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Review of the Atlantic Seal Management Strategy Precautionary Approach Framework

S.L.C. Lang[1], C.E. den Heyer[2], G. B. Stenson[3], M.O. Hammill[4], J. Van de Walle[4], C.D. Hamilton[1]

[1]Fisheries and Oceans Canada
Northwest Atlantic Fisheries Centre
P.O. Box 5667
St. John’s, NL
A1C 5X1

[2]Fisheries and Oceans Canada
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, NS
B2Y 4A2

[3]Bidesuk Consulting
St. John’s, NL
A1A 3N2

[4]Fisheries and Oceans Canada
Maurice Lamontagne Institute
P.O. Box 1000
Mont-Joli, QC, G5H 3Z4

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The Atlantic Seal Management Strategy (ASMS) was the first Precautionary Approach (PA) framework developed for a fishery in Canada and was adopted in 2003, prior to the implementation of the Department of Fisheries and Oceans' (DFO) PA Policy. Since then, it has been used to provide advice on sustainable harvest levels for Atlantic seals (harp, grey and hooded seals) and other marine mammal stocks in Canada. Components of the ASMS have been reviewed and refined since its implementation, however, in light of the time since the initial development of the ASMS, DFO Science was asked to review the current PA framework for Atlantic seals to ensure consistency with DFO's PA Policy. Here we review the ASMS PA framework and make recommendations for adjustments to the current strategy and suggestions for future work.

INTRODUCTION

The Precautionary Approach (PA) strives to be more cautious when information is less certain, does not accept the absence of information as a reason to not take action and defines, in advance, decision rules for stock management when the resource reaches clearly-stated reference points (Punt and Smith 2001). As a signatory to the United Nations Convention on the Law of the Sea (UNCLOS), Canada has committed to applying a PA to the management of its marine resources, with the objective of maintaining or restoring populations of harvested species to levels at or above those which can produce the maximum sustainable yield (MSY). As part of this commitment the Department of Fisheries and Oceans (DFO) has developed a Sustainable Fisheries Framework which provides the basis for ensuring that Canadian fisheries support the conservation and sustainable use of resources (DFO 2022e).

DFO's *Fishery Decision-Making Framework Incorporating the Precautionary Approach* (hereafter referred to as the PA Policy, DFO 2009a) is one of the policies included under Canada's Sustainable Fisheries Framework (DFO 2022e). The PA Policy describes a general decision making framework for implementing harvest strategies that incorporate a PA for key harvested fish stocks managed by DFO (DFO 2009a). Key harvested fish stocks are stocks that are the specific and intended targets of a fishery, whether in a commercial, recreational or subsistence fishery (DFO 2009a). Undede gest r the *Fisheries Act* (RSC 1985, c F-14), marine mammals are included in the definition of "fish".

Under the PA Policy the primary components of the generalized framework are:

1. Reference points and stock status zones;
2. Harvest strategy and harvest control rules (HCR) for each stock status zone; and,
3. The need to take into account uncertainty and risk when developing reference points and developing and implementing decision rules.

Three stock status zones (Critical, Cautious and Healthy) are defined by the Limit Reference Point (LRP) and Upper Stock Reference Point (USRP; Figure 1). The LRP represents the stock status below which the stock is in the Critical Zone and there is a risk of serious harm to the stock. The USRP is the stock level that defines the boundary between the Cautious and Healthy zones. Below the USRP removals must be progressively reduced to avoid reaching the LRP. At a minimum, the USRP must be 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 an effect to avoid serious harm to the stock. The primary role of the USRP is to identify a trigger point for a decision to be made to reduce the risk of approaching the LRP. Other control points for changes in harvest strategy can be defined, and pre-agreed HCRs for each zone are designed to achieve the objectives of the fishery and avoid serious harm to the stock.

The Atlantic Seal Management Strategy (ASMS; Hammill and Stenson 2003) was the first PA approach developed for a fishery in Canada and was adopted prior to the implementation of the PA Policy in 2006. The ASMS was created in response to concerns about the sustainability of the management approach being used for the commercial harvest of Northwest Atlantic harp seals (*Pagophilus groenlandicus*). The abundance of harp seals was thought to have declined considerably during the 1950s and 1960s (Sergeant 1991). As a result, harvest quotas were introduced in 1971 with the objective of allowing the stock to increase (Anonymous Canada 1986). The management strategy in subsequent years used a replacement yield approach whereby the objective was to adjust the Total Allowable Catch (TAC) so that a constant stock abundance would be maintained over a specified period (e.g. Shelton et al. 1996). In 2001, the

Eminent Panel on Seal Management concluded that the replacement yield approach was not sufficiently risk adverse to avoid a decline in the stock if the full TAC was taken every year (McLaren et al. 2001). The committee suggested that a management framework that incorporated benchmarks and HCRs be established instead. In response, DFO developed the ASMS framework (Hammill and Stenson 2003). Following consultation with industry (2002 Seal Forum, St John's, NL), the framework was adopted and has been used to provide advice on sustainable harvest levels for harp seals, grey seals (*Halichoerus grypus*) and hooded seals (*Cystophora cristata*) since 2003 (DFO 2003, 2006, 2011).

Components of the ASMS have been reviewed and refined since its initial implementation, however, in light of the time since its initial development, DFO Science was asked to review the existing framework for Atlantic seals to ensure consistency with DFO's PA Policy. In 2019, the *Fisheries Act* was amended to include new Fish Stocks provisions (FSP, Section 6, "Fish Stocks") which outline specific management obligations for prescribed major fish stocks listed under the *Fishery (General) Regulations* (*SOR/93-35,* Schedule IX; DFO 2022b). Currently no marine mammal stock is prescribed under Schedule IX of the regulations (i.e. is subject to the FSP). Therefore, the 2009 PA Policy remains the general reference framework for the application of a PA to harvest strategies for commercially harvested seal stocks in Canada. Here we review the ASMS framework and make recommendations for adjustments to the current strategy and suggestions for future work.

THE ATLANTIC SEAL MANAGEMENT STRATEGY (ASMS) FRAMEWORK

For marine mammals, an estimate of total stock abundance is the metric used to indicate current stock status. The amount of available information on abundance, trend, levels of removals and vital rates can vary substantially between stocks. Given that the key element of a PA is the avoidance of serious harm to the resource, it is essential that the approaches developed consider the current state of knowledge and the uncertainty associated with estimates of stock status. To account for differences in the state of knowledge for different stocks, two stock categories are distinguished within the ASMS, 'Data Rich' and 'Data Poor', each with its own PA (Hammill and Stenson 2003, 2007, Hammill et al. 2024).

If there are enough data to understand the dynamics of a stock and how removals or changes in the ecosystem may impact it, a stock may be considered to be Data Rich. A stock is considered Data Rich if it has three or more abundance estimates within a 15 year period, with the last estimate being ≤ 5 years old, and sufficient additional information on age composition, fecundity and/or mortality to be able to assess stock status (Hammill and Stenson 2007; Hammill et al. 2024). If information on the abundance or dynamics of the stock is limited, the stock is considered to be Data Poor (Hammill and Stenson 2003, 2007; Hammill et al. 2024).

ASMS – DATA RICH

The current ASMS for Data Rich stocks is outlined in Figure 2. Three reference points are identified in the ASMS:

1. The LRP ($N_{critical}$);
2. The Precautionary Reference Point, (PRP, or USRP, N_{buffer}); and,
3. N_{risk}, a second precautionary point, which lies halfway between $N_{critical}$ and N_{buffer}.

The Critical, Cautious and Healthy zones are defined by the LRP and the PRP. Based on values used within the International Union for the Conservation of Nature (IUCN 2012) and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2021) for assigning categories of concern based on a percentage decline in abundance, the PRP is set at 70% (N_{70}), N_{risk} at 50% (N_{50}) and the LRP at 30% (N_{30}) of the maximum stock abundance observed or estimated (N_{max}) (Hammill and Stenson 2003, 2007). N_{max} was selected as the reference level as a proxy for environmental carrying capacity (K), which could not be estimated for any seal stock when the ASMS was first developed (Hammill and Stenson 2003, 2007).

The current management objective is to maintain the stock above N_{70} (DFO 2003, 2006, 2011). The HCR applied is to ensure an 80% probability that the stock will remain above N_{70} for at least 15 years, where the 80% probability accounts for the increased uncertainty in the abundance estimate that occurs over time following a survey (Hammill and Stenson 2009; Stenson and Hammill 2011). If the stock falls below N_{70} but is above N_{50}, the HCR is to reduce catches to ensure an 80% probability that the stock will return above N_{70} within 10 years (DFO 2006). The strategy identified that "significant conservation measures" would be required for a stock below N_{50} but above N_{30}, and suggested that the HCR should reduce catches to ensure an 95% probability that the stock will return above N_{70} within a specified period. However, no time period for this HCR was identified under the ASMS and this remains a gap in the strategy. For stocks below N_{30} the HCR is for removals to be kept to the lowest possible level. Removals from all sources must be included when applying the framework.

Since its adoption in Canada, the general ASMS framework has been adopted by the International Council for the Exploration of the Sea (ICES), Norway and Russia for the management of harp and hooded seal stocks in the Northeast Atlantic (ICES 2008). The ASMS reference levels (N_{max}, N_{70} and N_{30}) have also been used to explore sustainable harvest scenarios for other marine mammal stocks in Canada which meet the criteria for Data Rich (Hammill et al. 2017a, 2017b, 2023b, 2024).

Reference Levels

The most difficult challenge when developing a PA is determining the levels at which the reference points should be set. Multiple definitions have been used to set reference points for PA frameworks in Canada and other jurisdictions (see Marentette and Kronlund 2020; Marentette et al. 2021, DFO 2023c, Table 1). Under the PA Policy, the requirement is that the reference points for a stock be appropriate for the stock and consistent with the intent of the PA Policy (DFO 2009a).

Setting the reference points relative to biomass or number of individuals at MSY is a widespread approach used for the management of fisheries in several jurisdictions (Marentette and Kronlund 2020, Table 1). However, MSY is difficult to estimate for marine mammals because its estimation requires substantial stock abundance and demographic rate data that is not available for most species (Cooke 1995; de la Mare 1986). Many marine mammal stocks were heavily exploited historically (Magera et al. 2013) and there are limited examples of stocks near K which would enable the dynamics of stocks at high densities to be estimated. In addition, while retrospective analyses may enable MSY to be calculated for a few stocks, given spatial and temporal variation in environmental conditions, whether these values are appropriate for stocks which may currently be experiencing different environmental conditions is uncertain (Punt and Smith 2001).

For marine mammals, theoretical studies suggest that the stock size at MSY (N_{MSY}) is between 50% and 80% of K (de la Mare 1986; Taylor and Demaster 1993; Ragen 1995; Wade 1998), with estimates from a small number of studies suggesting that N_{MSY} may be in the lower half of that range at 60-65% of K (Ragen 1995; Jeffries et al. 2003; Brown et al. 2005; Punt and Wade 2010). Setting MSY at 60% of K has been used to explore potential PA frameworks for some cetacean stocks in Canada using the PA Policy default refence points (0.4 and 0.8 MSY for the

LRP and PRP, respectively; Hammill et al. 2017a, 2023b). However, further work is needed to determine how uncertainties in the estimation of N_{MSY} would impact our perception of the stock status (Healthy, Cautious, Critical) and our understanding of the probability of breaching limits before an MSY approach could be applied. For example, if the N_{MSY} for a marine mammal stock is 80% of K, under the default PA Policy reference levels, the values for both the LRP and PRP would be higher and the relative distance between them (size of the Cautious zone) would be greater than for N_{MSY} at 60% of K (Figure 3). Given that variable responses to changes in environmental conditions may impact the value for N_{MSY} as a percentage of K, distributions of N_{MSY}/K may be a more appropriate metric to use (Taylor and Demaster 1993). In addition, whether the default PA Policy reference levels for fish stocks are applicable for slow growing, late maturing, low productivity species like marine mammals requires further evaluation. For example, Australia recommends setting the LRP for low productivity stocks at 0.5 MSY (DARW 2018, Table 1).

In some PA frameworks reference points are established with respect to pristine (pre-exploitation) stock biomass (B_0) or abundance (N_0) as an estimate of K (Table 1, Marentette et al. 2021). This is typically easier for stocks whose history of exploitation is relatively short. For marine mammal species with long histories of exploitation, estimates of N_0 may be problematic. For many species, the estimate of N_0 may rely on unreliable or incomplete catch data records with unknown sources of bias. More importantly, given the large scale ecosystem changes which have occurred in many regions, any estimate of N_0 is likely to reflect a stock size that existed under very different ecosystem conditions and, thus, may lead to unrealistic expectations.

An alternative approach is to set the reference points relative to a model estimate of K obtained from the population model used to determine current abundance, where K is estimated in the absence of harvest mortality. When the ASMS was created, it was not possible to obtain estimates of K under the assessment models in use at the time (Hammill and Stenson 2003). Therefore, the reference points were established with respect to the largest population abundance observed or estimated (N_{max}) as a proxy for K (Hammill and Stenson 2003, 2007). However, with additional data and new modelling approaches (e.g. Hammill et al. 2023c; Tinker et al. 2023), it may be possible to obtain an estimate of K from the model used to assess stock status. Therefore, we recommend that, if a reliable model-based estimate of K is available, it should replace N_{max} as the reference abundance level in the ASMS (Figure 4).

In order for reference points to be robust to temporal variation in environmental conditions, DFO technical advice recommends that reference levels be based on the longest possible time series of data (DFO 2013). However, given the large scale ecosystem changes which have occurred in many regions, consideration must be given as to what constitutes a reasonable timeframe for estimating K. For some stocks, the time series used in the population model could extend back into historical periods that are highly unlikely to reflect more recent environmental conditions (e.g. 1865, St Lawrence Estuary beluga whales, *Delphinapterus leucas*, Tinker et al 2024), resulting in an unrealistic estimate of K if calculated across the full time series. Therefore, we recommend that K be estimated over the longest possible time period while accounting for variation in contemporary environmental conditions. The specific time frame used to estimate K will depend on the understanding of the shifts in relevant environmental conditions and the potential impacts of those shifts on the stock in question. However, it is important to note that, under the PA Policy, the only circumstances where K should be estimated solely using information from a period of low productivity is when there is no expectation that the conditions consistent with higher productivity will ever recur naturally or be achievable through management (DFO 2009a). In all cases, the time frame used to calculate K and the reason for the selection of that time frame must be described.

The reference points in the ASMS were established primarily based on values used under the IUCN (2012) and COSEWIC (2021) guidelines for assigning categories of concern based on a percentage decline in abundance (30%, 50% and 70%; Hammill and Stenson 2003, 2007). The LRP (N_{30}) and PRP (N_{70}) levels have been reviewed several times since the adoption of the ASMS framework and have been shown to be consistent with the PA Policy and sufficiently robust as to avoid a decline below levels where serious harm may occur (Hammill and Stenson 2009, 2013; Stenson and Hammill 2011). In addition, assuming that N_{MSY} for marine mammals occurs between 50% and 80% of K, the ASMS values for the LRP and PRP relative to K (N_{30}, N_{70}) are similar to levels used in other jurisdictions (Stenson et al. 2012; Hammill and Stenson 2013; Table 1).

Harvest Strategies and Harvest Control Rules (HCRs)

The management objective for the ASMS is to maintain the stock above the PRP (N_{70}; DFO 2003, 2006, 2011). When the ASMS was established, the time frame over which the results of proposed management actions should be compared to the PRP (i.e. the time over which the stock should remain in the Healthy Zone) was not specified (DFO 2003; Hammill and Stenson 2003) and the initial default period used was the end of the management plan (typically 5 years). However, given that the Atlantic Canadian seal harvests focused almost exclusively on young of the year (YOY), it was recognised that the impact of removals under the current management plan would not be observed in the short term based on the frequency of pup production surveys (4-5 year intervals) and the time it takes for YOY to subsequently recruit to the breeding population (average 4-6 years). Subsequent simulation studies indicated that a projection period of 15 to 20 years would be required to evaluate the full impact of harvests (Hammill and Stenson 2009; Stenson and Hammill 2011). Therefore, the HCR applied was to ensure an 80% probability that the stock will remain above the PRP for at least 15 years, where the 80% probability accounts for the uncertainty in the abundance estimate (Hammill and Stenson 2009; Stenson and Hammill 2011; Figure 2). Although 15 years was initially used for subsequent projections, more recent assessments have used projection periods of 20 years for harp seals (Hammill et al. 2021) and 30 years for grey seals (Hammill et al. 2023c). Based on the current management plan timeframe for Atlantic seals (5 years), the timing of pup production surveys (5 years), and the timing of stock assessments for both harp seals and grey seals, the impact of a 5 year management plan which focuses on the harvest of YOY should be fully observed in 15 years, assuming the average age of first reproduction is ≤ 8 years of age. Therefore, we recommend that, if the stock is in the Healthy Zone, the time frame over which the results of proposed management actions are compared to the PRP (the period used for projection) be set at 15 years.

If a stock is in the Cautious Zone, pre-agreed HCRs are applied with the objective of returning the stock above the PRP within a specified period. PA frameworks for Canadian fisheries use a variety of approaches to determine the control rules applied to stocks below the PRP (see Marentette et al. 2021). The ASMS uses a form of a variable control rule whereby the harvest rates and risk tolerances for future decline become more restrictive as the stock approaches the LRP. In the ASMS, there is a second precautionary point (initially termed N_{risk}) which divides the Cautious Zone into two compartments at N_{50} (Figure 2). This precautionary point serves as an operational control point within the Cautious Zone which triggers a change in the management strategy to increase the required probability for returning the stock above the PRP. Above N_{50}, the current HCR is to set the harvest rate at a level which results in an 80% probability of the stock increasing above the PRP in 10 years (DFO 2006). The time frame for this HCR was set to promote rapid recovery above the PRP, accounting for the minimum time (two survey cycles) it would take to begin to detect a change in the stock status (ICES 2004; DFO 2006). Below N_{50}

the required probability of increasing above the PRP increases to 95% (Hammill and Stenson 2007), however, the time period for this HCR was never defined.

To date, the timeframes required for harp or grey seal stocks in the Cautious Zone to increase above the PRP based on the stock status and trend, and the need to balance harvest rates against the risk of substantial depletion, are not known. However, under the PA Policy a suggested reasonable time frame for rebuilding is within 1.5 to 2 generations, where generation length is estimated for the stock in the absence of harvest following the IUCN criteria for calculating the generation length for an exploited stock (IUCN 2012, DFO 2022c). Using the suggested values under the PA Policy as a guideline, we recommend that the timeframes for each of the HCRs in the Cautious Zone be set at 1.5 generations until simulations can estimate timeframes for recovery above the PRP based on stock status and trend, and the established risk tolerance levels for preventable decline in the Cautious Zone under the PA Policy (see Table 1, DFO 2009a). Here generation length is defined based on the IUCN criteria for an exploited stock. In keeping with the PA Policy, the calculation used to estimate generation length must be clearly outlined.

Under the PA Policy, the obligation to implement a rebuilding plan is triggered when a stock declines to, or below, its LRP. For a stock which is decreasing and approaching the LRP, the requirement is to:

1. Implement management measures to encourage stock growth and arrest preventable declines; and,
2. Initiate the development of a rebuilding plan sufficiently in advance to ensure that the plan is ready to be implemented if the stock declines to its LRP (DFO 2009a, 2022c).

Given the time required to develop a rebuilding plan, the length of time between abundance estimates (typically 5 years) and the life history of pinnipeds that limits their stock growth rate, we recommend that a stock decline to or below N_{50} (with an 80% probability) be used as the trigger to initiate the development of a rebuilding plan.

Under the PA Policy a stock is considered to be at or below its LRP if the terminal year stock status indicator is estimated to be at or below the LRP with a greater than 50% probability. Once in the Critical Zone, management actions must promote stock growth and removals by all human sources must be kept to the lowest possible level (DFO 2009a). The current HCR for the Critical Zone in the ASMS (removals kept to the lowest possible level) is consistent with this management objective.

Simulations

Although simulations have been undertaken to evaluate components of the ASMS Data Rich framework since its development (Hammill and Stenson 2009; Stenson and Hammill 2011), these simulations were limited in scope and used a deterministic population model for harp seals and limited life history and environmental data. Since then, integrated population models have been developed for both grey seals and harp seals (Hammill et al. 2023c; Tinker et al. 2023). With these new models, a more detailed simulation approach that considers uncertainties in population dynamics, monitoring data, and environmental conditions could be developed to evaluate reference points and the effectiveness of different HCRs for achieving management objectives under the PA framework (Butterworth and Punt 1999, Huynh et al. 2022, Johnson et al. 2024, Wildermuth et al. 2024). Therefore, we recommend that new simulations based on the current integrated population models for assessment of harp and grey seals be undertaken to evaluate strategies for achieving objectives under the PA framework.

Although the ASMS's LRP and PRP (N_{30} and N_{70}, respectively) have been used to explore sustainable harvest scenarios for other marine mammal stocks in Canada (Hammill et al. 2017a, 2017b, 2023b, 2024), the time frames we have recommended for the HCRs in the Healthy and Cautious Zones of the ASMS (15 years and 1.5 generations, respectively) are specific to data rich stocks of seals with harvests predominantly targeted towards YOY. To extend the revised framework to encompass other marine mammal stocks, simulations could be run to evaluate what the appropriate HCRs would be for the Healthy and Cautious Zones for stocks which have different life histories and harvest compositions.

ASMS – DATA POOR

Under the ASMS total allowable removals for stocks categorized as Data Poor are estimated using the Potential Biological Removal (PBR) approach. PBR is a precautionary approach which was developed by the United States (US) under the *Marine Mammal Protection Act* (MMPA 2019) as a mechanism for responding to the uncertainty associated with assessing and reducing human-caused mortality of marine mammals. Under the MMPA, PBR represents the limit for human-caused mortality to a stock.

The PBR is a product of three parameters:

1. A minimum estimate of abundance (N_{min}), which provides reasonable assurance that the stock size is equal to or greater than the estimate which is calculated as the 20th percentile of the lognormal distribution around the abundance estimate;
2. One-half of the maximum intrinsic rate of population growth (R_{max}); and,
3. A recovery factor (F_R) between 0.1 and 1.0 (Wade 1998):

$$PBR = N_{min} \cdot 0.5R_{max} \cdot F_R$$

Under the MMPA, the management objective is for stocks of marine mammals to be maintained at or above their optimal sustainable population (OSP) level. OSP is defined as a level between the maximum net productivity level (MNPL) and K. MNPL is equivalent to MSY in concept and is thought to occur between 50% and 80% of K (de la Mare 1986; Taylor and Demaster 1993; Ragen 1995; Wade 1998). The management objective of PBR is that there is a 95% probability that the stock will be above its MNPL after 100 years (Wade 1998).

PBR represents a removal control rule in that it accounts for total human removals from all sources, therefore, all known harvest, rates of struck and loss, estimates of bycatch (if available), and any other potential source of removals, must be taken into consideration when applying PBR to determine sustainable harvest levels. For transboundary stocks, the levels of removal occurring in other jurisdictions may also need to be accounted for.

Under the ASMS Data Poor category, the PBR approach has been used to provide advice on sustainable harvest levels for hooded seals (Hammill and Stenson 2006) and was used for grey seals prior to the transition to the Data Rich category in 2008 (DFO 2006, 2009b). PBR has also been used to provide advice on sustainable harvest levels for Data Poor stocks of walrus (*Odobenus rosmarus rosmarus*, e.g. DFO 2023b), narwhal (*Monodon monoceros*, e.g. DFO 2020a, 2022a), and beluga whales (e.g. DFO 2018, 2023a).

In 2016 the US implemented the MMPA Imports Provisions Rule (81 FR 54389) (NOAA 2016). Through this legislation, countries that export fish or fish products to the US that are not exempted by the National Oceanic and Atmospheric Administration (NOAA), must demonstrate that they meet the same standards as the US for monitoring and mitigating marine mammal bycatch. Therefore, under this legislation, a PBR value may be required for any marine mammal stock in Canada that is subject to incidental mortality or serious injury that is likely to result in death (see National Marine Fisheries Service (NMFS) 2022) in a fishery which exports fish or fish product to the US. As such, the recommendations made below regarding R_{max} and the choice of the value for F_R are also applicable to the calculation of PBR for stocks categorized under the ASMS as Data Rich.

Estimated Abundance for Calculation of N_{min}

The strength of the PBR approach is that it only requires a single abundance estimate to calculate an acceptable level of removals. However, under the ASMS Data Poor category there is a continuum from stocks with only a single recent abundance estimate (e.g. Atlantic harbour seals, *Phoca vitulina vitulina*, Lang et al. 2024), to those which have multiple abundance estimates but insufficient data to develop a population model (e.g. Pacific harbour seals, *P. v. richardii*, DFO 2022d), to those with multiple abundance estimates and sufficient information to provide a model estimate of current abundance (e.g. Northern Hudson Bay narwhal, Biddlecombe and Watt 2022).

When the ASMS was adopted, no standard was set for how abundance estimates should be used for calculating PBR in situations where multiple estimates may be available. Nor was a time limit placed on how long an abundance estimate would be considered valid for use in the calculation of PBR.

We recommend that, where a stock is categorized as Data Poor but it is possible to construct a population model that can provide a current estimate of abundance that is robust to differing model assumptions (e.g. Hudson-Bay Davis Strait walrus, Hammill et al. 2023a), the N_{min} for PBR should be calculated using the model estimate of current abundance. How N_{min} is calculated must be clearly described.

Where there are multiple estimates of abundance available for a Data Poor stock but insufficient information to construct a population model, N_{min} should be estimated using only the most recent abundance estimate (although see below). However, given that there will be uncertainty about the dynamics of a stock since the last survey was conducted, the most recent abundance estimate will become a less reliable estimate of current stock abundance over time. To account for potential abundance changes that may have occurred since the last survey, the NMFS guidelines recommend that, depending on the value chosen for the F_R and the length of time elapsed since the last survey (> 4 years or > 8 years), adjustments be made to the value for N_{min} (NMFS 2023). However, these proposed adjustments rely on information (e.g. past abundance trends, assumed distributions of stock growth rate) that is unlikely to be available for Data Poor stocks which, by definition, have limited data on abundance or dynamics. Therefore, rather than attempting to adjust the value for N_{min}, we recommend that, where only the most recent abundance estimate is used for calculating N_{min}, a limit be placed on the length of time that the abundance estimate is considered valid for use in the calculation. Based on the typical 5 year survey cycle for marine mammals in Canada, we recommend that the limit be set at 10 years (2 survey cycles). If the most recent abundance estimate is greater than 10 years old it should not be used to calculate N_{min}. In this situation PBR would be considered to be unknown. Note that this is not the same as considering PBR equal to zero.

Where there are multiple abundance estimates but insufficient data to construct a population model, an alternative to using only the most recent estimate is to average multiple abundance estimates. Although averaging has the potential to provided greater stability in PBR estimates (Brandon et al 2017), it is necessary to consider both the trend in the abundance estimates and the time frame over which the estimates have been obtained prior to averaging. Averaging across a declining trend in stock abundance will result in a PBR that is less conservative than what would be calculated based on only the most recent abundance estimate and, therefore, averaging of abundance estimates should only be considered for stocks with evidence of a stable or increasing trend. Conversely, averaging across an increasing trend will result in a more conservative PBR and, therefore, the suitability of this approach will depend on management objectives. For stocks with a declining trend, only the most recent abundance estimate should be used. Consistent with the time frame recommended above, only abundance estimates obtained within the last 10 years should be considered valid for use in calculating the average.

In summary, we recommend that, where there are multiple estimates of abundance available for a Data Poor stock but insufficient information to construct a population model, N_{min} should be estimated using the most recent abundance estimate. If the most recent abundance estimate is greater than 10 years old, it should not be used to calculate N_{min} for PBR. In this situation PBR is considered to be unknown. Alternatively, weighted averages could be used to calculate N_{min} for PBR if the abundance estimates were obtained within the last 10 years and the population is considered to be increasing or stable. The rationale for including multiple estimates and the method used to calculate a weighted average must be clearly described.

Maximum Rate of Population Growth (R_{max})

The default values typically used for R_{max} are the “base case” values used in the management strategy evaluation (MSE) conducted by Wade (1998) for the development of PBR and are 0.04 for cetaceans and 0.12 for pinnipeds. However, the actual value for R_{max} for a given stock is likely to differ from these default values. Simulations indicate that PBR is very sensitive to the value for R_{max} and, thus, a bias in R_{max} can impact the probability of meeting management objectives (Brandon et al. 2017; Punt et al. 2018). If the default R_{max} is an overestimation (i.e. the true value for the stock is lower) the PBR may not be sufficiently precautionary, conversely, if the default R_{max} is an underestimation (i.e. true value for the stock is higher) the PBR may be too precautionary (Brandon et al. 2017; Punt et al. 2018). Thus, replacing the default values for R_{max} with values specific to the stock under consideration can improve the probability of meeting management objectives, although additional adjustments may be needed to account for bias (see below). Given the potential impact on the PBR we recommend that:

Where it is possible to obtain a reliable estimate, the value of R_{max} for the stock being assessed should be used to calculate PBR (e.g. Watt et al. 2021). Alternatively, an estimate of R_{max} calculated for other stocks of the same species living in a similar environment could be used. The use of R_{max} values of 0.08 and 0.20 when calculating PBR for walrus and sea otters (*Enhydra lutris*), respectively, are examples of this approach (U.S. Fish and Wildlife Service 2013; DFO 2020b, Hammill et al. 2023a). The source and rationale for an R_{max} value which is different from the default value must be clearly documented.

Recovery Factor (F_R)

The F_R is defined as being between 0.1 and 1.0 and is used to account for uncertainties associated with our understanding of the stock (Wade 1998). An F_R of less than 1.0 allocates a proportion of expected net production towards population growth and compensates for potential biases which may impact the PBR estimate. The F_R can be selected on a case-by-case basis depending on the level of the biases potentially affecting the PBR estimate and the tolerance for risk (e.g. Richard and Abraham 2013). However, having criteria for the selection of the recovery factor provides consistency and reduces the potential for arbitrary decisions. Some guidelines have been developed for setting the F_R but these remain jurisdiction specific. For example, under the MMPA the default F_R for endangered species is 0.1 and for all other stocks is 0.5, except in the case of stocks:

1. Known to be at or above their OSP;
2. Of unknown status that are known to be increasing;
3. Taken primarily by aboriginal subsistence hunters; or,
4. Declining, especially if threatened or depleted.

In the first three cases the F_R may have higher values than 0.5, up to and including 1.0. For the last case, consideration should be given to lower recovery factors (NMFS 2023). In the UK, criteria for selecting the F_R for estimating PBR for grey seal and harbour seal stocks have been developed based on a matrix approach that evaluates the level of confidence in the abundance estimate (high, intermediate or low) and the understanding of stock trend and demography (Boyd et al. 2010). In the case of differing levels of confidence, the most precautionary is selected.

When the ASMS was developed, no guidance was provided for the choice of F_R (Hammill and Stenson 2003, 2007). However, in an effort to ensure consistency in the application of F_R to PBR estimates for marine mammals in Canada, Hammill et al. (2017a; DFO 2018) proposed criteria which could be used to set the F_R based on the general status of the stock and an understanding of the trend (Table 2). These criteria have been used to estimate the PBR for several stocks in Canada (e.g. Marcoux et al. 2019; Watt et al. 2021; Biddlecombe and Watt 2022; Sauvé et al. 2024). However, the recent application of these criteria to the assessment of Atlantic harbour seals (Lang et al. 2024) which were categorized as abundant but which only have a single range wide survey (i.e. F_R=0.75 for “survey effort limited” under Justification, Table 2) and for which the recent abundance trend is uncertain (i.e. either F_R=0.5 for “unknown” or F_R=0.75 for “data limited” under Trend, Table 2) highlighted the need for further refinement.

Although the trend in stock abundance is a useful metric for considering potential values for F_R whereby stocks which are increasing or stable may justify a less precautionary value (Table 2), the evaluation of whether a stock is ‘Abundant’ versus ‘Small’ is subjective and can be challenging to assess, particularly across different species and differing environments. Given that the management objective of PBR is that there is a 95% probability that the stock will eventually be above its MNPL, the current abundance of the stock relative to some type of reference level is the metric of interest and is more consistent with a PA approach.

We propose the criteria outlined in Table 3 as possible guidelines for setting the value for the F_R. The proposed criteria are based on the evaluation of:

1. Current stock status;
2. Current stock trend; and,
3. Adjustments for bias in R_{max}.

In keeping with the continuum of information which may be available for Data Poor stocks we have considered current status as belonging to one of two categories:

1. Stocks of unknown status, whereby there is insufficient information to make an assessment of the relative level of the current abundance. This may be due to a lack of information on historical population levels, lack of confidence in historical estimates, and/or limited survey data.
2. Stocks with sufficient information to make an assessment of current status relative to an estimate of K (accounting for variation in contemporary environmental conditions, see

Reference Levels above), or a proxy for K such as N_{max} or N_0. For stocks in this category, we have outlined 4 status levels, set as a proportion of K (or its proxy), which mimic the levels used in the Data Rich framework of the ASMS: >0.7, ≥ 0.5 and < 0.7, ≥ 0.3 and < 0.5, and < 0.3.

The current stock trend and the estimate of R_{max} relative to the default value is only considered in the setting of the F_R for stocks of unknown status or stocks with a current status between 0.3 and 0.7 of K (or its proxy; Table 3). We consider populations with a status estimated to be greater than 0.7 of K (or its proxy) in a Healthy Zone and, therefore, adjustments to F_R based on stock trend or values of R_{max} are not required. Populations with a status below 0.3 of K (or its proxy) are considered to be in the Critical Zone and are assigned an F_R of 0.1 or 0 regardless of stock trend or values of R_{max}. We have assigned an F_R of 0.1 for stocks assessed as endangered under the COSEWIC or which meet the criteria for endangered under the COSEWIC guidelines (COSEWIC 2021). We have assigned an F_R of 0 for stocks which meet the criteria for critically endangered under the IUCN guidelines (IUCN 2012; e.g. North Atlantic right whale, *Eubalaena glacialis*) and are, therefore, considered to be facing a very high risk of extinction in the wild (COSEWIC 2021). If the stock has not been assessed by the COSEWIC or IUCN within the last 10 years, the criteria used to categorize the stock as endangered or critically endangered, respectively, must be provided.

For populations of unknown status or with a current status between 0.3 and 0.7 of K (or its proxy), we consider a stock trend of either “increasing or stable” or “decreasing or unknown”, with increasing or stable stocks assigned the highest (less precautionary) F_R value within each status range (Table 3).

For stocks which have a decreasing or unknown trend, we consider uncertainty in the R_{max} in the setting of the F_R where the estimated value for R_{max} is either:

1. Greater than the default value (0.04 for cetaceans or 0.12 for pinnipeds); or,
2. Less than the default value or the default value is used.

Simulations conducted by Punt et al (2018) with more realistic population dynamics than those used in the original MSE conducted by Wade (1998) show lower rates of increase and, thus, lower probabilities of the stock being above its MNPL after 100 years when R_{max} is less than the default. In this situation, lowering the F_R to 0.5 or lower can increase the probability of meeting the management objective of PBR (Punt et al. 2018). Where the default R_{max} is used, we have taken the more precautionary approach of assuming the true value (if known) would be less than the default. Where the estimated value for R_{max} is greater than the default value, we have set the F_R at the same value as for a population which is increasing or stable since a conservative adjustment downward based on trend may be overly precautionary when R_{max} is greater than the default (see above). However, when the estimated R_{max} is less than the default or when the default value is used, we have adjusted the F_R within each zone downward.

For stocks of unknown status which are known to have an increasing stock trend, the NMFS guidelines suggest that an F_R of > 0.5 be used to calculate PBR (NMFS 2023). However, the default recovery target and recovery timeframe for PBR (0.5 of K and 100 years, respectively) differ from the ASMS recovery target (0.7 of K or a proxy) and the recommended timeframe for recovery under the PA Policy (1.5 to 2.0 generations). Therefore, to be more consistent with the objectives of the ASMS, for stocks of unknown status with an increasing or stable trend, we have assigned the more precautionary F_R of 0.5. As with stocks of known status, where the estimated value for R_{max} is greater than the default value, we have set the F_R at the same value as for a stock which is increasing or stable and adjusted the F_R value downward when the estimated R_{max} is less than the default or when the default value is used (Table 3).

Although the approach proposed in Table 3 provides guidelines for selection of the F_R, it cannot account for all potential biases which may impact the estimation of PBR. Where stock structure is uncertain, consideration should be given to lowering the level of selected F_R depending on the risk of depletion. Given the 100 year timeframe for recovery under PBR (Wade 1998), a lower F_R may need to be considered for species with high age-at-maturity (e.g. bowhead whale, 18 years), when using the default R_{max} or when R_{max} is known to be lower than the default value (Punt et al. 2018; Richard and Abraham 2013). The PBR calculation also assumes that removals by age or sex are proportional to their occurrence in the stock. If removals are skewed with respect to age or sex, the PBR may be either too precautionary or not precautionary enough. If removals are predominantly of young animals and/or males, PBR may be overly conservative. Conversely, the PBR may not be sufficiently precautionary if removals consist predominantly of mature females. Therefore, adjustments to the F_R may be required to account for situations where the composition of removals are skewed toward a specific component of the stock (e.g. see NMFS 2023). In cases where the F_R is adjusted to account for a bias not addressed in the approach outlined for Table 3, the justification for the change must be provided.

CONCLUSION

The ASMS PA framework was reviewed to ensure consistency with DFO's PA Policy and revised to address gaps and clarify approaches. Both the Data Rich and Data Poor PA frameworks used in the ASMS are consistent with the intent of the DFO PA Policy.

For the ASMS Data Rich PA framework there is a need to undertake simulations with recently developed integrated population models for grey and harp seals to further evaluate the recommended HCRs for the Cautious Zone based on stock status and trend and the established risk tolerance levels for preventable decline under the PA Policy.

The time frames recommended here for the HCRs in the Healthy and Cautious Zones of the ASMS Data Rich PA framework are specific to data rich stocks of seals with harvests predominantly targeted towards YOY. However, the revised ASMS framework could be generalized to extend to other marine mammal stocks in Canada by running simulations to evaluate variations in the HCR timeframes for marine mammal stocks which have different life histories and harvest compositions.

In addition, the revised ASMS Data Rich framework does not address how to deal with long term changes in the state of the ecosystem. Additional evaluation is needed to determine the most appropriate timeframe to use when calculating reference levels in a changing environment, and how to establish HCRs that are robust to ecosystem change.

Although we considered the impact of the shorter recovery timeline and higher recovery target of the ASMS framework compared to those of PBR when establishing the guidelines for selecting the F_R under the Data Poor ASMS framework, simulations to evaluate the impacts of different recovery targets and timeframes could help to further refine our approach to the selection of the F_R for PBR in Canada.

SUMMARY OF RECOMMENDATIONS

ASMS - DATA RICH PA FRAMEWORK

Recommendations 1-4 are illustrated in Figure 4.

Recommendation 1

- If a reliable model based estimate of K is available, it should replace N_{max} as the reference abundance level in the ASMS.
- K should be estimated over the longest possible period while accounting for variation in contemporary environmental conditions.

Recommendation 2

- If the stock is in the Healthy Zone, the time frame over which the results of proposed management actions are compared to the PRP be set at 15 years.

Recommendation 3

- The timeframe for each of the HCRs in the Cautious Zone be set at 1.5 generations until simulations can estimate timeframes for recovery above the PRP based on stock status and trend, and the established risk tolerance levels for preventable decline in the Cautious Zone under the PA Policy.
- Here generation length is defined based on the IUCN criteria for an exploited stock. In keeping with the PA Policy, the calculation used to estimate generation length must be clearly outlined.

Recommendation 4

- A stock decline to or below N_{50} (with an 80% probability) be used as the trigger to initiate the development of a rebuilding plan.

Recommendation 5

- New simulations based on the current integrated population models for assessment of harp and grey seals be undertaken to evaluate strategies for achieving objectives under the PA framework.

ASMS - DATA POOR PA FRAMEWORK

Under the MMPA Imports Provisions Rule (81 FR 54389) (NOAA, 2016) an estimate of PBR may be required for marine mammal populations which meet the criteria for Data Rich under the ASMS. As such, recommendations 4 and 5 below are also applicable to the calculation of PBR for Data Rich populations.

Recommendation 1

- Where a stock is categorised as Data Poor but it is possible to construct a population model that can provide a current estimate of abundance that is robust to differing model assumptions, the N_{min} for PBR should be calculated using the model estimate of current abundance. How N_{min} is calculated must be clearly described.

Recommendation 2

- Where there are multiple estimates of abundance available for a Data Poor stock but insufficient information to construct a population model, N_{min} should be estimated using the most recent abundance estimate. Alternatively, weighted averages could be used to calculate N_{min} for PBR if the abundance estimates were obtained within the last 10 years and the population is considered to be increasing or stable. The rationale for including multiple estimates and the method used to calculate a weighted average must be clearly described.

Recommendation 3

- If the most recent abundance estimate is greater than 10 years old, it should not be used to calculate N_{min} for PBR. In this situation PBR is considered to be unknown.

Recommendation 4

- Where it is possible to obtain a reliable estimate, the value of R_{max} for the stock being assessed should be used to calculate PBR. Alternatively, an estimate of R_{max} calculated for other stocks of the same species living in a similar environment could be used. The source and rationale for an R_{max} value which is different from the default values must be clearly documented.

Recommendation 5

- The F_R used in the calculation of PBR should be set based on the guidelines summarized in Table 3. In cases where the F_R is adjusted to account for a bias not addressed in in Table 3, the justification for the change must be provided.

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TABLES

Table 1: Examples of reference points used in precautionary approach (PA) frameworks for marine mammals and fisheries in Canada and other jurisdictions. LRP, limit reference point. PRP, precautionary reference point. DFO, Department of Fisheries and Oceans. ASMS, Atlantic Seal Management Strategy. MMPA, Marine Mammal Protection Act. IWC, International Whaling Commission. N_{max}, maximum population observed or estimated. K, environmental carrying capacity. ND, not defined. MNPL, maximum net productivity level. B_{MSY}, biomass at maximum sustainable yield. B_0, pre-exploitation or unfished biomass.

Marine Mammals:	**LRP**	**PRP**	**Reference**
DFO – ASMS	0.3 N_{max}	0.7 N_{max}	Hammill and Stenson 2003, 2007
DFO – ASMS *(revised)*	0.3 K	0.7 K	This paper
USA - MMPA	ND[a]	N_{MNPL}	NMFS 2023
IWC – Commercial	0.54 K	0.72 K[b]	IWC 1994
Fisheries:			
DFO[c]	0.4 B_{MSY}	0.8 B_{MSY}	DFO 2009
USA	0.5 B_{MSY}	B_{MSY}	NOAA 2018
New Zealand	Higher of 0.25 B_{MSY} or 0.1 B_0	Higher of 0.5 B_{MSY} or 0.2 B_0	Ministry of Fisheries 2008
Australia	0.2 B_0 or 0.3 B_0/0.5 B_{MSY}[d]	B_{MSY} / 0.4 B_0	DAWR 2018

[a] no limit reference point is defined but recovery above PRP should occur within 100 years
[b] "tuning level"
[c] DFO PA Policy default values, other approaches possible
[d] suggested alternative for low productivity stocks

Table 2: Current guidelines for the selection of the Potential Biological Removal (PBR) recovery factor (F_R) in Canada (from Hammill et al. 2017a, DFO 2018).

F_R	Population Trend	Justification
1	Abundant, increasing or stable	Abundant, infrequent surveys, other
0.75	Abundant, data limited	Abundant, survey effort limited
0.5	Abundant, declining or unknown	Abundant, limited data
0.25	Small, increasing or stable	Small, appears stable
0.1	Small, declining or unknown	Small, appears declining or unknown

Table 3: Proposed guidelines for the selection of the Potential Biological Removal (PBR) recovery factor (F_R) in Canada. K, environmental carrying capacity. Proxies for K may include estimates of N_{max} (largest population abundance observed or estimated) or N_0 (pristine abundance or unharvested abundance). R_{max}, maximum rate of population increase. COSEWIC, Committee on the Status of Endangered Wildlife in Canada. IUCN, International Union for the Conservation of Nature. In cases where the F_R is adjusted to account for a factor not addressed here (e.g. uncertain stock structure, age or sex bias in removals), the justification for the change must be provided.

Status (proportion of K or proxy)	Population Trend	R_{max}[a]	F_R
≥ 0.7	-	-	1
≥ 0.5, <0.7	increasing or stable	-	0.75
	declining or unknown	> default	0.75
	declining or unknown	< default or unknown[b]	0.5
≥ 0.3, <0.5	increasing or stable	-	0.5
	declining or unknown	> default	0.5
	declining or unknown	< default or unknown[b]	0.25
<0.3 Or Meets COSEWIC (2021) criteria for Endangered	-	-	0.1
Meets IUCN (2012) criteria for Critically Endangered (see COSEWIC 2021)[c]	-	-	0
Unknown	increasing or stable	-	0.5
	declining or unknown	> default	0.5
	declining or unknown	< default or unknown[b]	0.25

[a] default values: cetaceans 0.04, pinnipeds 0.12 (Wade 1998)
[b] default value used
[c] the values for N_{min} (minimum estimate of abundance) and R_{max} must be provided when calculating PBR

FIGURES

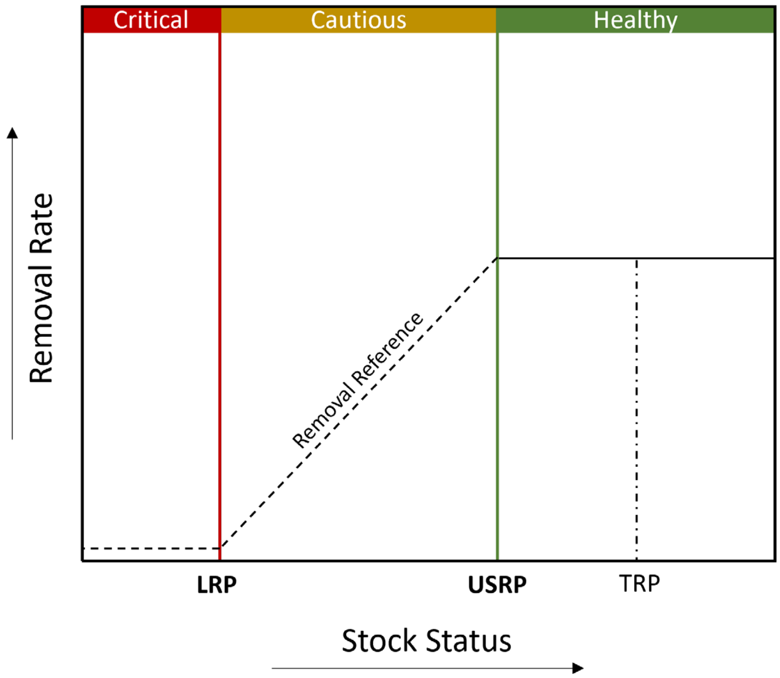

Figure 1: Schematic of the DFO Generalized Precautionary Approach Framework (DFO 2009). LRP, limit reference point. USRP, upper stock reference point. TRP, target reference point.

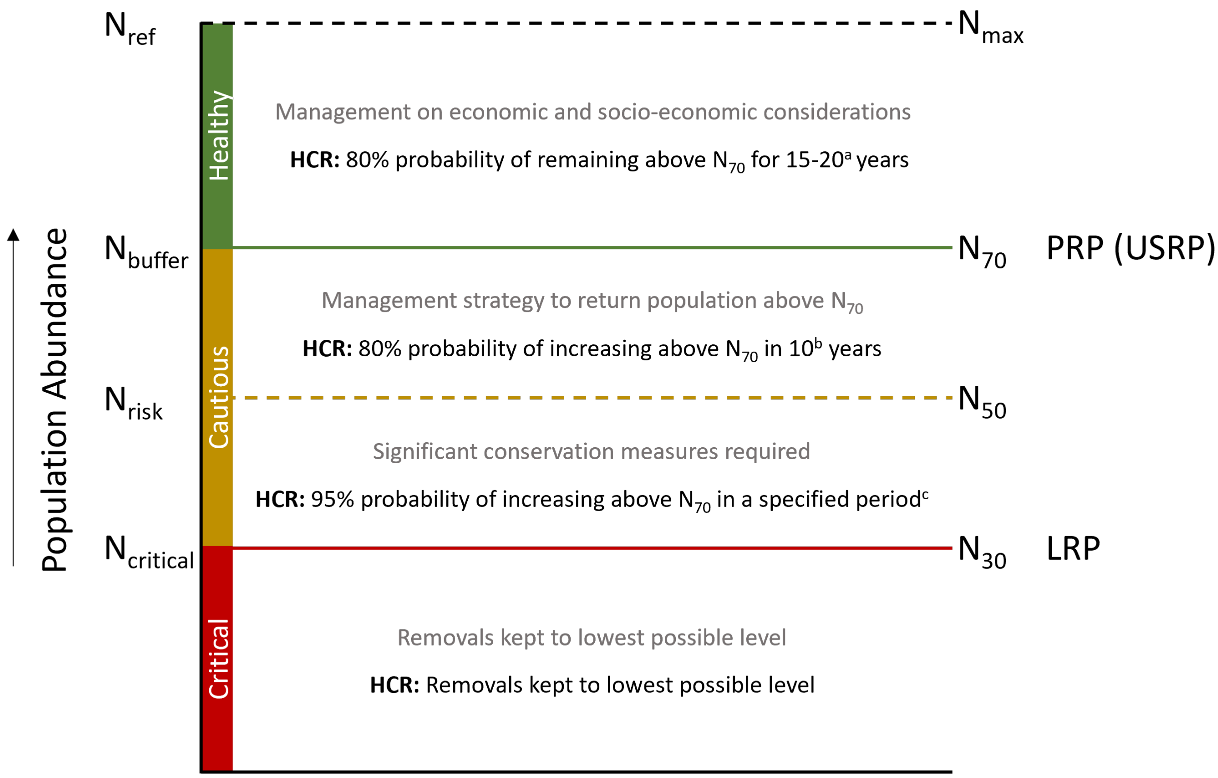

Figure 2: Schematic of the current Atlantic Seal Management Strategy (ASMS) for Data Rich populations. N_{ref}, reference level. N_{max}, largest population observed or estimated. LRP, limit reference point (30% of N_{ref}, N_{30}). PRP, precautionary reference point (70% of N_{ref}, N_{70}). USRP, upper stock reference point. N_{50}, 50% of N_{ref}. HCR, Harvest Control Rule. Adapted from: Hammill and Stenson 2003, 2007, [a]2009; Stenson and Hammill 2010, [b]DFO 2006. [c]period never defined.

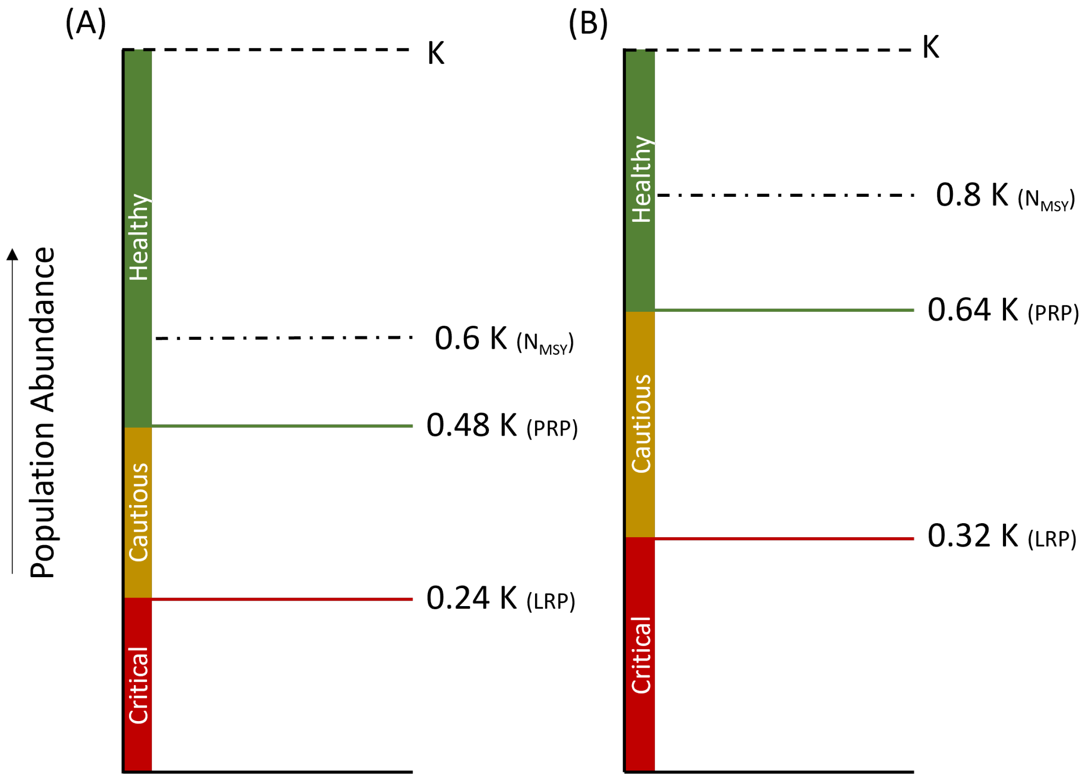

Figure 3: Values for the limit reference point (LRP) and precautionary reference point (PRP) calculated using the DFO Precautionary Approach Policy default values of 0.4 and 0.8 N_{MSY} (population abundance at MSY; maximum sustainable yield) for the LRP and PRP, respectively, where MSY is assumed to be at (A) 60% of K (environmental carrying capacity) or (B) 80% of K.

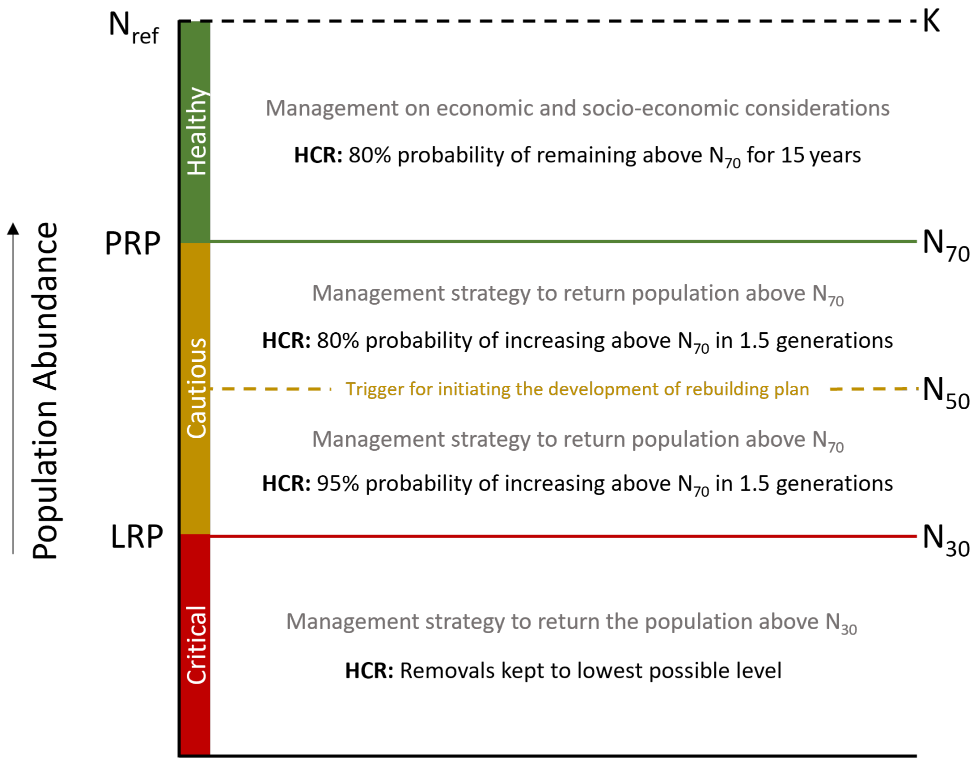

Figure 4: Schematic of the Atlantic Seal Management Strategy (ASMS) for Data Rich populations incorporating the recommended revisions. N_{ref}, reference level. LRP, limit reference point (30% of N_{ref}, N_{30}). PRP, precautionary reference point (70% of N_{ref}, N_{70}). K, environmental carry capacity. N_{50}, 50% of N_{ref}. HCR, Harvest Control Rule.