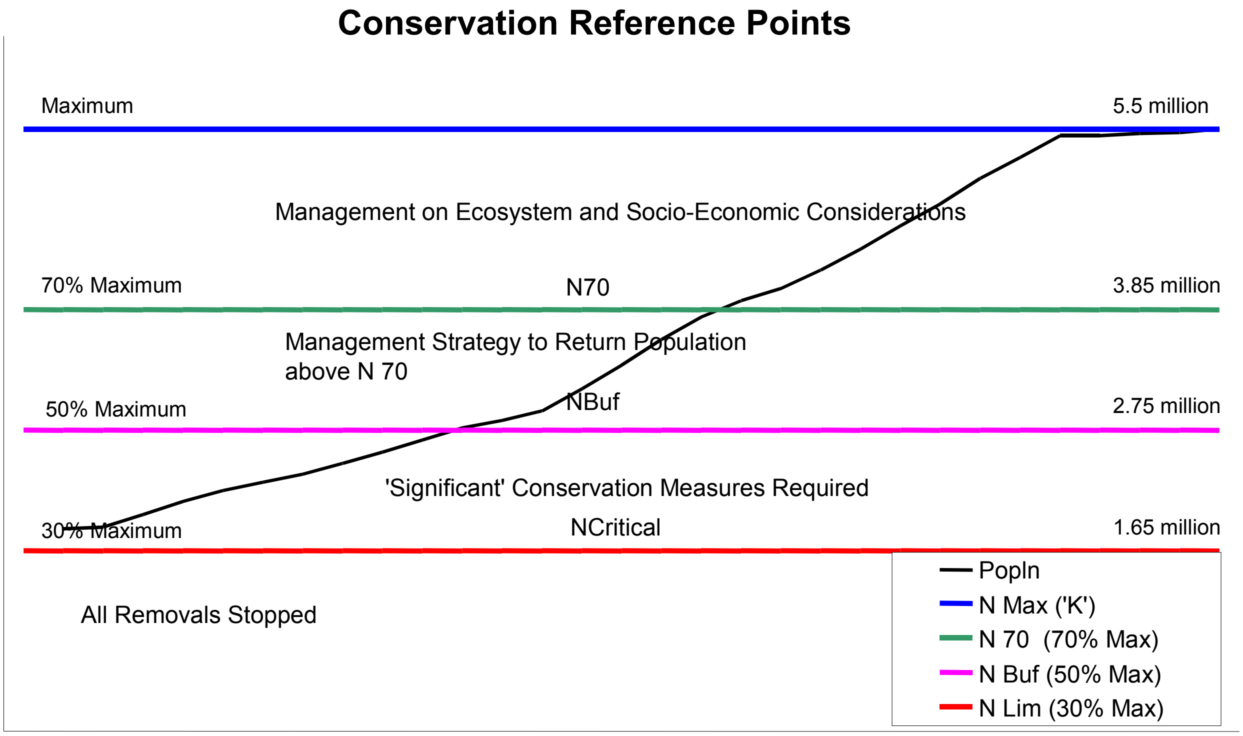

Figure 2. Reference points for management of NW Atlantic harp seals.

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