Short Communication

Towards a precautionary approach to managing Canada's commercial harp seal hunt

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The Canadian government's approach to the management of its commercial harp seal hunt is compared with other precautionary approaches developed for setting anthropogenic removal limits for marine mammal populations. For Canada's harp seal hunt, the current management strategy has not been fully specified or tested, and its robustness to changes in biological parameters, uncertainty in input data and environmental variability, remains unknown. As such, the management approach cannot be considered precautionary and there is a substantial, but not quantified, probability that it will not meet its objectives. There is an urgent need for a fully specified and rigorously tested management procedure, and steps towards this are suggested that should reduce the risks associated with the current approach.

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Introduction

The commercial hunt of harp seals (*Pagophilus groenlandicus*) off eastern Canada is the largest hunt of marine mammals currently undertaken. It is therefore appropriate to examine critically the science currently used to inform management objectives and decisions.

Hammill and Stenson (2007) outline the scientific advice used by managers when setting catch quotas for Canada's commercial hunt. The process involves: (i) estimating the production of harp seal pups from aerial surveys; (ii) estimating total population size using a model based on a time-series of estimates of pup production and pregnancy rate data; (iii) projecting the model forwards in time to simulate the effects of varying hunt levels; and (iv) assessing the simulated projections in terms of management objectives. Hammill and Stenson (2007) also describe the "objective-based fisheries management" (OBFM) approach used by Canada to manage Atlantic seal hunts and suggest that it is an example of the application of the precautionary approach (PA) to management. In Canada's current management plan (Anon., 2008), the PA is defined as "a conservation-oriented decision framework, to be applied when there is high scientific uncertainty and a prospect of serious harm".

The OBFM approach is now being more widely adopted and has been applied to other harp seal hunts, including that in the White Sea (ICES, 2006; Korzhev, 2008). To be considered precautionary, however, there needs to be convincing evidence that the management approach to exploitation will generate a low probability of harmful effects on the population. What constitutes a harmful effect and an acceptable level of risk of this happening are ultimately value judgements. Nonetheless, such criteria need to be incorporated as specific management objectives so that the probability of meeting them under different scenarios incorporating uncertainty can be evaluated.

Other procedures for setting limits on takes of marine mammals include the Revised Management Procedure (RMP) of the International Whaling Commission (Cooke, 1995; Punt and Donovan, 2007) and the calculation of levels of Potential Biological Removal (PBR; Wade, 1998; Johnston *et al.*, 2000). Both approaches are widely acknowledged to be precautionary, attempt to provide a fully specified catch algorithm, ensure a very low probability that the stock will decline below a given level, and are robust to errors in input data. Both the RMP and PBR follow the "management procedure type approach" of Butterworth (2007), where rules for setting catch limits are agreed in advance, and long-term performance has been tested by computer simulation.

In contrast, OBFM would be categorized as the "traditional" approach to management (Butterworth, 2007), in that it does not have a catch limit algorithm and has not been tested by simulation. OBFM is therefore potentially vulnerable to failure arising

from incorrect assessments, including model specification and biased input data. It also provides no guarantee that management measures will provide the desired balance among specified conservation objectives in the long term (Butterworth, 2007).

Here, we compare the current interpretation of the PA and management of the Canadian harp seal hunt with the RMP and PBR management procedures. We also assess whether the management approach meets all the criteria suggested by the currently employed OBFM approach (Hammill and Stenson, 2007).

Reference points and population substructure

Anon. (2008) gives the two primary management objectives for Canada's commercial harp seal hunt as (i) to facilitate a market-driven hunt that will allow sealers to maximize their benefits without compromising conservation, and (ii) to ensure conservation by maintaining the population at a level above 70% of the maximum observed population.

Reference points used to judge the population status of Northwest Atlantic harp seals are based on percentages (70, 50, and 30%) of the maximum estimate of population size, rather than on an estimate of carrying capacity. Although the population is above the 70% level (termed N_{70}), management measures should ensure an 80% probability that the population will not drop below N_{70} (Hammill and Stenson, 2007). If the population does drop below N_{70}, then management measures should ensure an 80% probability that the population will increase to $>N_{70}$ within 10 years (Hammill and Stenson, 2008a). Management measures for populations that fall below the 50% level (N_{50}) require a 95% probability that the population will increase and exceed N_{70} within a period (Hammill and Stenson, 2007). However, this period has not been specified in the current management plan. If the population were to drop below the 30% level (termed N_{Critical}), all removals would be stopped.

Hammill and Stenson (2007) acknowledge the difficulties of selecting reference points and suggest the reference points adopted by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2006) to be appropriate for management of the harp seal hunt. Previous recommendations (Rivard, 2005) had been that the limit reference point in the PA framework should be above the "Threatened" designation of COSEWIC or, in the harp seal case, 50%. The 30% figure actually set for N_{Critical} corresponds to the "Endangered" designation of COSEWIC and is also considerably lower than the 54% of estimated pre-exploitation population size agreed by the IWC for which commercial whaling catch limits would be zero.

The reference points in Anon. (2008) and the approach outlined by Hammill and Stenson (2007) only consider the case where the population can be treated as a single unit. In practice, this is an unlikely scenario. For example, it has been suggested that it would be precautionary to consider the harp seals that reproduce in the northern Gulf of St Lawrence as a separate management unit because of the very small numbers of seal pupping in this area in some years (Simon, 2005). If distinct subpopulations can be identified, then reference points should be set for each. It is preferable, therefore, either to incorporate population substructure explicitly into a management procedure (e.g. the way that Small Areas are defined in the RMP) or to use a procedure that sets catch limits that are sufficiently conservative to allow for plausible substructure. Options for allocation of the total allowable catch (TAC) into quotas by area need to be specified such that they can be tested for conservation performance for the different scenarios of population structure that are considered plausible.

Is the management approach likely to meet its stated objectives?

For the management-procedure-type approach, the likelihood of meeting objectives can be examined by simulation. Rademeyer *et al.* (2007) suggest that, at a minimum, these simulations should address past data, future availability of data, the dynamics of the population and the removal process, and environmental variability. Kell *et al.* (2005) suggest that consideration of environmental variability should include random stochasticity, catastrophes, and systematic change.

Such simulation trials for Canada's commercial harp seal hunt involve speculation about possible future management decisions because there is no specified algorithm for setting catch limits. Leaper and Matthews (2008) conducted simulation trials of the effects of hunting on harp seal numbers in Canada with the assumption of a constant catch and compared the information that would be available to managers with the true state of the simulated population. The results of these trials highlighted some potentially serious issues. Under combinations of bias in input parameters that were considerably less severe than used in RMP or PBR simulation (e.g. Wade, 1998), there were several scenarios under which the Canadian management plan would fail to meet its objectives. Not surprisingly, Leaper and Matthews (2008) found that the conservation implications were most severe for positive bias in aerial survey estimates of pup production. The maximum bias of 30% considered in the Leaper and Matthews (2008) simulations had conservation consequences for harp seals that included median depletion of the simulated population below N_{30} for catches that appeared to be consistent with the management plan assuming no bias. In contrast, the RMP (IWC, 1994a) and PBR (Wade, 1998) require populations to stabilize at optimal sustainable population levels with positive biases in survey estimates of 50 and 100%, respectively. We consider a bias of 30% to be within the plausible range for harp-seal aerial surveys, given the recent reliance on visual counting and that comparisons of photographic and visual techniques can produce large differences (Stenson *et al.*, 2005).

An additional factor that needs to be considered is whether there is an inherent bias in pup production estimates attributable to the fact that surveys can only be conducted in years with good ice conditions and good weather. The relatively low pregnancy rates of mature harp seals in recent years (Sjare *et al.*, 2004) suggest that a substantial proportion of animals has a multiyear breeding cycle, so changes in environmental conditions are likely to produce periodic fluctuations in pup production because animals tend to come into breeding condition in synchrony (Cooke *et al.*, 2003). In a year of poor ice or weather conditions that resulted in a high rate of abortion, a high rate of early neonatal mortality, or truncated lactation (Johnston *et al.*, 2005; Stirling, 2005), many females would use up less energy reserves than if they successfully reared a pup. In the year following, pup production might be greater than expected based on average pregnancy rates and mature population size because a larger proportion of mature females would be in breeding condition. If a survey was postponed one year because of the poor conditions,

a survey the following year might take place during a temporary peak in pup production. This situation may actually have prevailed when a scheduled aerial survey was postponed in 1998 (Fisheries and Oceans Canada, 1998). A survey was successfully completed the following year and resulted in a pup production estimate substantially higher than the overall trajectory fitted to all datapoints from previous surveys (Hammill and Stenson, 2007).

The sensitivity of the management model to time-dependent bias in surveys also needs consideration. This problem is potentially exacerbated by using different methods of abundance estimation at either end of the period. Early estimates were derived from mark recapture, whereas later estimates were from photographic or visual aerial surveys. Leaper and Matthews (2008) stated that the implications for model predictions of a 10% negative bias in mark recapture and a 10% positive bias in aerial surveys were similar to a 20% positive bias in aerial surveys.

A general principle of the PA enshrined in both the RMP and the PBR approaches is that greater uncertainty should result in lower levels of take (Wade, 1998). Among other things, this principle provides an incentive to collect data to allow higher catches. Hammill and Stenson (2007) address the issue of data availability by classifying populations into two categories, "data-rich" and "data-poor", with a different management approach in each case. They define data-rich populations as requiring three or more abundance estimates over a 15-year period, the last estimate being obtained within the past 5 years, and current information ($\leq$5 years old) on fecundity and/or mortality. Within such a management framework, it is critical to specify what is meant by "information", both in terms of the raw data and the analyses required. In the absence of precise specification, the classification of whether a species is data-rich will remain open to interpretation. For example, for Northwest Atlantic harp seals, the catch limit for 2007 was based on models that used pregnancy data collected up to 1997. Nevertheless the population was classified as data-rich because new data had been collected subsequently, although these data were not used in the assessment.

The type of information used to generate estimates of total abundance, e.g. direct surveys or model-based estimates, also needs to be specified. Direct surveys of the total population of harp seals are not possible, and pup production is the easiest population parameter to estimate directly because nursing pups are spatio-temporally aggregated and visible, unlike non-pup animals for most of the year. There are, however, several difficulties in estimating total population based on counts of young of the year. There is a requirement for either pregnancy or mortality data, and modelling difficulties arise if there are unmeasured changes in demographics over time. Estimates of grey seal (*Halichoerus grypus*) numbers around Scotland provide an example of such modelling difficulties. Despite nearly complete pup censuses being conducted annually, model-based estimates of total population differed by a factor of two, depending on model assumptions regarding changes in mortality and fecundity (SCOS, 2007). Changes in demographic parameters can also bias estimates of rates of population change (Berkson and DeMaster, 1985). Data-intensive studies of terrestrial and marine mammals, based on long-term mark-recapture estimators where a large proportion of a population is marked, demonstrate that substantial changes in mortality and fecundity should be expected in mammal populations (Gaillard *et al.*, 2000; Baker and Thompson, 2007).

In addition to difficulties in obtaining estimates of total population size, there will also be a delay of some 5–7 years (the time taken for pups to be fully recruited into the breeding population) before any overexploitation of pups will be reflected in reduced pup production. This delay really should be accounted for in the management procedure (McLaren *et al.*, 2001).

Comparison with other management procedures

In discussing other management approaches, Hammill and Stenson (2007) note that the objective of the RMP is to maintain stable catches to the extent possible, and allowing the largest possible yield while maintaining a low risk of depleting the population. They also acknowledge the value of the extensive simulation testing carried out on the RMP. Their assertion that the RMP has large data requirements, however, is not necessarily the case. In fact, the catch limit algorithm within the RMP actually requires less data (a time-series of catches and a sequence of abundance estimates) than Hammill and Stenson's (2007) requirements for data-rich species. The RMP utilizes a time-series of abundance and catch data that make the algorithm complicated compared with the single equation involving current abundance that is the basis of PBR, but utilizing these data result in RMP catch limits becoming more precise over time (Palka, 2002). The implications of model-based estimates of total abundance rather than surveys of the full population have not been fully explored for either the RMP or the PBR approaches. Therefore, there is potential to develop a procedure for Canada's commercial seal hunt that may give better performance than existing approaches. At a minimum, this would require consideration of the following steps:

(i) *Specification of management objectives*—Conservation objectives for populations $>N_{50}$ are adequately specified to allow the development of a management procedure approach, but the period over which a population below N_{50} should recover (with the stated 95% probability) needs to be specified. Quantified economic objectives for management also need to be specified fully, such that the performance of candidate management procedures can be evaluated against them in addition to conservation objectives. Although the objective in Anon. (2008) is to "allow sealers to maximize their benefits", these benefits need to be quantified to allow different options for potential future takes to be compared.

(ii) *Errors in input data*—The levels of bias in input parameters to which the management procedure needs to be robust has to be specified. These should include uncertainty in historical estimates of abundance (including mark-recapture surveys with different methodology), recent aerial surveys (including both photographic and visual estimates), total catches, and pregnancy rates.

(iii) *Stock structure*—There should also be some agreement on plausible hypotheses on stock structure, for the spatial distribution patterns of potential stocks in relation to the manner in which the total TAC may be divided into regional quotas.

(iv) *Environmental change*—Finally, plausible changes in mortality and fecundity in response to environmental variability, including ongoing climate variability and global change (Johnston *et al.*, 2005; Hammill and Stenson, 2008b; Friedlaender *et al.*, in press), should be agreed and included in robustness trials.

Once objectives and robustness trials have been agreed, it would be possible to develop one or more candidate catch limit algorithms and to test their performance. Results could be compared with the performance of both the RMP and the PBR, appropriately tuned to achieve Canada's objective of an 80% probability of maintaining population numbers above N_{70}. Winship (2009) provides an example of tuning the RMP and the PBR to equivalent objectives, to allow comparison of the performance of the two procedures. He concluded that, where adequate time-series of data were available, the RMP generally performed better.

The population model used by Hammill and Stenson (2008a) makes use of the relatively long time-series of pup surveys to generate estimates of current population size. The RMP catch limit algorithm also involves fitting a population model to a time-series of total abundance estimates. Other studies have demonstrated that management procedures utilizing observational data directly perform better than those that rely on estimates of parameters derived from data by some process outside the management procedure (Cooke, 1995; Milner-Gulland *et al.*, 2001). Those studies indicate the potential for developing a procedure using the time-series of pup counts directly, which would likely perform better than generating a single, model-based, estimate of current total population that is subsequently input to a procedure such as the PBR.

We suggest the performance of any new procedure needs to be judged against the RMP tuned to meet the stated conservation objectives for Canada's commercial harp seal hunt, according to the criteria used by the IWC Scientific Committee for changes to the RMP. These are that "an amended procedure that allowed higher catches or lower catch limit variability will only be considered an improvement if it performs adequately on all risk-related performance statistics and better than the current version of the RMP on at least some catch- or risk-related performance statistics" (IWC, 1994b).

Concluding remarks

Over the past 6 years (2003–2008) Canada's commercial harp seal hunt has landed 1 782 560 animals, almost all (97.7%) recently weaned pups (ICES, 2008), with updated figures from DFO for 2005 (DFO, pers. comm. 2 December 2005) and 2008 (DFO, pers. comm. 16 October 2008; tabulated in Fink, 2009). Hammill and Stenson (2007) acknowledge the need for simulation trials of the management approach, but suggest that there is no need to wait for these. In contrast, we suggest that simulation trials are an urgent requirement and that catches more than replacement yield (Lavigne, 2009) without a fully specified and rigorously tested management strategy risk repeating the historical overexploitation experienced by many populations of marine mammals, including harp seals (Lavigne, 2009). A step towards reducing this risk using an approach that has been shown to be precautionary would be to limit catches to within the PBR, as suggested by Johnston *et al.* (2000) and currently applied by the ICES Working Group on Harp and Hooded Seals to data-poor populations (ICES, 2006). This could be implemented immediately but, as noted above, it is likely that a specific procedure using the full time-series of data would give better performance against management objectives if they were specified fully.

Whether the published management plan will be implemented as currently described remains to be seen. In the run-up to the announcement of the TAC for 2009, government scientists advised that "To respect the management objective [outlined in the management plan] the TAC must be set at 270 000 animals or lower" (Hammill and Stenson, 2008/2009). In announcing that the 2009 TAC was 280 000 (Fisheries and Oceans Canada, 2009), the Minister of Fisheries and Oceans exercised a level of discretion that would not be permitted in a management procedure approach.

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