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EVALUATION OF A PROVISION TO CARRY-OVER UNUSED LICENCES FOR EASTERN CANADA-WEST GREENLAND BOWHEAD WHALES (*BALAENA MYSTICETUS*) IN CANADA

*Bowhead Whale (*Balaena mysticetus*). Photo credit Ricky Kilabuk taken Cumberland Sound 2020.*

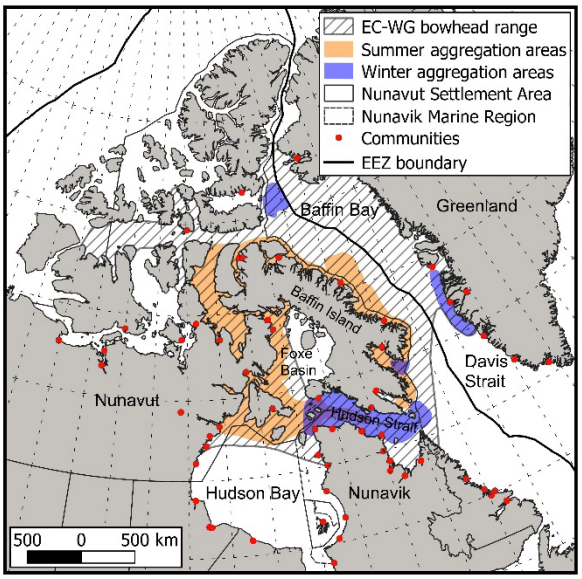

Figure 1. Location of summer and winter range of the Eastern Canada-West Greenland bowhead whale population (modified from Ferguson et al. 2021).

Context:

*Bowhead whales (*Balaena mysticetus*) from the Eastern Canada-West Greenland (EC-WG) population are hunted by Inuit in Canada (Nunavut, Nunavik) and Greenland. The co-management regime currently in place in Canada for EC-WG bowhead whales lacks a provision to carry-over unused bowhead strikes (attempts to kill the whale during a community hunt) to subsequent year(s). To address this, DFO Fisheries Management has requested Science Advice on the sustainability of implementing a carry-over provision for unused strikes of Inuit subsistence harvest of EC-WG bowhead whales in Nunavut and Nunavik. Similar carry-over provisions are authorized for subsistence harvests of EC-WG bowhead whales in West Greenland and Bering-Chukchi-Beaufort (B-C-B) bowhead whales in Alaska.*

Licence allocations for Canadian bowhead whale hunts have increased over time as better information on stock assessment became available. In 2007 and earlier there was one licence issued for all of Nunavut every 2–3 years, which increased to two whales per year for 2008 and 2009 and in 2009 the quota increased again, to three whales per year for 3 years (2010, 2011, 2012) until 2015, when the Nunavut quota increased to five per year (two for the Kivalliq and Qikiqtani regions, one for the Kitikmeot region). Not every licence has been used; for example, four licences were issued in 2019, and three in 2020. Inuit of Nunavik resumed their subsistence hunt for bowhead whales in 2008. In 2008, the Nunavik Marine Region Wildlife Board (NMRWB) established a Total Allowable Take (TAT) of one bowhead whale per year. In total, one whale was taken by Nunavik in 2008, 2009 and 2017. In

Canada, the EC-WG bowhead whale fishery is subject to provisions of the Nunavut Agreement (NA), the Nunavik Inuit Land Claims Agreement (NILCA), and the Fisheries Act and its supporting regulations. The current bowhead whale management approach in Canada restricts Inuit from carrying over unfilled annual EC-WG bowhead whale quota to subsequent harvest seasons.

DFO is committed to developing an evidence-based approach to assess potentially viable co-management measures including enabling carrying-forward of unused annual strikes while continuing to provide for the conservation and protection of the EC-WG bowhead whale population. This information is critical to determine the appropriate level of restriction of Inuit right to hunt bowhead whales pursuant to the Minister's obligation under NLCA s.5.3.3.(a) and NILCA 5.5.3(a). The requested information will be used to inform co-management discussions regarding the inclusion of a carry-over provision to the subsistence EC-WG bowhead whale fishery in Canada, including the possibility of a multi-year block allocation of the Total Allowable Take (TAT) instead of annual TAT harvest limitations.

*This Science Advisory Report is from the November 23, 2021 regional advisory meeting on the Evaluation of the Viability of a Provision to Carry Forward Unused Strikes of Eastern Canada-West Greenland Bowhead Whales (*Balaena mysticetus*). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.*

SUMMARY

- Eastern Canada-West Greenland (EC-WG) Bowhead whales (*Balaena mysticetus*) are sustainably harvested by Inuit in Canada at up to seven individuals per year, but the current bowhead whale management approach does not contain a provision for Inuit to carry-over unused strikes to subsequent years.
- A deterministic population model was used to evaluate whether a provision to carry-over unused strikes could be considered for bowhead co-management. To determine the sensitivity of the model to inputs, a range of parameters were used to assess uncertainty in the population dynamics.
- Model scenarios were simulated over a 40-year time period that examined the use of 5-year and 10-year allocation blocks with high licence totals (50 per five-year block, 100 per 10-year block). Various carry-over scenarios were used, including front-loading and back-loading of harvests, and an extreme case in which all licences could be carried over through the entire allocation period.
- The results, which were robust to various input parameters, indicate that any of the carry-over provisions that were assessed (over 5 or 10-year allocation blocks) would have little impact on the EC-WG bowhead population trajectory.
- The simulations investigated here do not account for increasing uncertainty related to the impacts on bowhead life history parameters resulting from environmental change (e.g., climate change) and increased anthropogenic activities (e.g., resource development, shipping). Regular population abundance estimates are needed to ensure sustainable harvest advice is consistent with Potential Biological Removal (PBR) assumptions.

INTRODUCTION

Bowhead whales (*Balaena mysticetus* L., 1758) of the Eastern Canada-West Greenland (EC-WG) population have been hunted by Inuit for millennia. The EC-WG bowhead population is distributed from the central Canadian Arctic Archipelago to the west coast of Greenland and whales travel extensively following the seasonal growth and ablation of sea ice (Figure 1). Significant commercial harvests, conducted by non-Inuit whalers for approximately four centuries, ended ca. 1915 due to economic extinction. A co-managed subsistence harvest from

this population has occurred irregularly in Canada and Greenland since 1996 and 2009, respectively. Since near extirpation from commercial whaling, population abundance has increased and the Inuit subsistence hunt now requires a harvest management framework that incorporates knowledge of abundance trends, population dynamics, and environmental relationships.

Support of authorized subsistence Inuit hunts for small numbers of EC-WG bowhead whales requires an evidence-based assessment of potentially viable co-management measures, including determining whether a less restrictive harvest limitation, that enables carrying over of unused annual strikes, can be implemented:

1. Is it sustainable to carry-over unused strikes (or some proportion of them) from one year to a subsequent year(s)?; and if so,
2. What are the probabilistic risks associated with the time interval within which unused strikes could be carried over before resetting the accumulation to 0?

The EC-WG bowhead whale population is considered to be in the “Cautious Zone” (between N_{30} and N_{50}) or “Healthy Zone” (> N_{50}) of DFO's Precautionary Approach framework (Ferguson et al. 2021), however this has not yet been Departmentally peer-reviewed at present. Various carry-over scenarios were considered with modelled trajectories, to determine whether the bowhead whale population would continue to grow towards carrying capacity. Here, the assessment used a deterministic logistic population growth model to address the request for science advice, an approach broadly similar to that used to assess the sustainability of carry-over provisions for beluga (*Delphinapterus leucas*), narwhal (*Monodon monoceros*) and Atlantic walrus (*Odobenus rosmarus rosmarus*) harvest management. The model scenarios are meant to support informed discussion with co-management partners and provide information to help the NWMB and NMRWB decision-making process.

METHODS

Population Model

The population model used for the assessment is a standard discrete time logistic growth model as used by the International Whaling Commission to project forward in time and incorporates: total population size, r_{max} as the intrinsic rate of population increase, carrying capacity, an exponent setting the maximum sustainable yield level (shaping parameter), the recorded catch in terms of numbers of whales, and a correction for whales killed and lost (or struck and lost that subsequently died from their injuries).

The model requires an estimate of the current population size. Several estimates for current (or recent) population size are available. The aerial survey conducted in August 2013, provided abundance estimates for EC-WG bowhead whales of 6,446 (95% CI: 3,838–10,827) (Doniol-Valcroze et al. 2020). Genetic capture-mark-recapture estimated EC-WG bowhead whale abundance for 2013 of 11,747 individuals (95% highest density interval 8,169–20,043) (Frasier et al. 2020). These estimates suggest a range for current population size of 5,000–12,500 animals.

EC-WG Modelling Approach

Preliminary modelling looked at the effects of full removals at Potential Biological Removal (PBR of 52 whales) levels compared with no harvests. Results from these preliminary models indicated that harvests of 52 whales per year were not appreciably different than the trajectory

with no harvests at the end of a 100-year time horizon and therefore, additional modelling of carry-over provisions used a 40-year time-frame to investigate shorter-term effects only.

The base models considered population trajectories under no harvest and 10 whales/year, which is higher than current harvest levels. Two licensing blocks were used for assessment of carry-over provisions, 5 years and 10 years, with total licences of 50 for 5-year blocks and 100 for 10-year blocks. Front-loaded and back-loaded scenarios were assessed, where all harvests occurred at either the first or last year of each block.

Two additional carry-over scenarios were modelled. The first used a 100% carry-over process with no temporal constraints. This is a cautious assessment as it does not limit carry-over allowances to a minimum number per year or limit the number of years that licences can be carried over. The second scenario considered a carry-over level of 50% which was additionally limited to single-year carry-over only.

Models used a starting population size of 10,000 whales and examined the same four carrying capacity values (12,500; 15,000; 17,500; 20,000) and similar initial simulations (no struck and lost correction, shaping parameter, and r_{max}). The models with carry-over provisions were run for 1,000 simulations and compared to the two base case trajectories of no harvests and a consistent harvest of 10 whales/year.

Model sensitivity was also investigated by using a range of starting population sizes, carrying capacity, r_{max} and shaping parameter estimates to inform scenario uncertainty.

ASSESSMENT

Initial deterministic models which explored 100-year population trajectories for different combinations of parameters resulted in a fully recovered population. These model results indicate that relatively high harvests are sustainable, as would be expected given the precautionary nature of the PBR calculation (Figure 2). The much lower removals under current harvest levels are therefore expected to have no major effect on population growth and recovery under any reasonable flexible quota scenario. However, additional modelling was conducted to explore this in greater detail under a shorter time frame of 40 years.

The models run for a 40-year timeframe showed that even extreme carry-over provisions allowing harvests of an unrealistically high number of whales (> 50 whales/year towards the end of a 10-year licence block) had no appreciable impact on EC-WG bowhead whale population growth (Table 1). Front-loaded and back-loaded harvests result in more chaotic annual changes in population growth trajectories but in all scenarios the population recovery is similar at the end of the 40-year scenario. No matter which extreme is considered, carry-over models did not result in population growth trajectories that vary significantly from a zero harvest model.

The model results presented (100-year and 40-year simulations) provide confidence that modest carry-over provisions for bowhead whale licenses are sustainable based on the parameter values employed. The model results were, however, highly dependent on these parameter values and therefore, a range of parameter values was used to help address uncertainty. Even the most conservative models, with a starting population size of 5,000 whales, showed positive population growth under realistic carry-over scenarios. For example, a model with 50% carry-over in a 10-year licensing block still allowed the population to grow from 5,000 to over 9,000 under the most conservative choice of model parameters.

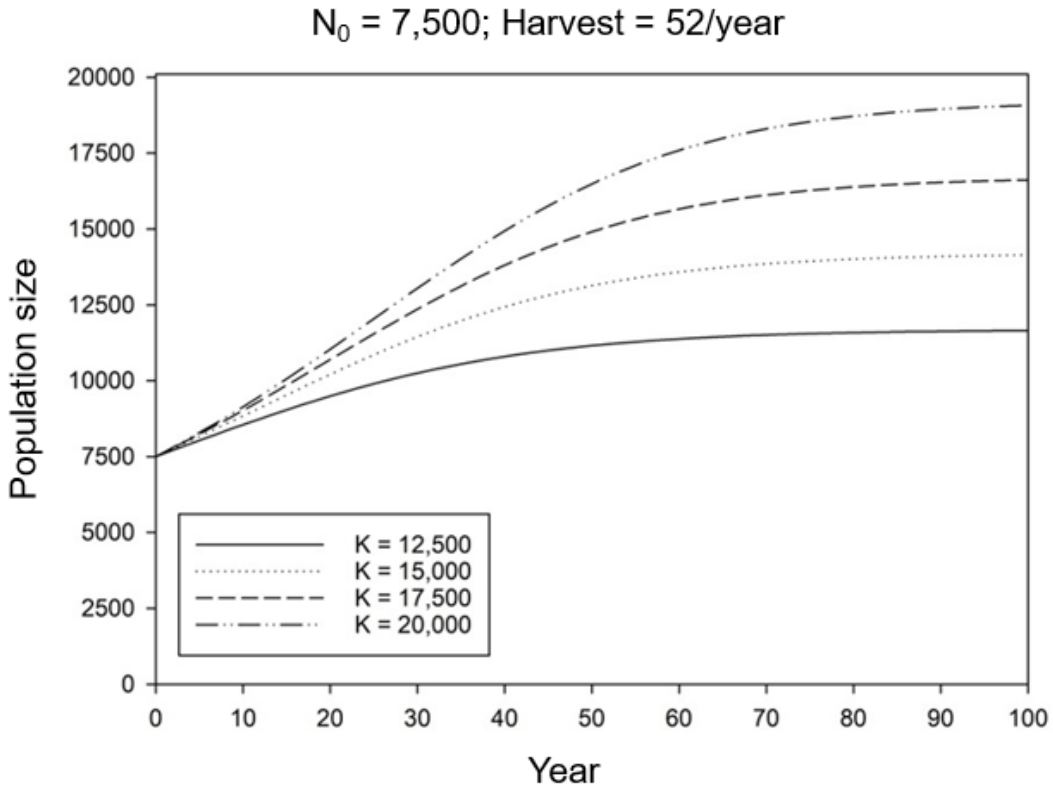

Figure 2. Results of 100-year simulations for EC-WG bowhead whales with annual harvests equal to Potential Biological Removal of 52 whales. Four different levels of carrying capacity (K) are shown.

Table 1. Population sizes after 40 years, comparing various base cases with unlimited carry-over and carry-over limited to five whales per year, with an annual reset, for five-year allocation blocks. All simulations used 10,000 whales as the starting population size and r_{max} = 0.04.

K	Final population size at N_{40}, with range for carry-over assessments (n = 1,000 simulations)					
	No harvest	10 whales/year	Front-loaded	Back-loaded	Unlimited carry-over	Limited carry-over (5/year)
12,500	12,432	12,321	12,340	12,300	12,335	12,355
15,000	14,807	14,687	14,705	14,667	14,701	14,725
17,500	17,109	16,977	16,994	16,958	16,996	17,018
20,000	19,325	19,178	19,193	19,160	19,195	19,227

Sources of Uncertainty

The above conclusions are based on models with important parameter assumptions. Although sensitivity of parameters was assessed and determined to be minimal, more research into bowhead whale population dynamics would assist with future analyses. For example, models assumed that sources of human-induced mortality other than hunting, such as vessel strikes, are negligible. Our understanding of bowhead abundance, trend and demographic rates, and the impact of climate change remains limited (e.g., most recent abundance estimate data were collected in 2013), and as such, research efforts to obtain the needed data to validate and update the model are required.

The models do not take into account the impact of rare natural mortality (i.e., stochastic events), such as unusually high killer whale predation, nor do they include environmental effects that might negatively impact birth and death processes in the population. Environmental impacts on birth and death processes are largely unknown but, should there be evidence of long-term negative effects, expanded population assessments would be needed.

CONCLUSIONS AND ADVICE

Modeled approaches indicate that the use of a flexible quota system is unlikely to have a negative impact on the bowhead whale population. A 10-year block for carrying over catches was assessed here, but this may be too long to provide management flexibility in the face of environmental change and the establishment of additional information on bowhead population status. While the details of any carry-over provision will need to be established with co-management partners, a 5-year block would maintain flexibility and more closely align with the management systems used in other jurisdictions (Alaska, Greenland) and the life-cycle for Integrated Fisheries Management Plans in Canada.

OTHER CONSIDERATIONS

The model scenarios used here also assume that West Greenland harvests do not appreciably increase over time, and close international cooperation on bowhead whale management is required (Ferguson et al. 2021).

As better information (e.g., updated abundance estimates, life-history parameters, impacts of killer whale predation or shipping-related morality rates, environmental carrying capacity) becomes available, models could be used to incorporate changes in demographic parameters and environmental relationships over time.

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SOURCES OF INFORMATION

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Doniol-Valcroze, T., Gosselin, J.-F., Pike, D.G., Lawson, J.W., Asselin, N.C., Hedges, K.J., and Ferguson, S.H. 2020. Distribution and Abundance of the Eastern Canada – West Greenland Bowhead Whale Population Based on the 2013 High Arctic Cetacean Survey. NAMMCO Scientific Publications, 11.

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