Advisory Committee on Fishery Management ICES CM 2003/ACFM:13

REPORT OF THE

WORKSHOP TO DEVELOP IMPROVED METHODS FOR PROVIDING HARP AND HOODED SEAL HARVEST ADVICE

JOINT ICES/NAFO WORKING GROUP ON HARP AND HOODED SEALS

Woods Hole, MA, USA
11-13 February 2003

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1 WGHARP BACKGROUND

1.1 History of the WGHarp (WP1 – Haug)

Since the establishment of a working group to deal with issues related to the management and harvest of harp and hooded seals in the North Atlantic within the ICES framework in 1984, there has been an improvement in the availability of necessary assessment data. From an initial situation, where almost no relevant data were available for some of the stocks in question, the present state of the art is that at least some assessment data (certainly with variable quality) are available for all stocks. During the work of the group, now named the Joint ICES/NAFO Working Group on Harp and Hooded Seals (WGHarp), it has been recognized that as more information became available on the various stocks there would be an increased need to standardize a suite of population models that could most effectively accommodate the range and type of data collected (ICES 1998, 1999). To accomplish this, WGHarp proposed to sponsor a workshop on the modelling of pinniped populations, with a specific focus on North Atlantic harp and hooded seal populations (ICES 2001a). A subgroup was designated to work by correspondence to develop and carry out the workshop during the winter of 2001-02. The result is ”A Workshop to Develop Improved Methods for Providing Harp and Hooded Seal Harvest Advice”, to be held in Woods Hole, MA, USA, 11-13 February 2003.

The history of WGHarp, the working group that spawned this workshop, is not particularly long (1984 to present). Nevertheless, the group has been, and still is, important in the management of harp and hooded seals in the North Atlantic. The group started with a restricted geographical mandate but expanded to included all harp and hooded seal populations in the north Atlantic. Major topics were to assess status of the populations, provide advice on sustainable harvest levels, and to assess interactions with prey (i.e. ecological role of seals). Terms of references (TORs) given to WGHarp are based on requests for information and advice related to management of the seal stocks, as provided to ICES or NAFO by commissions (e.g., NAMMCO) or member governments. Formulation of the TORs is the responsibility of the ICES Advisory Committee on Fisheries Management (ACFM) and the NAFO Scientific Council (NAFO SC). After meetings, WGHarp reports the results of its deliberations to ACFM and NAFO SC. Subsequently, ACFM and NAFO SC provides the advice requested for the northwestern and northeastern stocks, respectively.

At present, WGHARP include 21 appointed members from Canada, Denmark (Faroe Islands and Greenland), Germany, Iceland, Norway, Russia, UK and USA.

1.2 Goals/Terms of Reference of the Workshop (Stenson)

WGHarp in evaluating its history of providing advice on harp and hooded seal harvests in the North Atlantic felt the need to re-evaluate its approaches to harvest modeling for the two species. That is the purpose of this workshop with a specific need to:

- Review methods used to assess population status and provide management advice
- Explore alternative methods used to assess marine mammal status and provide management advice
- Provide advice on model formulations that could be used under different levels of data availability
- Explore available reference points and determine applicability to harp and hooded
- Provide advice on applicability of these models and reference points to other pinniped species
- Consider 1) density dependent vs. non-density dependent models, 2) differing management goals, 3) differing legal structures

A clear specification of the management goals will be necessary before appropriate advice can be given. These goals may be different in the four harvesting nations (i.e., Canada, Greenland/Denmark, Norway, Russia). Originally the goal was simply sustainability, which was defined as the level of harvest that will keep the population at current levels. Other objectives are now emerging, such as short-term harvests that are above “sustainable” level. Final resolution not possible in this workshop but through a continuing dialogue with ACFM.

2 BACKGROUND ON MODELING OF HARP AND HOODED SEAL HARVESTS

2.1 Review of the species managed and the basic data available (Stenson)

Harp Seals - There are four putative stocks of harp seals in the North Atlantic (Figure 1) including – White Sea/Barents Sea, Greenland Sea (aka, West Ice), Northwest Atlantic Front (near Newfoundland) and the Northwest Atlantic Gulf (Gulf of St. Lawrence). All four stocks appear genetically distinct, with the Northeast stocks more closely related to each other than to the Northwest stocks, and visa versa.

Data availability and quality for harp seals varies substantially between stocks, with much more known about the Northwest Atlantic stocks (Table 1). Their population assessments are based on a combination of estimates of pup production (mark recapture, aerial survey), reproductive rates (ovulation, late-term pregnancy), and catch at age (0 vs. 1+). Late term pregnancy rates may be a better indicator of fecundity than ovulation. Less data are available for Northeast Atlantic stocks (e.g., no late-term pregnancy data).

Catch data also varies between stocks. Data from the Northwest stocks (Gulf and Front) are available for a long time series and includes some age structure information. These data are obtained from logbooks, some dockside monitoring, and comparisons of catch data and sales numbers. Canadian harvests switched from large to small vessel in 1982, and have resulted in somewhat questionable numbers. Little is known about the catch in the Canadian Arctic. Harvests in the Greenland and Barents Seas all come from large vessels and there is generally more confidence in these harvest numbers. There are several decades of harvest data available to harps in the Greenland, Barents, and White Seas. Takes of these stocks have likely been well below sustainable levels, due largely to a poor market for pelts and subsidies.

The bulk of the harvest (90+%) has been pups or young-of-the-year in recent years.

<u>Hooded Seals</u> – There are two stocks of hooded seals (Figure 2) – Northwest Atlantic (Gulf, Front, Davis Strait) and Northeast Atlantic (Greenland Sea). All of the Northwest groups moult east of Greenland, but all pup and mate at other locations. Hooded seals are considered to be one stock but there is insufficient genetic information to evaluate this assumption.

Less is known about the population dynamics of hooded seals (Table 2) than harp seals, and more is known about the Northwest stock than the Northeast. In the Northwest, a short time series of pup production numbers is available from aerial surveys, with data on reproductive rates available from the whelping patches. Some limited data on age structure is also available from catches. There is little data on pup production and no data on reproductive rates for the Northeast stock.

There is virtually no Canadian harvest; that is, there is no harvest in the Gulf, with catches at the Front amounting to only 30-40 animals/year. The harvest off Greenland (the NW Atlantic moulting patch) is usually around 6-10,000/year. There is no way to know if the take is proportionate between the Davis, Gulf and Front groups. However, takes in last 20yrs have been well below sustainable levels (driven primarily by market, and subsidy). Again, there are several decades of harvest data available for hooded seals in the Greenland Sea where takes have likely been below sustainable levels due to a poor market. Recent catches have mainly been pups.

2.2 Review of the basic WGHarp modeling to date (WP2 - Skaug)

The first of the WGHarp assessment models for the Northeast Atlantic harp and hooded seal stocks was developed in the early 1990s by Ulltang (e.g., Ulltang 1989). This was based on an equilibrium approach with age structure dynamics. A new model was developed by Oien and Skaug for the 2000 meeting of WGHarp (ICES 2001a). This model was still based on an equilibrium approach, but used two stages (pups, nonpups), attempted to estimate all parameters, and calculated uncertainty in projections. Now we have a third generation of models. Skaug and Oien (2003) estimated the population size of White Sea/Barents Sea harp seals to have been between 3.5 million and 5.5 million individuals in the year 1875, when exploitation by Norwegian and Russian hunters started. In deriving this interval they consider three different mechanisms for density regulation in an age-structured population dynamics model, and studied their impact on the estimated population size. They fit the model to a synthesis of all available information about the population using the principle of maximum likelihood. Together with estimates of current and historical population size they obtained estimates of mortality and fecundity rates.

In this first application of the new model form, it was applied to the Barents Sea harp seal stock using historical catch data (back to 1875), pup production (White Sea data 1998, 2000), age data from catches and breeding grounds, and estimates of the mean age at maturity (MAM). The reproduction ogive was then estimated from mean age at maturity and the age of reproductive senescence. All parameters are estimated simultaneously from the same dataset.

Points for discussion raised about the modeling included:
- Resolution of age structure in model
- Age at senescence needs to be addressed better
- How to set parameters in the model; a) guesstimates, b) estimates (requires strong assumptions)
- Uncertainty in predictions; a) uncertainty in current status, b) stochasticity in the model
- The K assumption and the approach to incorporating density dependence need further testing

2.3 Review of the DFO harp seal model (WP3 - Stenson)

Pup production and population size of Northwest Atlantic harp seals *(Pagophilus groenlandicus)* for the period 1960 to 2000 were estimated using independent survey estimates of pup production, annual estimates of pregnancy rates, and age-structured removals.

- Pup production was estimated from aerial surveys, and corrected for time of birth and compatibility of readers.
- Pregnancy rate data are sporadic; therefore annual pregnancy rates were estimated from late-term sampling data using kernel smoothing, a non-parametric regression procedure. Earlier had used sequential chi square to fill in gaps in data
- Removals were estimated from included reported catch, estimated bycatch, and assumed levels of seals killed but not landed (struck and lost). Reported catches are available from the Front and Gulf, the Canadian Arctic (very small), and from Greenland (~100,000). Incidental catches are mostly in the lumpfish fishery (10-15,000 animals per year). Struck and lost seals were estimated as 5% of pups in Front and Gulf, and 10-15% of adults in Front and Gulf and all seals in Arctic and Greenland (highly variable. Adjusted removals now are around 500K animals per year.

Population dynamics were modeled with SAS using a three-parameter age structured model. The two parameters estimated in the model are the pup selection parameter (s) and unaccounted mortality (m). The impact of assuming that the mortality of young seals (age 0) was greater than that of seals one year of age and older was illustrated by using a fixed parameter (γ) as the ratio of age 0 mortality to age 1+ mortality). Assuming different values changed the estimates slightly, but differences were minimal. Uncertainty associated with the estimates was determined by randomly re-sampling from within the sampling error of the pup production and the prediction error of the pregnancy rates.

Harp seal numbers at age for 1960 to 2000 were estimated. Assuming the mortality of age class 0 seals is 3 times that of age 1+ animals, the total population was estimated to be approximately 5.2 million in 2000 (95% CI 4.6-5.8 million). The population was estimated to have increased from around 2 million in the early 1970s through 1996; since then population size appears to have remained relatively stable.

A second version of the DFO population models have been developed using EXCEL with and @RISK added in. Though essentially the same as the SAS model, this version has the advantage of being easier to modify for simulation. The @RISK model closely matches results from the SAS model (and is preferred because it is simpler)

Points for discussion raised about the DFO modeling included:

- Population model should include ages past 25
- Use the Northeast model with the Northwest (Canadian) data to compare the two
- Put all Canadian data into likelihood function

3 ALTERNATIVE APPROACHES

3.1 Review of marine mammal harvest modeling worldwide (Smith)

The development of approaches in fisheries modeling was described, including a range of models accounting for the effects of harvesting predator species. These included classical predator-prey relationship models, increased per capita resource availability models, and sigmoid population recovery models. Hjort's insight of equating per capita population growth to equilibrium catch levels (e.g. surplus production) was subsequently elaborated in a number of fisheries contexts, ranging from North Sea cod to Antarctic blue whales. The simplifications involved in Hjort's leap of faith included the effects of the changes in the harvested populations on their predators and competitors and the changes in the survivors of the harvest in terms of size, spatial distribution and sex. All of these factors have potentially substantial affects that belie the simplicity of equating population growth with equilibrium harvest. Notwithstanding the extensive use of the surplus production theory in fisheries management, the importance of treating it as a hypothesis rather that a fact was emphasized. Several approaches to testing it were outlined.

It was noted that management objectives and reference points do not arise naturally from the existing population models, leading to a requirement for defining management objectives external to the modeling enterprise. The types of data used in management contexts were outlined, as was the basic structure of what is termed catch control law management regimes. The necessity of having a suite of management objectives defined in a way that allows them to be quantified was noted, as was the need to be able to rank the relative importance of members of suites of objectives. Finally, in the control law approach, managers must be able to agree on the degree of risk that they are willing to take. Such a balancing among the necessarily conflicting management objectives is essential to defining an implementable management procedure.

3.2 IWC's Catch Limit Algorithm approach (Punt)

The International Whaling Commission (IWC)'s Revised Management Procedure (RMP) was developed by the Scientific Committee of the IWC based on extensive testing of candidate management procedures using Monte Carlo simulation. Five candidate management procedures were compared using performance statistics based on the management objectives identified by the decision makers (the International Whaling Commission). The RMP consists of standards for data collection and the set of rules that are used to convert the data into a catch limit. The Revised Management Scheme (RMS) for commercial whaling was developed to be applied generically and consists of the Catch Limit Algorithm (CLA), which determines a catch limit when stock structure is not uncertain, rules to handle stock structure uncertainty by spreading catch spatially, and rules regarding enforcement and observers (although the latter aspects have yet to be finalized). The CLA was tested using simulation trials that examined its robustness to a wide range of uncertainties. Case-specific trials are developed for each specific implementation to ensure robustness and to select rules related to dealing with stock structure uncertainty. To date such trials have been developed for the North Pacific, North Atlantic and Southern Hemisphere minke whales as well as the North Pacific Bryde's whales.

The approach to managing commercial whaling differs from that used to manage aboriginal subsistence whaling in that the latter is based on case-specific management procedures rather than a generic management procedure. This is because there are few aboriginal whaling operations and the management objectives are notably different for aboriginal and commercial whaling (e.g. satisfaction of need compared to obtaining the largest long-term continuing catch).

The management procedure approach adopted by the IWC and several other fisheries jurisdictions (in particular South Africa and Australia) has the advantages of encouraging the specification and quantification of management objectives, explicit consideration of various sources of uncertainty, and a long-term view of resource utilization. The key difficulties with the approach are the time to conduct the analyses and identify management objectives (often several years) as well as how to assess the plausibility of the alternative scenarios.

3.3 US Potential Biological Removal (PBR) approach (Smith)

The origins of the US Marine Mammal Protection act were traced from the initial ecosystem objectives through the initial reliance on estimating population status in terms of Maximum Net Productivity Levels (Palka 2002). The difficulties with implementing this criteria for many species due to lack of information on abundance and human removals (usually by-catch) resulted in the implementation of a less data demanding management criteria, termed Potential Biological Removals. The details of the management setting and the quantitative criteria underpinning it were described, focusing on the need for an interactive scheme that involves extensive review and interaction with fishermen.

The development of the quantitative management criterion, PBR, was described in terms of meeting management objectives for population status. This included a limited suite of simulation trials (in comparison with the International Whaling Commission's Catch Limit Algorithm) that were designed to meet the three management objectives. It was noted that this procedure was tailored to the particular management context in the US for marine mammal by-catch. As such, it accommodated the limitations of the available data for many species, including lack of information on stock structure, by allowing an order of magnitude of flexibility in definition of a key parameter in its central management criterion, PBR. The complex series of steps in implementing the PBR criterion can be seen in one sense as offsetting the potential risk of this flexibility; however, those steps and their administrative delays in themselves also pose some risk in cases where there is disagreement and conflicting points of view. As such, it was emphasized, PBR is unlikely to be a reliable management approach absent specific management objectives, and even with such objectives the development would have to be repeated. More generally, the PBR criterion should not be used for management in the absence of a broader context that addresses the weaknesses inherent in the limited data requirements.

3.4 Northern fur seal models (York)

Northern fur seals have been harvested from the Pribilof Islands by non-native peoples since their discovery by Gerasim Pribilof in 1786. Under Russian rule, early exploitation was unregulated until 1799 when the Russian American company took control of the fur seal herds. The harvests decreased, in spite of temporary protections, until the harvest of females was prohibited in 1834. Following that prohibition, the herd grew and was recovering when Russia sold Alaska to the United States in 1867.

In the first few years of US ownership, independent parties harvested about 250 000 fur seals. During 1870 - 1909, The US government had a series of leasing arrangements with private companies. The revenue from these arrangements paid for the purchase of Alaska in the first 10 years. The harvest on land was closely regulated, but pelagic sealing begun shortly after the US purchase of Alaska took at least 600,000 mostly adult females. By 1909, the herd was reduced to about 300,000 animals. In 1911, a treaty, the North Pacific Fur Seal Convention, was signed by the United

States, England (for Canada), Russia, and Japan. The United States and Russia agreed to share their harvests on land with Canada and Japan in exchange for a prohibition on pelagic sealing.

The Convention was abrogated by Japan in 1941 on the grounds that the Pribilof herd had grown too large and was damaging Japanese fisheries. Following World War II and the end of occupation of Japan by American forces, the Fur Seal Convention was renegotiated. Coincidentally, the United States decided to reduce its fur seal herd on the basis of a density dependent model (Anonymous 1955) which assumed that if the fur seal herd were reduced, density dependent responses of a decrease in the age at first reproduction and increases in pregnancy rates would occur, and that a similar sized harvest of sub-adult males would be available from a smaller population.

Consequently, the United States began a commercial harvest of northern fur seal females. From 1956-1968, approximately 300,000 females were harvested. As result of the female harvest, numbers of pups born on St. Paul Island decreased from about 450,000 in 1956 to about 250,000 in 1968. The predictions of an increase in reproductive rates and a decrease in the age at first reproduction did not materialize. In fact, the age at first reproduction increased beginning with the 1956 year-class, the first cohort born after the harvest commenced. Survival of pups during their first few months increased as the herd was reduced and but the survival of juveniles to age 3 yr did not change.

Pup production declined again from 1976 - 1983 at about 6% per year. Pup production was approximately stable during 1983 - 1996 and is currently declining at about 5% per year. The causes of the declines in the late 1970s or late 1990s are not known. Nor is it known the extent to which the commercial harvest of females during the 1950s and 1960s may have contributed to those declines.

4 BIOLOGICAL REFERENCE POINTS

4.1 Review of the ICES charge to adopt the use of biological reference points (WP4 - Haug)

Recognizing the need for a precautionary approach to management of seal populations, including selection of reference points, the following method for development of target and limit reference points for seal management was recommended by ACFM (ICES 2001b):

- Management agencies are requested to specify the goals for seal management (one of the major problems with biological reference points is that it is still unclear what the management goals are for seal populations)
- Risk assessment should be incorporated into the population models applied to seal stocks. The precise form of appropriate risk assessment methods remain to be determined, but will likely include the estimation of the probabilities of reaching threshold values or trends, in addition to estimating probability distributions of abundance
- Estimates of yield based on alternative biological reference points such as the IWC's CLA and the U.S. PBR approaches for comparison to results from the current models for NW Atlantic harp seals (replacement yield model) and NE Atlantic harp and hooded seals (long-term equilibrium model) should be prepared.

The present status of the NE Atlantic harp seal diet data precludes the establishment of multispecies biological reference points involving these stocks. Considering the importance of establishing such reference points, improvements of the database as well as exploratory model work should be encouraged. A possible aim could be to establish the rate of change of F_{msy} for consumed fish species as function of the rate of change of the catch control rule for seals near the F_{msy} point. Another possibility would be to use the lowest recorded population size from which the stock has recovered (N_{min}).

4.2 Canadian Response to biological reference points (WP5 – Stenson and Hammill)

One of the basic principles of the precautionary approach to which Canada has subscribed, is the need to account for the uncertainty associated with estimates and to develop a basis for taking action in cases with insufficient scientific understanding. Thus, protocols are needed for situations where considerable data are available (i.e. 'data rich') as well as for situations where the available data are limited ('data poor'). In order to determine sustainable levels of removals of seals, current estimates of fecundity, mortality and abundance are needed. If these data are available the species could be considered 'Data Rich'. In contrast, if they are not available the uncertainty associated with any management action will increase substantially. In these situations, the species should be considered 'Data Poor'.

Data rich species - Where sufficient harvest and population information for a species are available, we can identify reference points that can be used as guides for fisheries management. In most fisheries, reference points have been linked to estimates of biomass or fishing mortality. However, neither of these is routinely used when discussing marine mammal populations. Instead, estimates of total population size are used as indicators of the status of a population. Moreover, reference points based on direct observational information (e.g. pup production, reproductive rates or condition) may be more effective than those that rely on parameter estimates derived from these observations.

With this in mind it is suggested that a Conservation reference point be set based upon abundance, called $N_{Critical}$ and associated with this limit reference point will be two Precautionary reference points, which initially we will call N_{Buf1} and N_{Buf2}. These latter reference points identify 'buffer' population ranges within which different management control rules would apply. The first reference point would be N_{Buf1}. In situations where seals are abundant and are above N_{Buf1} managers could establish a target reference point based upon any number of considerations such as ecosystem impacts and/or socio-economic benefits. As long as the population remained above N_{Buf1} higher risk strategies for removing animals from the population (e.g. harvesting, incidental catch) could be adopted. These may include continuation of the current replacement yield strategy where there is a 50% chance that the population would decline (or increase) or, alternatively, managers could opt for a specific target population that is either lower or higher than the current level. For example, if harp seals were considered to be above N_{Buf1} then management considerations could include consideration of the impact of seal consumption on the recovery of Atlantic cod stocks and if seals were found to be impeding the recovery, they may decide to lower the population. On the other hand, harp seals off northeast Newfoundland are a food resource for polar bears. Reductions in the size of the harp seal population might impact polar bears. Because polar bears are culturally and economically important to First Nations peoples and are involved in provincial and international management agreements, changes in harp seal management objectives should take these issues into consideration. Similarly, management objectives could be based on economic returns to the industry. In addition to the conservation requirement to maintain a population above the N_{Buf1} level, management objectives will also have to address potential conflicts with other legal requirements such as Canada's Species at Risk Act (SARA) or other international agreements.

For populations falling between the range of N_{Buf1} and N_{Buf2} conservation concerns become a higher priority and the primary management strategy would be to return the population to a state above N_{Buf1} within a specified period of time (e.g. 10 years or less). Although harvesting and other human induced removals could continue, these strategies would adopt a higher probability (e.g. 80% versus 50% for replacement yield) that a population would increase or conversely a lower risk that the population would continue to decline (e.g. 20%). For populations below N_{Buf2}, conservation becomes a very high priority, such that substantial conservation measures are required. Harvest strategies should ensure that there is a very high (e.g. 95%) chance that the population will increase and reach N_{Buf1} within a specified time period. If a population is estimated to be below $N_{Critical}$, the population would be considered to be a conservation concern and that there is an unacceptable risk of serious or irreversible harm. Under this situation, all human induced mortality would be stopped.

The greatest difficulty is to determine the population levels at which the reference points should be set. A number of different approaches have been used previously including general models discussed within the Fisheries (ICES\NAFO) literature based on the principle of Maximum Sustainable Yield (MSY), an approach developed within the COSEWIC/IUCN framework, reference points identified under the US Marine Mammal Protection Act, and the Revised Management Plan of the International Whaling Commission (Table 3).

Data poor species - In the absence of information on current abundance, the uncertainty associated with the resource's status and the impact of a particular management action increases and more caution is required. One approach could be to 'discount' acceptable removals with increasing time since the last estimate. Another option that could be adopted if several abundance indices do exist, but are all > 5 years old, may be for the population to automatically fall to the next lower management category, with appropriate harvest control rules. After another five years, and in the absence of new data, the status of the stock could drop another level. For example, in the absence of recent estimates a population starting out with abundance estimates greater than N_{Buf1} would automatically drop into the next lower category between N_{Buf1} and N_{Buf2} and instead of a harvest strategy that involved higher-risk , the new rule would establish that human induced mortality must be limited to allow a greater probability (e.g. 80%) chance that the population will increase. After a further 5 years, in the absence of an updated abundance estimate, the population would fall below N_{Buf2} and harvesting levels would be established with a higher likelihood (e.g. 95%) that the population would increase. A third option may be to consider the species 'data poor' and apply the conservation rules applied to these species even for species for which we have historical but no current data.

5 MODEL DESIGN – DISCUSSION OF APPROACHES TO FURTHER DEVELOPMENT OF WGHARP MODELING

Several points were made prior to the detailed discussion of models:

- WGHarp should be careful about the management goals it pursues and not bias the science advice it provides
- Care should be taken not to base management on data collected from a different place than where it is going to be applied (e.g., the age-structure collected from pelagic fur seal harvests was not appropriate for use in managing seals on land)

- Density dependent responses are poorly understood, and the way it is incorporated into models could be problematic
- Over parameterization of the models is a concern. While addition of parameters to the model may improve the model fit, this may reduce the utility or reality of the model. Sensitivity testing need to be conducted to determine which parameters are meaningful.

5.1 Should there be one model or a model hierarchy?

No conclusion was reached as to whether one or more models should be used. The Northeast Atlantic (NEA) modeling framework was favored by some participants because it can consider many variables and thus provides a framework from which other models can be built. The variables can be modified to apply to different situations and different data availability. Its framework may be the *one model* that could be modified to accommodate the different data available for the different regions. The problem with this approach is that the amount of time and resources that are necessary to continually modify and fit the model to the data may exceed the time and resources available.

The strongest recommendation of the group is to test the NEA model using data from NW Atlantic harp seals (Canadian data). If the NW population is treated as data poor (this may require some modifications to the model), and the NEA model applied to the data, the results would provide an idea of the robustness of the underlying approach and whether it can be applied to both the NW and NE populations.

One of the major issues with the NEA model is the assumption of a historically constant K. It was suggested that this assumption be replaced with an exponential population increase (a much weaker assumption); this could improve the model.

The NEA model will allow maximum data use and thus be a good predictive model (i.e. productivity, survival rate, and population status). However, models based on imitating historical population and matching it to current population may not be the best forecasting models.

The next problem in establishing a single model is data availability. Data available for each population are so variable that it is currently impossible to have one model for all without serious modification. Effort needs to go into having the same data for each population, but this is very difficult due to limitations in data collection for each population.

Management objectives also need to be considered in formulating model(s). The following must be considered:
- How well can the models reflect outcomes of different harvest levels?
- How well can the models predict population outcomes of different management schemes?

The models need to clearly identify the outcomes of different management schemes and be able to identify key biological levels/reference points to be useful to successful management.

5.2 How should model testing/simulation be dealt with?

The main recommendation is to test the NEA model by running it using the NW (Canadian) data.

In generating new models, testing and simulation must be done to determine the robustness of the model. The following suggestions were made:
- Use simulated data (*Pagophilus electronicus*) to examine model behavior in a variety of situations
- Conduct sensitivity analyses of parameters (e.g., linearization around estimated parameter values) and test assumptions (e.g., year 1 survivorship which is always assumed constant in models)
- Assess usefulness of proxy data (e.g., life history data from another stock) vs. no data for a particular variable

Extensive testing has not yet been possible with the NEA model

5.3 How should density dependence be dealt with?

Density dependence is poorly understood, yet it is incorporated into both the NWA and NEA models. Because density dependent responses are unclear (e.g. response of the northern fur seal to harvesting), concerns with its inclusion in models were raised. The following points were raised:
- Sensitivity analysis testing of the model needs to be done to better understand how density dependence works in the model
- How density dependence is ascertained needs to be examined more closely
- Are the population’s density dependent? Should this be included in the model?

5.4 Should models be age-structured (e.g., age-aggregated versus desegregated models, especially where the age structure of the catch is highly skewed)?

The group agreed that age structure should be incorporated into the model if possible. Concerns about existing models were: 1) how representative is it of the reproductive portion of the population, 2) if sampling is truly random or if areas where seals are taken is representative of sorting by age class on the whelping grounds, and 3) the importance of the non-reproductive/senescent portion of the population in the age structure.

5.5 Are biological reference points relevant to seal harvest management?

Discussion began with a consideration of whether N[1]$_{MSY}$, N_{LIM} or an alternate was practical as biological reference points (BRP) for seals. The group quickly agreed that N_{MSY} was not, largely due to the lack of data on seal populations which would make this BRP very difficult to estimate. The group did agree than N_{LIM} was possible to consider and identified several options ($N_{LOSS,}$ N_{CRIT}). The group was concerned, whoever, that if N_{LIM} was set too low (e.g., N_{LOSS}) the population might not respond in a deterministic way, so N_{LIM} should be set well above N_{CRIT}. The Canadian N_{LIM} is N_{CRIT}, but based on the principles of precautionary management they want to keep seal numbers higher. This is the reason for their specification (Figure 3) N_{PA} of $N_{70\%}$ and $N_{BUF\ (50\%\ of\ K)}$ separately from $N_{CRIT(30\%\ of\ K).}$

One philosophical point here is that all BRP could be specified either with reference to N_{CRIT} or K. Then all that is necessary (assuming they can be defined) is to develop and implement a plan for managing the population at whatever levels with respect to N_{CRIT} or K that are decided. Using the K approach may be more a more successful (and more precautionary) approach than waiting until the population gets to the N_{CRIT} level. However, the difficulty of defining K and dealing with environmental change suggests that the group cannot give practical advice to ACFM about a reference point pegged to K. Thus, a surrogate of K is necessary, and the group suggested N_{MAX} = K.

Rules of thumb suggested by the group in defining the BRP's were:

- N_{LIM} is also not something that can be made generic, but is specific to species and ecosystem combinations.
- N_{LIM} is appropriate but you need buffers above it
- N_{LIM} can be defined in many ways: e.g. US ESA, IWC's 54%, fisheries B_{20} or B_{40} etc (many examples of different levels exist and WGHarp should consider laying them out as options to ACFM)

Perhaps most importantly the group suggested that strong management advice and controls to be associated with $N_{LIM.}$ Without invocation of controls once reference points are reached, it is useless to have the reference points.

6 RECOMMENDATIONS

6.1 Advice on Model Formulations – Comparison

a. Run NE model on NW Atlantic data
b. Run NE model against simple RY model using the NE data
c. Run NE model against Ulltang model (old WGHarp model) using the NE data

6.2 One model or more?

a. More than one model should be used (at least for now) with NW and NE models continuing to be used
b. Model form will depend upon data available, but should use as much data as possible
c. The NW model is for replacement yield while the NE is for sustainable yield. Only one yield should probably be used.

6.3 Advice on Model Formulations – Sensitivity Simulations

a. Run NE model starting in 20th Century (w/out K assumption)
b. Run NE model removing different parameters to see how removing data affects model output (which data is critical, how data poor can we be and still have an effective model)

[1] N (number) rather than B (biomass) was considered to be the appropriate metric for marine mammals, and could be defined as total number of seals, number of pups, or number of mature females. The group suggested number of pups would be the most useful as these data were usually available for harp and hooded seal stocks.

c. Evaluate sensitivity to input parameters – age at maturity and late-term pregnancy rates. Also, test the assumption that age samples from the breeding grounds are representative for mature female.

d. Evaluate how important a valid age structure is to the NE model. AND, if important, increase priority of collecting these data. **There was disagreement as to whether the existing age-structure data are representative of whelping females.**

e. Track survival rates for realism

f. Consider running simulations on both the real datasets and simulated datasets (*Pagophilus electronica*), and consider contacting Wade, Punt, Taylor or Barlow for advice

g. Density Dependence - If you have data, use it and don't specify density dependence separately. If you don't have data and you incorporate, test sensitivity (run with and without)

6.4 Suitability of IWC's RMP and MMPA's PBR as alternative model forms

a. The RMP and PBR approaches are based on different management objectives which probably would not satisfy the ICES/NAFO objectives

b. However, consider implementing the process and implementation frameworks as a potential model for the WGHarp

6.5 Management Models

a. Lack of advice now, but what will be asked for in the future may be different

b. WGHarp needs to further discuss the distinction between assessment and management models

6.6 Data Requirements

a. Primary data needs are pup production on regular intervals, reproductive rates, harvest, and age composition of the population and/or harvest.

b. Most of the data are of high priority for collection (Age composition may be an exception)

c. Existing models can get by with limited data but the full suite of data is ultimately needed. Also, there are differences in the data that are needed for modeling and management.

6.7 Biological Reference Point Recommendations

a. N_{LIM} can be defined, N_{MSY} probably not practical (though it can be defined in theory for seals), where N could be: total population, total pups born, or mature females

b. There are several options to defining N_{LIM} including N_{LOSS} as the lowest level at which pop has been seen and sustained recovery; DFO's $N_{CRIT(30\%);}$ IWC's 54% of K (number of mature females) as a protection level; USA's endangered classification under the ESA; and certain Fishery definitions like B_{20} to B_{40} (Australia, US)

c. Must set one or more B_{PA} between B_{REF} and B_{LIM}

d. It is critical to set and implement control rules which will be associated with N_{LIM} and N_{PA}

e. Biological reference points should index N_{MAX} not K

APPENDIX I

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APPENDIX II

FINAL AGENDA

February 11: Background

WGHarp Background

930-1000	Introduction (Haug/Merrick) - Welcome (John Boreman, NMFS NE Center, Science and Research Director) - History of the WGHarp - Goals/Terms of Reference of WGHarp - Reason for the workshop - Workshop goals-what we hope to achieve
1000-1030	Review of the species managed and the basic data available (Stenson)
1030-1100	Review of the basic WGHarp modeling to date (Skaug) - How the model is applied - Basic goals and design of the models - What the models do
1100-1115	Break
1115-1200	Review of the DFO harp seal model (Stenson)
1200-1230	Open discussion of morning presentations
1230-1330	Lunch

What the Rest of the World is Doing

1330-1500	Continue discussion of the WGHarp modeling effort in the context of other modeling efforts worldwide
1500-1515	Break
1515-1545	Review of marine mammal harvest modeling worldwide (Smith)
1545-1730	Relatively “simple” approaches to” harvest modeling” - Review of IWC's CLA approach (Punt) - Review of the US PBR approach (Smith)
1730	Break for the Day

February 12: Model Design

0900-0930	Northern fur seal models (York)
0930-1000	Review of the ICES charge to adopt the use of biological reference points (Haug; Stenson/Hammill)
1000-1200	Discussion of approaches to further development of WGHarp modeling - Should there be one model or a model hierarchy - What should the models look like - Model testing/simulation - Density dependence - Should models be age-structured (e.g., age-aggregated versus desegregated models, especially where the age structure of the catch is highly skewed) - How incorporate biological reference points
1200-1300	Lunch
1300-1700	Continue morning discussions
1700	Break for Day

February 13: Model Development and Next Steps

0900-1200	Discussions of Workshop Recommendations
1200	End Workshop

APPENDIX III
REFERENCES

I. Working Documents Presented at the Meeting

WP 1: Haug, T. 2003. WGHarp – A brief historical review. 6 pp.

WP 2: Skaug, H. J. and N θien. 2003. Historical population assessment when data are sparse: the case of the Barents Sea harp seals **(***Pagophilus groenlandicus*). 17 pp**.**

WP 3: Healey, B.P. and G. B. Stenson. 2003. Modelling the population dynamics of the Northwest Atlantic harp seal (*Pagophilus groenlandicus*). 40 pp.

WP 4: Haug, T. and S. Tjelmeland. 2003. On the use of biological reference points in management of harp and hooded seal populations. 8 pp.

WP 5: Hammill, M. O. and G. B. Stenson. 2003. Application of the precautionary approach and conservation reference points to the management of Atlantic seals: A discussion paper. 16 pp.

II. Other Background Documents

Anonymous. 1955. United States statement on estimates of maximum sustainable productivity for the Pribilof seal herd. Document No. 48. North Pacific fur seal conference, Washington, DC. 5p

ICES 1998. Report of the Joint ICES/NAFO Working Group on Harp and Hooded Seals, ICES Headquarters, 28 August-3 September 1997. ICES CM 1998 / Assess: 3: 35 pp.

ICES 1999. Report of the Joint ICES/NAFO Working Group on Harp and Hooded Seals, Tromsø, Norway, 29 September-2 October 1998. ICES CM 1999 / ACFM: 7: 33 pp.

ICES 2001a. Report of the Joint ICES/NAFO Working Group on Harp and Hooded Seals, ICES Headquarters, 2-6 October 2000. ICES CM 2001 / ACFM: 8: 40 pp.

ICES 2001b. Report of the ICES Advisory Committee on Fishery Management 2000. ICES Cooperative Research Report 242: 911 pp.

Palka, D. 2002. Incorporating uncertainty into marine mammal management. Amer.Fish. Soc. Symp. 27: 157-169.

Ulltang Ø. (1989) Simulations of development in stock size and pup production for Harp Seals in the Greenland Sea (" West Ice") 1946 – 1989. ICES working paper SEA-16.

Figure 1. Locations of North Atlantic harp seal stocks

Figure 2. Location of North Atlantic hooded seal stocks

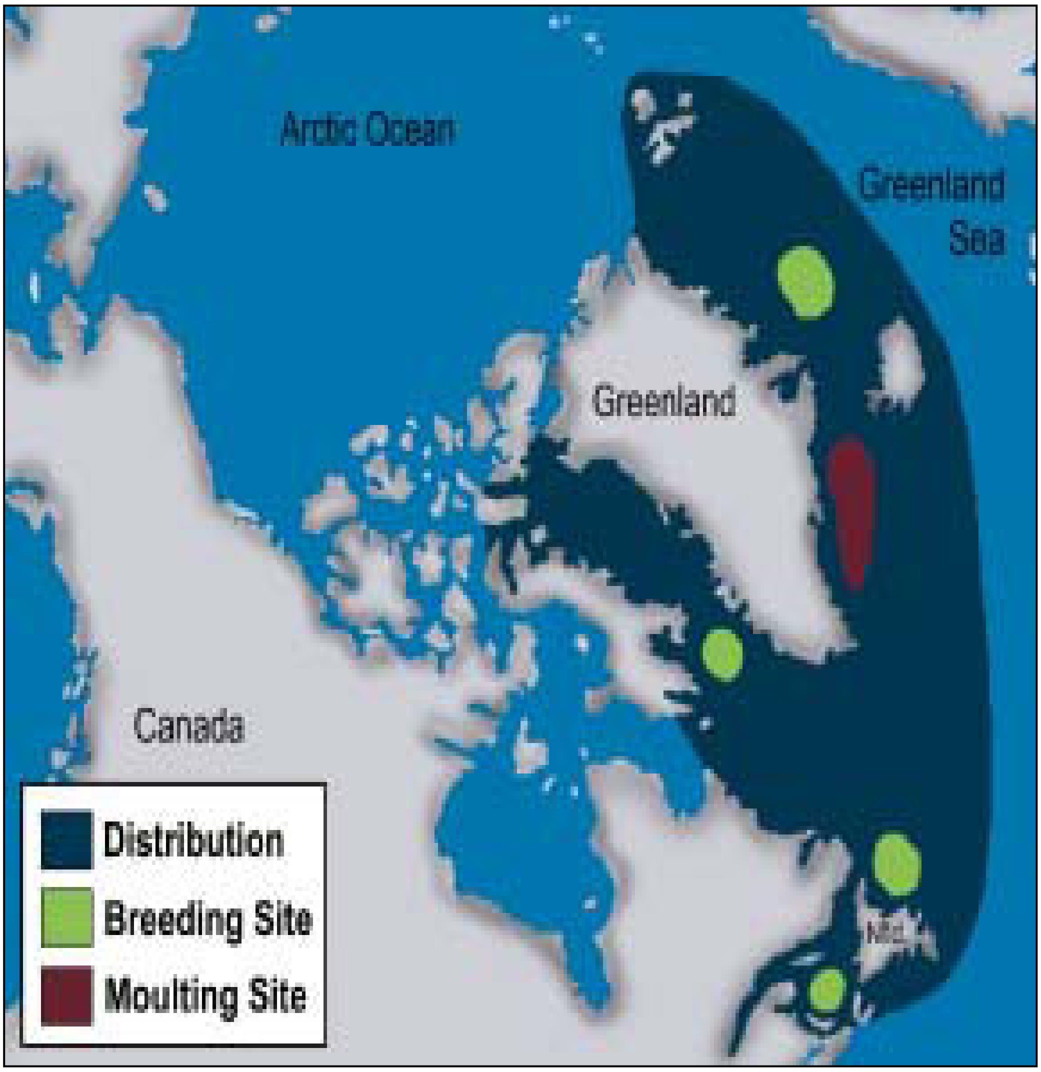

Figure 3. Potential biological reference points for a data rich seal stock (e.g., Northwest Atlantic harp seals)

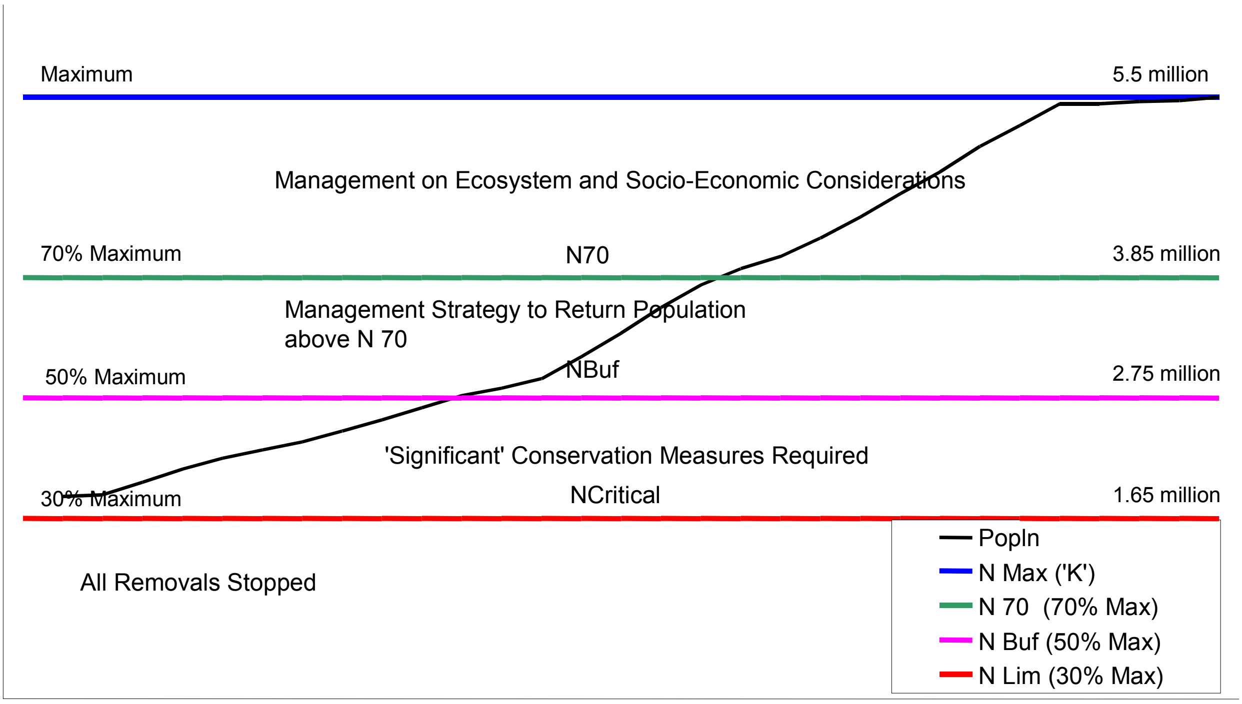

Table 1. Status of assessment data for North Atlantic harp seal stocks

Area	Pup Production		Reproductive data		Catch at age		
	M-R	Aerial survey	Ovulation	Late-term pregnancy	Subarea	Catch	Age
Northwest Atlantic	1978 1979 1980 1983	1990 1994 1999	1951-1954 1964-1970 1978-2003	1951-1954 1965-1970 1978-2003	Greenland Davis Strait Gulf Front	1954-2000 1978-1980 1952-2002 1800s + 1952-2002	Limited V. Limited 0 vs 1+ only Good
Greenland Sea - West Ice	1983- 1991	1991 2002	1959-1964 1978 1987 1990-1991		Norwegian Russian	1946-2002 1956-1994	0 vs 1+, good in some yrs 0 vs 1+
White Sea		1998 2000	1962-1972 1976-1985 1988-1993		Norwegian Russian	1946-2002 1946-2002	0 vs 1+, good some yrs

Table 2. Status of assessment data for North Atlantic hooded seals

Area	Pup Production			Reproductive data		Catch at age		
	Subarea	M-R	Aerial survey	Whelping	Moulting	Subarea	Catch	Age
Northwest Atlantic	Davis St Gulf Front		1984 1990,91 1984,90	1984 1979,83, 84,90	1982	Greenland Front	1954-2000 1952-2002	None 0 vs 1+ >0 is Limited
Northeast Atlantic	Greenland Sea		1997			Norwegian Russian	1946-2002 1956-1994	0 vs 1+ 0 vs 1+

Table 3. Precautionary reference points obtained the fisheries (NAFO/ICES) and endangered species (COSEWIC/IUCN) literature.

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