LIMIT REFERENCE POINTS AND MINIMUM POPULATIONS OF HARP SEALS (*Pagophilus groenlandicus*)

Figure 1: Reference levels identified under the current Atlantic seal management strategy

Context:

Harp seals, Pagophilus groenlandicus*, are the most abundant pinniped in the northwest Atlantic with an estimated maximum population size in 2008 of 7.3 million animals. The Canadian and Greenland hunt for Northwest Atlantic harp seals is the largest marine mammal harvest in the world. Since 2003, the Canadian commercial harp seal harvest has been managed under the Atlantic Seal Management Strategy which incorporates the principle of the Precautionary Approach. Under this approach, two reference levels are identified which create three population management zones (Fig 1). Those zones are associated with pre-agreed management actions that are to be enacted if the population is predicted to decline further (DFO 2003). The current management objective is to set harvests that will ensure an 80% probability (L20) that the population will remain above the Precautionary Reference Point (PRP; N70; 70% of the maximum observed population). The Limit Reference Level (LRL), also known as a "critical reference level" where all harvesting should cease, has been set at N30 (30% of the maximum observed population).*

Ecosystems and Fisheries Management (EFM) is currently considering revising the objectives of the Atlantic Seal Management Plan. EFM has asked Science to consider alternatives to the current LRL and to evaluate the impacts of various harvest levels on population size for a range of probabilities of risk associated with dropping below the LRL.

SUMMARY

- The Atlantic Seal Management Strategy provides a framework that identifies precautionary and limit reference levels which define healthy, cautious and critical zones of abundance, along with management actions that are triggered when these levels are crossed in order to reduce serious harm to the resource.
- Currently, the precautionary and critical reference levels are defined as 70% and 30% of the maximum observed or inferred population size.
- As the true size of most wild populations is unknown, our perception of the population size will change as new data become available and/or the methods used to estimate abundance improve. This uncertainty must be acknowledged when setting precautionary reference levels by using proportions rather than fixed numbers, as proportions maintain the relative conservation levels in the face of changes to our perception of the population abundance.
- The lowest population level observed should not be used as limit reference level. Recovery from low levels under past environmental conditions does not guarantee recovery will occur under current conditions.
- The Limit Reference Level (LRL) should be set as a proportion of carrying capacity (K) or some proxy for K. If an estimate of K can be obtained, the LRL can be expressed as a proportion of the number of seals required for a maximum sustainable yield (N_{MSY}) which would be consistent with DFO guidelines and international approaches.
- Because of uncertainties in our ability to estimate K and the shape of the density dependent relationship, we recommend that if N_{MSY} is used, the LRL be set at 50% $N_{MSY.}$
- If K or N_{MSY} cannot be estimated, the maximum population observed or inferred can be used as a proxy for K. However, with few exceptions, this will be lower than K and therefore less conservative. Given that 50% N_{MSY} is estimated to be at least 30% of K, care should be taken when setting a reference level based upon N_{max}. The current LRL (N_{30}) is at the low end of the possible values.
- The framework proposed here is appropriate for other marine mammal populations which are considered to be data rich.
- Precautionary reference levels should remain the same between periodic reviews. For harp seals, levels should remain constant between major assessments which occur every 4 to 5 years.
- Using the 2011 assessment model that assumed a carrying capacity of 12 million seals, a maximum population of 8.3 million and a N_{lim} of 2.5 million, the minimum population required to support a sustainable harvest varying from 100,000 to 400,000 was estimated under different levels of risk. Generally, a larger minimum population size was needed to support a larger harvest; a larger population size was also needed to have a higher probability (i.e. lower risk level) of respecting the management objective.
- For example, a population of approximately 5.3 million seals was estimated to be necessary to sustain an annual catch of 100,000 with a 95% likelihood of remaining above the limit reference point for a 15 year period if reproductive rates do not change while a population of 4.7 million is required if we assume that reproductive rates will increase as the population declines.

INTRODUCTION

Within the context of fisheries management, 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 the failure to implement conservation measures, and defines, in advance, decision rules for stock management when the resource reaches clearly stated reference points. In 2003, the Privy Council Office, on behalf of the Government of Canada published a framework applicable to all federal government departments that sets out guiding principles for the application of precaution to decision making about risks of serious or irreversible harm where there is a lack of full scientific certainty.

The Atlantic Seal Management Strategy, adopted in 2003 (as Objective Based Fisheries Management), was the first plan to incorporate a precautionary approach in the management of marine species in Canada. The framework identifies a limit (or critical) reference level (N_{lim}) which represents the (estimated) level at which continued removals would lead to serious harm to the population, and a Precautionary Reference Level which 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. Under the current approach, N_{lim} is set at 30% of the maximum population size observed (or inferred). The Precautionary Reference Level is identified as 70% of the maximum population. The maximum population is used as a proxy for the carry capacity which is difficult to estimate. A third threshold, referred to as the Target Reference Level (TRL), represents the desired population size and is generally set above the Precautionary Reference Level. The level of the TRL has not been set for seals but will depend upon the management objectives of the harvest.

After nearly a decade, Resource Management and industry have requested that the Atlantic seal PA framework be reviewed. Of particular concern is that because the current thresholds are set as a proportion of some proxy of K, the thresholds have varied considerably across years. This variation is due, in part, to changes in population sizes as they recover from lower levels, but more importantly, as we have learned more about the resource, and improvements to the population models were incorporated, significant changes have been made to our perception of both population abundance and trend.

Specifically, Science was requested by Resource Management to: 1) Review the methodology/criteria to establish the Limit Reference Point (LRP) 2) determine an appropriate Limit Reference Point; and 3) determine the minimum harp seal population size that can maintain an ongoing (i.e. 15 years) sustainable harvest of 100K, 200K, 300K and 400K, while maintaining a probability of 85%, 90% and 95% of staying above the Limit Reference Point. In evaluating the impacts of different harvest levels on the population, reported harvests by Canadian and Greenland hunters, losses due to animals struck but not landed or reported by-catch in fishing gear, changes in reproductive rates, and unusual mortality due to poor ice conditions are taken into account.

BACKGROUND

Estimates of harp seal abundance

The identification of specific reference levels assumes that the population size is known (with its estimated uncertainty). However, for a wild population, the true population size is not known. The dynamics of the Northwest Atlantic harp seal population are described using an age-structured model that incorporates data on annual reproductive rates, mortality and periodic estimates of pup production. First developed in the early 1980's, this model has since undergone many revisions including the way in which reproductive data are used, and the incorporation of struck and loss and unusual mortality related to poor ice conditions.

The dynamics of the harp seal population were initially described assuming that the population was growing exponentially. During 2003-2005, when the PA framework was first implemented, the population was estimated to vary from 5.3 to 5.7 million animals. Following the 2008 aerial survey it was recognized that the inter-annual variation observed in the reproductive data reflected real changes in pregnancy rates. As a consequence, the model formulation was changed during the 2010 assessment to incorporate the annual measured pregnancy rates and from describing the dynamics of the population assuming exponential growth to a model assuming density-dependent changes in young of the year mortality. This change altered our perception of the population, from one that may have been as high as 9 million animals, and still increasing under the assumption of exponential growth, to a population that had leveled off at a lower number (7.5 - 8.5 million in 2008, depending upon assumptions about carrying capacity) (Fig. 2). Recent model runs estimate the population during the period 2003-2005 at approximately 7.3 million animals which is similar to the maximum population size seen (Hammill et al*.* 2012).

The greatest sources of uncertainty in a density-dependent model are the estimated carrying capacity (K) and the shape of the curve used to describe the density-dependent changes in the trajectory of the population. The shaping parameter and K are highly correlated and at the current time it is not possible to further refine these two parameters. The consequences of this uncertainty can be important with respect to our understanding of the dynamics of the population and its response to environmental and harvesting conditions.

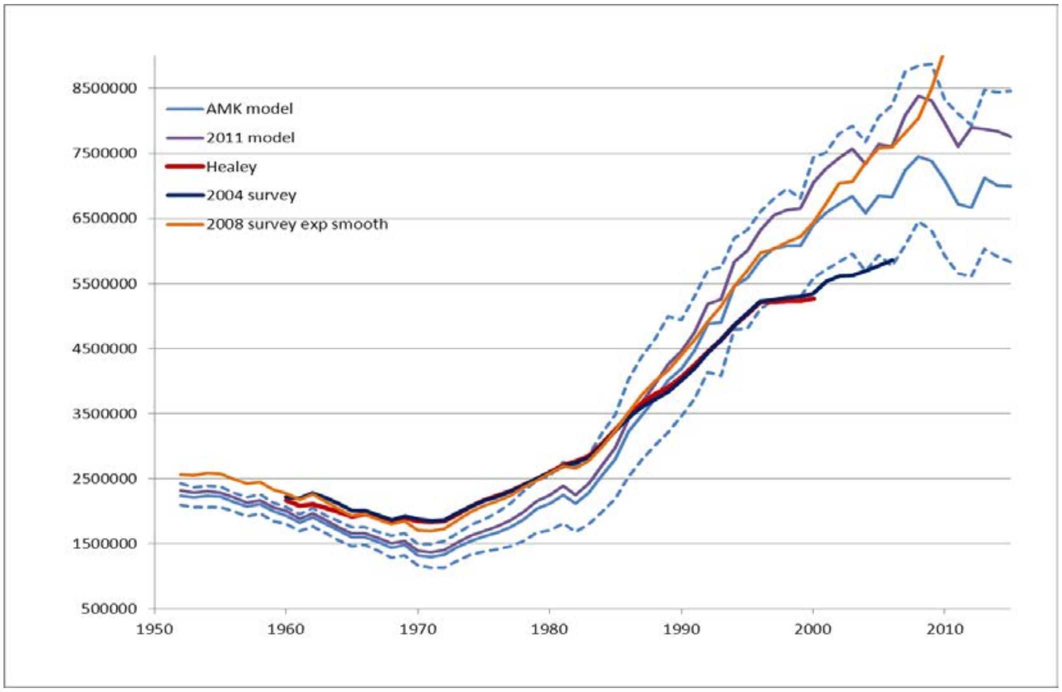


Figure 2. Estimated total population size of the Northwest Atlantic harp seal population as determined from different assessments from 2000 to 2011. The "Healey" and "2004" estimates reflect an exponential growth model using smoothed reproductive data up to 1998 and 2004 respectively. The "2008" estimates were obtained using smoothed reproductive rates updated to 2008 and an exponential growth model. The "2011 model" (Hammill et al. 2011) used annual values for the reproductive rate data updated to 2010 and assumed a K=12 million. The "AMK model" (Hammill et al. 2012) fits the model to the survey data, the reproductive data and estimates K=10 million.

ASSESSMENT

Identification of the Limit Reference Level (N_{lim})

N_{lim} separates the Critical and Cautious zones. It identifies a threshold, below which the population is considered to suffer serious harm. A number of different approaches were examined for setting a LRL.

1) N_{loss} (B_{loss} for fisheries) is the lowest population size that has been observed in the past and from which recovery has occurred. It has been used in some fisheries as a N_{lim} or B_{lim}. It is based on the concept that if a population has been reduced to this level in the past, and has recovered, then it will do so again under the current conditions. The use of B_{loss} has been considered in a number of situations but has generally been adopted in fisheries that have not been affected by ecosystem changes (e.g. scallop).

   However, it is not prudent to assume that a population that has been reduced to low levels will recover. The need to understand changes in the productivity regime underscores the major weakness of using N_{loss} as a LRL. The lack of recovery of a number of Atlantic cod stocks from recent declines illustrates that populations that have recovered from low levels in the past may not do so again.

For harp seals, all model runs completed since the 1990s indicate that the population probably reached a minimum in the early 1970s. The population at this time was estimated to range from 1.5 – 1.8 million animals, depending upon the model assumptions. However, current ecosystem conditions differ from those experienced by the population during the previous period of low abundance. Recent environmental conditions appear to have a significant influence on the abortion rate, fecundity, juvenile survival due to poor ice conditions, particularly in the Gulf of St Lawrence. These changes make it unlikely that harp seals will have the same high level of recruitment as they did in the 1970s.

2) $N_{\%}$ is the population size where a threshold is set as a proportion of a reference level such as carrying capacity (K) or the biomass at Maximum Sustainable Yield (MSY). This approach has been used extensively among marine mammal populations where it is usually set as a proportion of K or a pre-exploitation level. A modification of this is used in the current Atlantic Seal PA framework that uses maximum population size as a proxy for K. Another approach would be to use an estimate of historical (pre exploitation) abundance as a proxy for K but these estimates are very uncertain and assume that ecological conditions in the two periods are similar.

   This approach has also been used extensively among fish stocks both internationally and within DFO. The general DFO guidelines recommend setting N_{lim} at 40% of MSY. In New Zealand, the standard is to set N_{lim} at 50% of MSY for low productivity stocks.

   Estimating MSY for marine mammals depends upon the level of K and the shape of the density-dependent relationship. Generally, it is estimated to be between 60 and 80% of K. If, for example, we assume that MSY occurs at 60% of K and that K=10 million harp seals, then N_{lim} would occur at 2.4 or 3 million animals assuming 40% or 50% of MSY, respectively.

   The current Atlantic seal management approach was developed before estimates of K were available for harp seals. Therefore, the largest population observed was taken as a proxy for K, and the N_{lim} was set at 30% of this proxy. The most recent estimate of maximum population is 7.3 million which results in an estimate of N_{lim} of 2.2 million animals.

   The advantage of the $N_{\%}$ approach is that it is self-adjusting to changes in our perception of the size of the population, the MSY level and K, and therefore does not require a change in the framework itself if any of these components of the population changes. N_{lim} may change in absolute terms, but the limit remains the same with respect to the other reference levels

3) $N_{conservation}$ is a variant of $N_{\%}$, whereby the LRL is set at a proportion of some index of abundance, but in this case the population threshold is set based on the magnitude of decline from a reference population size. The reference population could be K (if known), the largest population estimated, or the population size before a decline. This approach is used by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the International Union for the Conservation of Nature (IUCN). They consider a population to be endangered if there is a 70% (cause known and stopped) or 50% (cause unknown and decline not stopped) decline in the population within 10 years or 3 generations, whichever is longest.

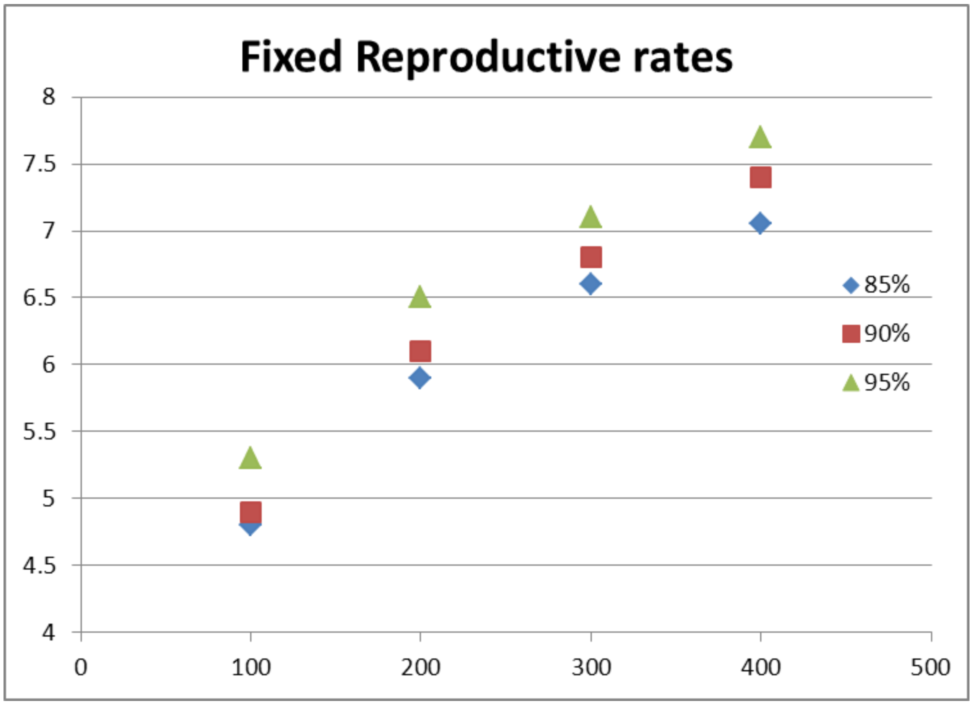
4) N_{number} where the LRL is set at a fixed number that could continue to withstand some low level of harvesting. Currently, no framework uses this approach. Although the number remains fixed, which may be considered an advantage, this approach has two major disadvantages. First, it is very difficult to determine an acceptable number, and second, because we do not know the true population size, it is possible for the population to change status (e.g. fall into the cautious zone) due to changes in our perception of the abundance without any actual biological change. This would trigger management action to reduce the harvest when that action was not necessary.

Minimum population sizes of harp seals required for different levels of commercial harvest

The 2011 harp seal assessment model was used to determine the minimum population sizes required to sustain annual harvests of 100,000, 200,000, 300,000 and 400,000 while maintaining a probability of 85%, 90% or 95% of staying above the limit reference point. This model assumed a harvest composition of 90% beaters with a carrying capacity (K) fixed at 12 million animals. The LRL was assumed to be 30% of the maximum population of 8.3 million (Hammill et al. 2011). Two model formulations were used, one assuming fixed reproductive rates based upon the previous 5 years, whereas the second assumed that reproductive rates changed in a density-dependent manner.

As expected, a larger minimum population size was needed to support a larger harvest; a larger population size was also needed to have a higher probability of respecting the management objective. The minimum population size was also affected by the model formulation used to project population size. Given the current low pregnancy rates, the populations required to sustain catches assuming that reproductive rates were fixed, are higher than those that assume that reproductive rates will increase as the population declines (i.e. a density-dependent function) (Fig 3).

A population of approximately 5.3 million seals is required to sustain an annual catch of 100,000 with a 95% likelihood of remaining above the limit reference point if reproductive rates do not change, whereas 4.7 million animals are required if we assume that reproductive rates will increase as the population declines. Increasing the average harvest to 400,000 requires 7.7 or 6.7 million seals assuming constant or density- dependent fecundity, respectively. Increasing the risk by accepting a lower probability of remaining above the limit reference point (80% vs 95%) reduced the required population by approximately 500,000 – 600,000 seals (Fig 3). Currently, there is no way to determine which of these models is more likely, and so a conservative approach is recommended.



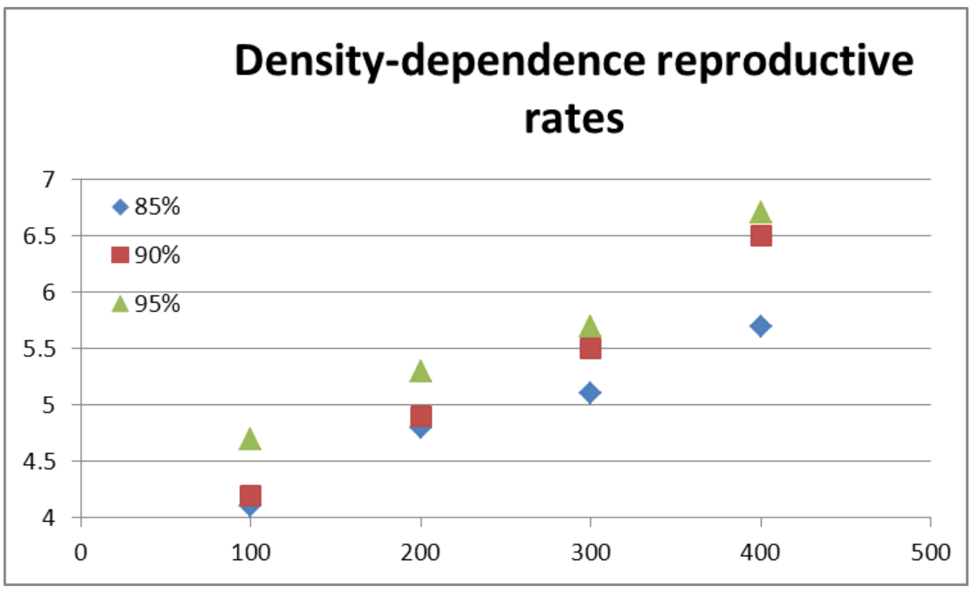


Figure 3. Minimum population sizes (y-axis, million) required under different levels of harvest (x-axis, thousand) and different probabilities that the harvest would respect the management objective, under two assumptions about future reproductive rates. For the density- dependent reproductive rates (bottom), rates varied with population size, assuming K=12 million and environmental conditions that could vary from 0.6 to 1.5 times the expected reproductive rate. The fixed reproductive rate scenario (top) assumed that reproductive rates were similar to those observed over the last five years.

Sources of Uncertainty

It is difficult to estimate carrying capacity (K) for marine mammals. Sufficient data are generally not available to quantify the density-dependence relationships that are needed to estimate K. In the harp seal model, the shape of the density-dependent relationship between population size and reproductive rates is assumed. Changing this relationship would produce different estimates of K and N_{MSY} which are required to estimate the N_{lim}.

Reproductive rates have exhibited increased interannual variability in recent years. Variability in survival rates may also have changed, but we cannot measure survival of different age classes in this population. The consequences of increased variability on population trends and reference levels have not been investigated.

CONCLUSIONS

Our perception of the abundance of any population can change as new data become available or model formulation improves. Therefore, fixed numbers (i.e. N_{number} or N_{loss}) should not be used to determine a limit reference level. Fixed reference levels do not respond to the changes in estimates of abundance or varying ecosystem/environmental influences on MSY and K.

A system that sets reference levels as proportions of K or some proxy (e.g. the current framework, the DFO general framework and international standards) instead of absolute numbers is self-adjusting, because reference levels shift as our understanding of the population changes.

The number of seals that provide Maximum Sustainable Yield (N_{MSY}) could be used as the basis for the proportional limit reference level. Because of uncertainty associated with estimating N_{MSY} for marine mammals, a LRL of 50% N_{MSY} should be considered.

If N_{MSY} cannot be estimated, the maximum population observed or inferred has to be used as a proxy for K. Because we do not know the relationship between N_{max} and N_{MSY}, a reference level based upon an estimate of N_{max} (e.g. 30% N_{max}) is a possible LRL, although this is almost always less conservative than using N_{MSY}.

One concern with the current approach has been the annual change in reference levels as data are added and our understanding of the population has changed. Given the frequency of pup production surveys, it would be reasonable that reference levels remain constant for the period between major population assessments, currently every 4 to 5 years for harp seals.

Although this advice was discussed with respect to harp seals, the Framework is applicable to other data rich marine mammal species (Stenson et al. 2012).

The minimum populations required to sustain harvests will depend upon the harvest level, the level of risk and assumptions about future reproductive and mortality rates.

SOURCES OF INFORMATION

This Science Advisory Report is from the October 29 to November 2 “Annual meeting of the National Marine Mammal Peer Review Committee (NMMPRC)”. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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ISSN 1919-5079 (Printed)
ISSN 1919-5087 (Online)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO. 2013. Limit Reference Points and Minimum Populations of Harp Seals (*Pagophilus groenlandicus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/067.