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Applying the Precautionary Approach to Marine Mammal Harvests in Canada

Application de l'approche de précaution à la récolte de mammifères marins au Canada

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ABSTRACT

In establishing harvest levels, resource management requires tradeoffs among conservation, economic and political concerns. The Precautionary Approach brings scientists, resource managers and stakeholders together to identify clear management objectives and to agree on population benchmarks that would initiate certain management actions when these benchmarks are crossed. A conceptual framework for applying the precautionary approach to marine mammal harvests is outlined. For a data-rich species, precautionary and conservation reference levels are proposed. When a population falls below the precautionary reference level, increasingly risk-adverse conservation measures are applied. A more conservative, risk-adverse approach is required for managing data-poor species. The framework has been implemented for the management of commercial seal harvests in Atlantic Canada.

RÉSUMÉ

Quand vient le temps d'établir des niveaux de récolte, la gestion des ressources exige que l'on fasse des compromis entre les préoccupations relatives à la conservation, à l'économie et à la politique. L'approche de précaution rassemble scientifiques, gestionnaires des ressources et intervenants pour déterminer des objectifs de gestion clairs et pour convenir de points de référence pour les populations. Ces points de référence sont des seuils dont le dépassement déclenche certaines mesures de gestion. On élabore un cadre conceptuel d’application de l’approche de précaution à la récolte des mammifères marins. Pour les espèces bien documentées, on propose un seuil de précaution et un seuil de conservation de référence. Lorsque la taille d’une population passe sous le seuil de précaution de référence, on met en œuvre des mesures de conservation de plus en plus prudentes. Pour la gestion des espèces mal documentées, il faut adopter une approche de précaution encore plus stricte. Ce cadre a été mis en œuvre pour la gestion de la chasse au phoque commerciale dans le Canada atlantique.

INTRODUCTION

Scientists provide advice to managers based on the best available information on the status of the population under consideration. However, because of natural variability and the fact that the information is often incomplete, many assumptions are required and estimates of parameters are imprecise, the resulting advice is associated with varying degrees of uncertainty. In the past, failure to recognize the importance of this uncertainty led managers to require proof that populations or resources were in difficulty before actions were taken (Taylor et al. 2000). Unfortunately, by the time the damage could be ascertained, populations had often already suffered serious harm. The collapse of Northwest Atlantic cod stocks and many large whale populations are examples in which traditional management approaches have failed (Rice and Rivard 2003; Baker and Clapham 2004). The Precautionary Approach (PA) strives to be more cautious when information is less certain, does not accept the absence of information as a reason for not implementing conservation measures, and defines, in advance, decision rules for stock management when the resource reaches clearly-stated reference points (Punt and Smith 2001). These reference points or levels are referred to as limit, precautionary, and target reference points (ICES 2001). Within fisheries, these may be expressed in terms of abundance or removals, but for marine mammals, they are usually considered as measures of abundance.

The limit (or critical) reference point (N_{lim}) represents the (estimated) level at which continued removals would lead to serious and irreversible harm to the population (DFO 2009). However, estimates of abundance are associated with considerable uncertainty and this uncertainty increases as the population is projected into the future. Managing a population close to the critical reference point could result in a high probability that the population declines below N_{lim}. Therefore, a Precautionary Reference Point (referred to as N_{buf}) identifies a population range within which risk-adverse management control rules would apply to ensure that the population does not fall below the critical reference level. When a population is above the precautionary reference point, conservation is not the major consideration in setting quotas.

The identification of critical and precautionary levels (see derivations, below) creates three zones. In the ‘critical zone’ (i.e., below N_{lim}), human-induced mortality should be reduced to a minimum and all directed harvesting eliminated. If the population is in the ‘cautious zone’, i.e., below N_{buf} but above N_{lim}, conservation concerns become a higher priority and pre-agreed harvest control rules would be applied with the objective to rebuild the population back above N_{buf} within a specified number of years. Although harvesting and other human-induced removals could continue, management strategies would require a high probability that the population would increase (or conversely, a lower risk that the population would continue to decline). A fixed control rule might be applied as long as the population was above N_{lim} or alternatively, a variable control rule that takes into account how close the population is to N_{lim} could be used. Above N_{buf}, the population is considered to be in the ‘healthy zone’ and managers may establish a target reference point based upon considerations such as ecosystem impacts and/or socio-economic benefits. As long as the population remained above N_{buf}, higher-risk harvest strategies could be adopted.

The key element within PA is the avoidance of irreversible harm to the resource. The approaches developed will depend in part on the current status and knowledge about the resource. It is critical that the uncertainty associated with estimates be considered and that a basis for taking action even if stock status is not known sufficiently is developed. Thus, protocols are needed for situations for which adequate data are available (‘data-rich’) to understand the dynamics of the population, as well as for situations in which resource information is more limited (‘data-poor’).

The first application of the PA to fisheries management in Canada was the Atlantic Seal Management Strategy (ASMS). Adopted in 2003, well before the publication of the DFO PA Framework in 2009, the ASMS (originally known as Objective Based fisheries Management, OBFM) was developed in response to the Eminent Panel report on seal management (McLaren et al. 2001). ASMS provides a framework that stipulates when a population is data-rich or data-poor, and identifies precautionary and critical reference points, along with management actions that are triggered when thresholds are exceeded to reduce potential damage to the resource. This approach was initially applied to commercially-hunted seals in Atlantic Canada: harp (*Pagophilus groenlandicus*), hooded (*Cystophora cristata*) and grey (*Halichoerus grypus*)(Hammill and Stenson 2003, 2007, Stenson and Hammill 2008). It has subsequently been adopted, with only minor changes, by ICES to provide advice on harp and hooded seals and is used by Norway and Russia to manage these species (ICES 2004, 2006a,b, 2008). The general concepts of this approach have also been used to provide advice for other marine mammals in Canada.

Establishing Marine Mammal PA Framework Reference Points

The amount of information available for resource management varies among populations. Therefore, we can distinguish two categories; “data rich” and “data poor”. Data-rich populations are those for which we think we have a reasonable understanding of their recent abundance and population dynamics. Currently, data-rich species are defined as having three or more abundance estimates over a 15-year period, with the last estimate obtained within the last five years, and current information (within the last five years) on fecundity and/or mortality to determine sustainable levels of exploitation. If these data are not available, the species would be considered as data-poor.

These criteria were developed for seals and will vary depending upon the life history of the species. Appropriate criteria for other species groups such as large, or small, cetaceans must still be developed.

Data-rich Species (Modelled)

Abundance and population trends of most marine mammals are estimated through the use of a population model based upon information obtained from aerial surveys or mark-recapture methods. The surveys may estimate abundance of the entire population (after correcting for animals not at the surface) such as many of the cetacean surveys, or only part of the population (e.g., seal pup production surveys). In the later case, some authors (e.g., Leaper et al. 2010) have suggested that the pup production estimates themselves be used as the metric to determine status of the population since they are the value measured. However, in the case of commercially hunted seals, Hammill and Stenson (2009) have shown that due to the nature of the harvest which focuses on young of the year and the interval between surveys (3-5 years), a 20% increase in pup mortality may not be recognized for 10-15 years during which time the population would have undergone a significant decline. For this reason, the estimates of total abundance obtained from a population model have been used as the measure of population status for these species.

Critical Reference Level

It is extremely difficult to determine the appropriate population levels at which the reference points should be set. The DFO PA Framework identifies reference levels with respect to the biomass that yields the maximum sustainable yield (B_{MSY}), setting the limit reference point (similar to the critical reference level) at 40% of B_{MSY} and an upper stock reference at 80% of

B_{MSY} (DFO 2009). Since numbers, rather than biomass, are used for mammals, this could be considered to be proportions of the number of individuals that provide the Maximum Sustainable Yield (MSY). Historically, MSY was used to provide advice on catch levels for marine mammals (e.g., the New Management Procedure of the International Whaling Commission) but it was soon realized that the information required to estimate MSY was not available for most populations (e.g., de la Mare 1986, Cooke 1994), consequently other approaches were developed. Theoretical studies have suggested that MSY may be between 50-70% and 80-85% of the population at carrying capacity (K) (de la Mare 1986, Wade 1998, Hammill unpublished), but most marine mammal populations have been heavily exploited historically and there are few examples of populations near carrying capacity to allow us to estimate the dynamics of populations at high densities. Also, estimates from one period may not be appropriate for a population living under a different set of environmental conditions (Punt and Smith 2001).

While the PA has been applied within fisheries to minimize the probability of serious harm, the conservation movement has developed a parallel approach to minimize the risk of extinction with quite different objectives that are rooted in different types of tolerance to risk (Rice and Legacé 2007). The framework developed within the International Union for the Conservation of Nature (IUCN 2001) and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2006) provides another approach for assessing population status: species are assigned to categories of concern based on a percentage decline in abundance of 30%, 50%, or 70% relative to a reference population size. Using the COSEWIC criteria, a species is considered Endangered if the population declined by 70% over a period of 3 generations which, for marine mammals would include anywhere from ~50 years (e.g., harp seals) to >100 years (e.g., bowhead whales). For most species, this is equal to, or greater than, the entire period during which we have been monitoring populations. Although this approach lacks a strict population dynamics basis, it moves the debate away from the MSY concept that is itself controversial. Instead, it shifts the focus towards clearly-defined benchmarks that are in keeping with magnitudes of change in species abundance that are broadly considered important enough to be of concern. Using the relative decline from some historical abundance estimate to trigger management concern has been recommended in other jurisdictions. For example, Mace et al. (2002) recommended that a decline to 30% of historical levels be considered as serious for low-productivity species.

Many applications suggest that reference points be established with respect to a pristine population size. However, estimating pristine levels is problematic, especially when populations have been historically exploited like most marine mammals and/or subjected to varying environmental impacts as appears to have occurred in Northwest Atlantic harp seals (Sjare and Stenson 2010, Stenson and Hammill 2011). Therefore, we have related the reference points to estimates of the maximum population seen or estimated as a proxy for K. The advantage in this approach is that reference levels are rescaled as new information becomes available. This is in contrast to setting fixed levels that may be too high, if subsequent surveys indicate that the resource is much lower than originally thought (i.e., suffer from a retrospective problem). This can result in changes to the reference levels as the population recovers to historical levels or if additional data improve our understanding of the true population size (e.g., Hammill and Stenson 2011). Industry and managers may have difficulties understanding why the levels change and changes may complicate their harvesting or management strategies, but using observed maxima allows us to apply a precautionary approach to ensure the population is not overexploited until additional information on potential K can be obtained.

Based upon these considerations, the critical reference level for marine mammals has been set at a level that is 30% of the maximum observed or estimated population (Hammill and Stenson 2007).

Precautionary Reference Level

The Atlantic Seal Management Strategy identifies a Precautionary Reference Level (PRL) that is similar to the Upper Stock Reference (USR) described in the DFO PA policy. However, under the DFO framework, the USR can perform two functions, the first being "*the stock level threshold below which removals must be progressively reduced in order to avoid reaching the LRP"* and the second being as the target reference point (TRP). For marine mammals, these two functions are separated with the Precautionary Reference Level being set at "*an appropriate distance above the LRP to provide sufficient opportunity for the management system to recognize a declining stock status and sufficient time for management actions to have effect*" (DFO 2009). More specifically, the Precautionary Reference Level is based upon the uncertainty associated with the population estimates, the type of exploitation, and other stochastic factors that can affect the population. The PRL should be set at a level that ensures that there is a high probability that the population does not fall below the critical (limit) reference level before the true state of the population is recognized (McLaren et al. 2001). In many jurisdictions, including the DFO policy, this is considered to be 5% or less (e.g., Wade 1998, DFO 2009, Stenson and Hammill 2011).

Ideally, the reference points would be selected after extensive simulation studies are completed. They must also be relatively easy to understand and acceptable to stakeholders. However, simulation studies are time-consuming and can result in delays in implementing the precautionary approach. For example, it took 12 years to complete the implementation trials under the International Whaling Commission Revised Management Plan (RMP) for western North Pacific minke whales (*Balaenoptera acutorostrata*)(Punt and Donovan 2007). However, frustration within the IWC Scientific Committee led to the development of a framework to examine the management procedure which indicated evaluations could be completed in as little as two years (Punt and Donovan 2007). In the case of the Northwest Atlantic harp seal, a request for reference levels was made in 2002 during a period of intense harvesting, and it was not possible to wait until the simulation studies were completed to establish a management plan.

The primary goal of the United States Marine Mammal Protection Act is to ensure that marine mammal populations are maintained at or above the 'Optimal Sustainable Population' which is defined as 50-70% of the 'known historical abundance" (Wade and Angliss 1997). The Revised Management Procedure of the International Whaling Commission 'tunes' the IWC catch limit algorithm to obtain a population that is 74% of virginal (i.e., pre hunting) levels (IWC 1994, Cooke 1995) while COSEWIC considers a population that has declined to 70% of historical numbers to be a candidate for 'Threatened' status (COSEWIC 2006). Mace et al. (2002) estimated that if a population with low productivity was at least 70% of its historical level, it would remain above 30% of its historical level even if it declined at a moderate rate (8%) for 10 years. In the case of Atlantic seals, this would allow for at least two surveys to take place to assess population status. Based upon these examples, Hammill and Stenson (2007) recommended that the precautionary reference level be set at 70% of the maximum population. Subsequent simulation studies have indicated that for NW Atlantic harp seals, this buffer level is required in order to ensure there is a 95% likelihood of remaining above the critical limit during the 15 years needed to detect changes in harp seal populations using the current assessment methods (Hammill and Stenson 2009, Stenson and Hammill 2011). The Precautionary Reference Level (70% of historical levels) has also been identified as the recovery target for eastern Hudson Bay beluga (Lawson et al. 2006). Until further simulation studies can be carried out, it seems reasonable to set the PRL for marine mammals at 70% of the observed or inferred maximum population size.

Uncertainty

As stated in the DFO PA policy "*Both scientific uncertainty and uncertainty related to the implementation of a management approach must be explicitly considered*". Also, "*Uncertainty should be incorporated in the calculation of stock status and biological reference points*". The uncertainty associated with estimates of marine mammal populations are explicitly expressed in each assessment. This uncertainty is considered when identifying the PRL. Also, because marine mammals are only surveyed periodically, uncertainty increases as the survey data become older. Under the ASMS, the lower 20^{th} percentile of the estimate is used to determine if the population is below the PRL. The longer it has been since the last survey, the greater the difference between this measure (L_{20}) and the mean population estimate.

In summary, the approach used for marine mammals identified a critical reference level at 30% of the maximum observed or estimated population size and a precautionary reference level at 70% of the maximum (Fig 1). In order to be considered a healthy population, there must be an 80% probability that the population is above the precautionary reference level.

Data-poor Species

For species not satisfying the data-rich criteria, the uncertainty associated with resource status and with the effects of particular management actions increases. Therefore, an even more risk-adverse approach is needed. The highly-conservative Potential Biological Removal (PBR) approach has been developed in response to the United States Marine Mammal Protection Act (Wade 1998). The management objective is to prevent populations from becoming depleted, where depletion is considered to have occurred if a population falls below its maximum net productivity level. The maximum net productivity level is a concept tied to MSY and density-dependence where, depending on the form of the density-dependent relationships, the maximum net productivity level would fall between 50% and 85% of carrying capacity, although it is more likely to fall at the lower end of this range (Taylor and DeMaster 1993). The PBR approach has been subjected to extensive simulation testing to examine how it behaves under different scenarios, with the objective that the population must have a 95% probability that it will not become depleted.

Although there is no commercial harvesting of marine mammals in the U.S., animals are taken as by-catch in fisheries. As long as incidental catches do not exceed the PBR, they are not considered to pose a conservation threat to the population. PBR is calculated as:

$$PBR = 0.5 \cdot R_{max} \cdot f \cdot N_{min}, \qquad (1)$$

where R_{max} is the maximum rate of population increase, *f* is a recovery factor (between 0.1 and 1.0) and N_{min} is the estimated population size using the 20-percentile of the log-normal distribution of the most recent population estimate (Wade and Angliss 1997, Wade 1998). In the U.S. the default for *f* is 0.5. The recovery factor may be increased to 1.0 for populations where there is reasonable scientific evidence that there are no large biases in estimates of abundance, mortality, R_{max}, or in the definition of population structure (Cooke et al. 2012). Within the ASMS, *f* is set at 1.0, unless there is an obvious serious conservation concern. In the absence of data, R_{max} has been assumed to be 12% for pinnipeds and 4% for cetaceans (Wade and Angliss 1997). Therefore, the only data required to calculate PBR is an estimate of population size, making it appropriate for data-poor species. Rigorous simulation testing has shown that PBR is robust when model assumptions were relaxed and plausible uncertainties were included (Palka 2002), although more recent modeling studies suggest that it may not be as conservative as previously thought (ICES 2011). In Canada, information on abundance, mortality, and reproductive rates is limited for many cetaceans that are the targets of aboriginal subsistence harvests. Consequently, these populations have been considered to be data-poor and the PBR approach has been used to provide science advice to managers for narwhal, beluga and bowheads (Richard 2008).

If a maximum population can be estimated, N_{lim} could be established using a similar approach to that used for 'data-rich' species, i.e., a critical limit of 30%. Above N_{lim}, PBR could be used to set a conservative harvest level, whereas below that value the population would be considered to be in the critical zone and no directed harvest would be allowed (Fig 2). If no information on maximum abundance is available, N_{lim} could be defined using the IUCN criteria for 'vulnerable' species (ICES 2006a,b).

Subsistence harvests

There has been little study of the application of the Precautionary Approach to marine mammal subsistence hunting in Canada, despite the requirements of international treaty obligations. The current management approach has provided advice based on a sustainable yield approach, where harvest levels would keep the population stable. This approach reduces the likelihood of recovery of depleted populations, and in fact has a high risk of decline, since harvest levels are based on the median estimate of population size, and there is a 50% probability that the population may be below the median estimate (McLaren et al. 2001). The IWC has examined subsistence hunts within the context of the Revised Management Plan (RMP) and for aboriginal whaling, has set the Lower Reference Level at 0.23K (Butterworth and Best 1994). It is not clear why the Lower Reference Levels should be different for commercial and subsistence whaling (Butterworth and Best 1994) although at the time it was thought that commercial whaling present a greater challenge to control. Within the current legal framework in Canada, limiting subsistence hunts requires collaboration with management boards but, there is no reason why the general approach presented in the previous section cannot be applied to subsistence harvests (or any other anthropomorphic removals), although the definition of data-rich and data-poor may be modified for species with different life histories.

For some populations there may be sufficient information to consider them data-rich. For example in the case of Nunavik beluga, which has been identified as Endangered by COSEWIC, there is good information on stock structure and stock composition of the harvest, and population size, with surveys in 1984, 2000, 2004, 2008, and 2011. However, it is difficult to decide at what the maximum population size should be set for such species that were heavily exploited historically. In the case of Nunavik beluga, the largest population estimate available from recent surveys is ~4000 animals (Hammill et al. 2004) while estimates of abundance prior to whaling (assumed to be a proxy for K) is around 12,500 animals (DFO 2005). If N_{max} was considered to be equal to K, based upon the estimated pristine population size, it could result in the closure of the harvest. However, this estimate is highly uncertain, and ecological conditions present in the 1800's may no longer apply to current environmental conditions. If instead, the N_{max} is based upon more recent estimates, harvests would be allowed that could result in little or no population growth. Another approach may be to follow COSEWIC and use an estimate of maximum within the past three generations. Our ability to identify N_{max} will depend upon the history of individual populations and it may not be possible to prescribe specific criteria that work for all.

International Approaches to the Conservation of Marine Mammals

The Revised Management Plan (RMP) developed by the IWC and the PBR are two of the better-known examples of Management Procedures (MP) that are compatible with the PA to manage removals from marine mammal populations. The Management Procedure approach uses simulations to determine if there is a reasonable chance that the management plan will reach its objectives given that there will be some uncertainty surrounding the current best estimate of the status of the resource (Butterworth 2007). The MP was first developed by the IWC during the 1980s (Butterworth 2007). Using medium-term projections, the simulation testing framework provides an appropriate basis for evaluation of risk and provides a framework for interactions with stakeholders, in particular before exploitation begins so that various approaches can be evaluated and decided upon which reduce the need for short-term haggling and meetings to decide upon actions in the face of unexpected results (Butterworth 2007). If presented properly, the simulations provide stakeholders with an opportunity to observe the consequences of specific management actions on a 'virtual' population and not the resource, which can help to guide decision making. Disadvantages of the MP approach include a lengthy development to complete the simulations (Butterworth 2007, Punt and Donovan 2007) although once these are done non-productive scientific and political haggling should be greatly diminished.

The basis of the RMP was a requirement for information on catches and estimates of absolute abundance to calculate acceptable harvest levels. Extensive simulation testing was undertaken under different scenarios to test how the approach satisfied three primary objectives: 1) catches should remain as stable as possible, 2) the stock should not be depleted below some chosen level, and 3) the highest continuing yield from the stock under consideration should be obtained (IWC 1994). The IWC decided that absolute estimates of abundance were superior to indirect indices such as Catch Per Unit of Effort (Punt and Donovan 2007). The basic assessment model assumed density-dependence using a surplus production model in the form of the Pella-Tomlinson model (IWC 1994). The key to the RMP is the Catch Limit algorithm. IWC set up a control rule that states that harvests would fall to 0 if the stock size fell below 0.54 of K (Cooke 1999). This could be considered to be the equivalent of the B_{lim} for commercial whaling. For aboriginal whaling, however, IWC has accepted that populations above 0.23K are not at serious risk of extinction by limited catches (Butterworth and Best 1994).

After development in the U.S., the PBR approach has been adopted by a number of countries, including Australia. The PBR formula, described above, is easy to use and unlike the IWC approach which fits a model to an increasing series of catch and abundance estimates to estimate allowable catches, the PBR uses a single point estimate to establish acceptable levels of removals. This avoids the need to identify trends in abundance before management decisions are taken, but increases the sensitivity of the approach to estimates from a single survey (offset to some extent by estimating N_{min}). However, the PBR was developed to address concerns about levels of incidental catches and the potential harm they may cause to a population, not to deal with commercial harvesting. A major limitation for some populations is that the PBR approach does not take into consideration any other information that may be available. For example, it assumes that the removals of different age classes occur in proportion to their abundance in the population and makes an assumption about the rate of increase rather than making use of multiple surveys that may be available. Many hunts are age- or sex-segregated, and therefore the assumption of random removals is violated. Hammill et al. (2011) have shown that the age structure of the harp seal harvest will have a significant impact on catch levels that will maintain the population above the PRL. Conversely, failure to consider the age-structure of the harvest can mean considerable unnecessary loss in economic opportunity to stakeholders because the acceptable removal levels estimated under a PBR approach are too conservative for a data-rich situation (Hammill and Stenson 2009)

Both of the above management procedures have undergone extensive simulation trials to examine how they might behave under certain deviations in model assumptions. Both approaches rely heavily on being able to describe the behaviour of a population using a density-dependent modeling framework, which assumes that density-dependent mechanisms will act in a predictable manner. However, population regulation is not so easy to predict because of the complex interaction between intrinsic factors related to density-dependent factors and extrinsic factors involving environmental variability (de Little et al. 2007). Below carrying capacity, extrinsic factors are thought to be the primary drivers of population change, while close to K, intrinsic factors are considered to be the dominant mechanism to limit population growth (Fowler 1981). The lack of recovery in the St. Lawrence beluga whale population and the failure of cod to recover in spite of almost two decades of limited (or no) fishing are examples in which an expected density-dependent response has not occurred with the removal of harvesting. Another example is the density-dependence mechanisms observed among the different harp seal populations in the north Atlantic that appear to be mediated by environmental and/or food availability (Sjare and Stenson 2010, Stenson unpublished data).

Since initially adopted, the Canadian Atlantic Seal Management Strategy has been adopted by a number of other organizations including the ICES/NAFO Working Group on Harp and Hooded Seals, WGHARP (ICES 2004, 2006a,b, 2008) and the Russian/Norwegian Sealing Commission for managing seal populations in the northeast Atlantic. However, WGHARP has incorporated some modifications to address some gaps in the original design (Stenson and Hammill 2008). They also noted that the use of MSY and carrying capacity of the environment ('K') were not appropriate for these species and identified a minimum precision (CV <30%) for surveys. ICES accepted the general approach and in 2005, WGHARP further refined the approach to require that abundance estimates must be unbiased and that at least three abundance estimates should be available spanning a period of 10-15 years in order for a population to be considered 'data rich' (ICES 2006a). WGHARP also stated that if no recent (i.e., <8 years), accurate abundance estimates are available, no harvest should occur. Using these criteria they recommended that all hunting of the Greenland Sea population of hooded seals, which are considered to be a data-poor species currently below N_{Lim}, be stopped (ICES 2006b). This recommendation was accepted by the Norwegian-Russian Sealing Commission. WGHARP also recommended that if a data poor population is considered to be above N_{lim}, an *f* of 0.5 should be used if the population is considered to be decreasing or have an unknown status while *f*=0.75 for populations thought to be increasing (ICES 2006b).

The Helsinki Commission developed a slightly different approach to manage seals in the Baltic. It identifies a lower limit below which the survival of the population may be at risk and no directed hunting is allowed (i.e. =B_{lim}), the maximum sustainable level, and the environmental carrying capacity. The long term objective is for the populations to reach K (HELCOM 2006). Licences for removals can be issued if the population is below MSY providing that the population has shown a long term increasing trend in abundance. HELCOM has set up an expert group to determine appropriate reference levels but so far none appear to have been approved (Lonergan 2011).

The IUCN/COSEWIC criteria for threatened and endangered species has also been used to identify abundance levels that trigger management actions for marine mammals but these occur at very low abundances (Longergan 2011). Similarly, the EU Habitats Directive applies to a variety of species. All marine mammals in European waters are considered to be species that member states must maintain at 'Favourable Conservation Status' which addresses environmental status in addition to abundance. In order to be considered as favourable, the population must be maintaining itself on a long term basis as a viable component of its natural habitat, the natural range is neither being reduced nor likely to be reduced in the foreseeable future, and the habitat is likely to be maintained on a long-term basis (Longergan 2011). Population size was further classified using a traffic light approach; a population that has a 'normal' age structure and is above its 'favourable reference population' (FRL) was classified as 'green' while one with an age structure that 'strongly deviated' from normal or was 25% below the FRL, or was below it and had declined by 1% /yr for the previous 6 years, is considered to be 'red'. All others were considered as Unfavourable Inadequate ('amber'). Unfortunately, the Directive provides few details on where to set these levels and the task has fallen to individual countries (Longergan 2011).

A comparison of how the different approaches would apply to northwest Atlantic harp seals is presented in Table 1

Management Control Rules

The ASMS has identified management control rules that are to be enacted if populations are below the critical and precautionary reference levels. If the population is in the healthy zones, quotas can be based upon social, economic and/or ecological considerations with an overall goal of maintaining an 80% likelihood that the population is above the PRL. The cautious zone is divided into two compartments. In the upper (50-70% of the maximum population, N_{max}), conservation is an important issue while in the lower (below 50% of N_{max} but above the CRL), conservation is a high priority and stringent conservation measures are required. In Canada, harvest strategies for a population in the upper compartment are required to have an 80% likelihood that the population will increase above N_{buf} within 10 years. There is no control rule set for populations that are in the lower half of the cautious zone, but WGHARP has suggested that an appropriate rule would be to ensure that the population increases to the upper half within 10 years (ICES 2006). If the population is in the critical zone, directed takes must be stopped and all anthropomorphic removals reduced to the lowest possible level.

The IWC Revised Management Plan specifies allowable catches directly with their catch limit algorithm while the PBR approach defines the maximum level of removals that are acceptable. If catches are higher than the PBR, the population is considered 'strategic' and a Take Reduction Team must be appointed to determine ways to reduce the catch.

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Table 1. Comparison of PA reference levels for Northwest Atlantic harp seals using different management approaches.

	Max Observed Population	K	MSY	Reference Levels (Millions)	
				Limit	**Precautionary**
ASMS	5.5 M (2003)*			1.6	3.8
	7.6 M (2003)**			2.3	5.3
	8.3 M (2008)			2.5	5.8
DFO PA		12M	60%	2.9	5.8
			80%	3.8	7.7
IWC		12M		6.5	8.6
US MMPA		12M		3.6	8.4

* Estimated maximum population in 2003 when ASMS was adopted.
** Most recent estimate of population in 2003 (Hammill et al. 2011).

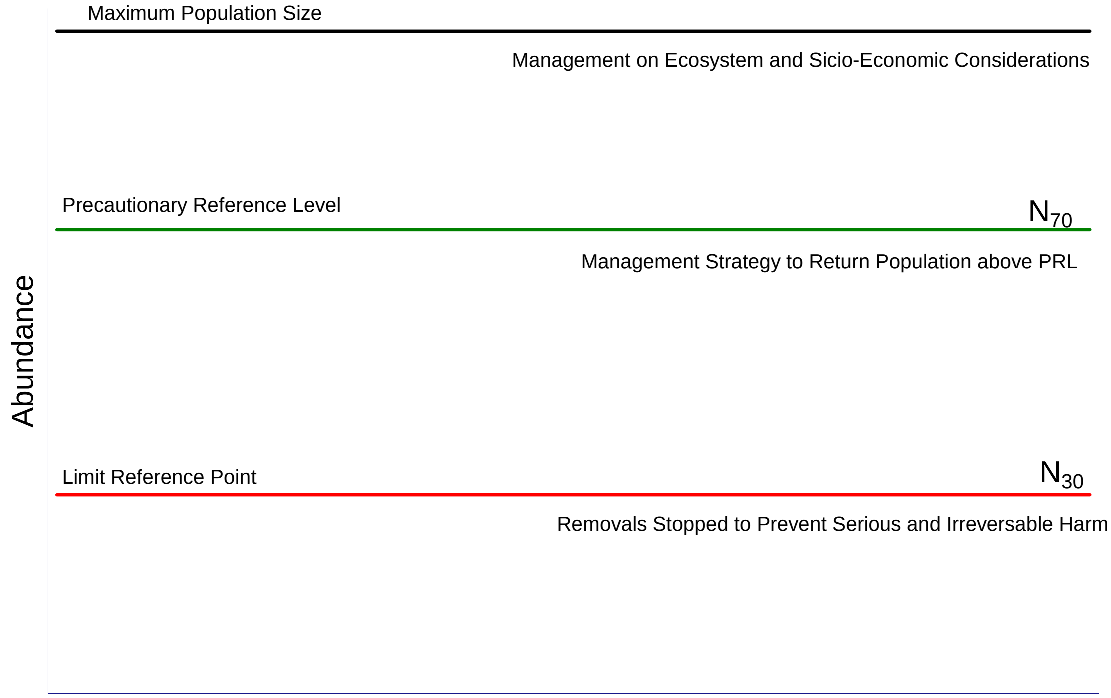

Figure 1. Reference points for the management of data-rich species.

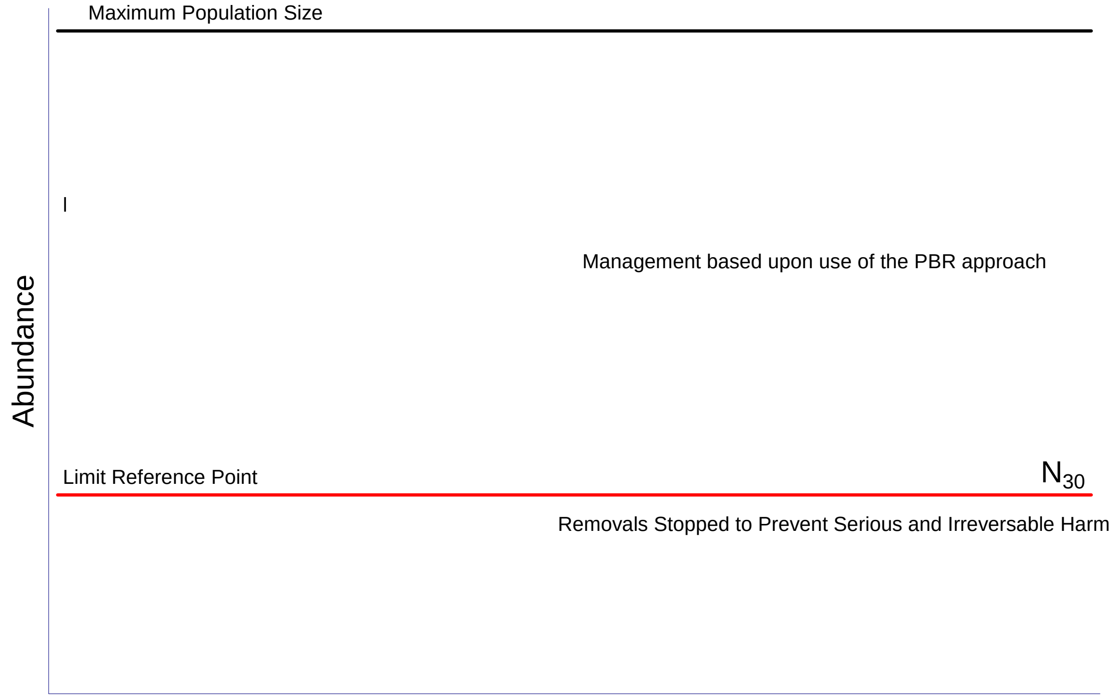

Figure 2. PA reference levels appropriate for data-poor species.