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Science Advisory Report 2021/001

HARVEST ALLOCATION MODELLING FOR BAFFIN BAY NARWHAL (*MONODON MONOCEROS*) STOCKS

*Narwhal (*Monodon monoceros*)*
by R. Phillips.

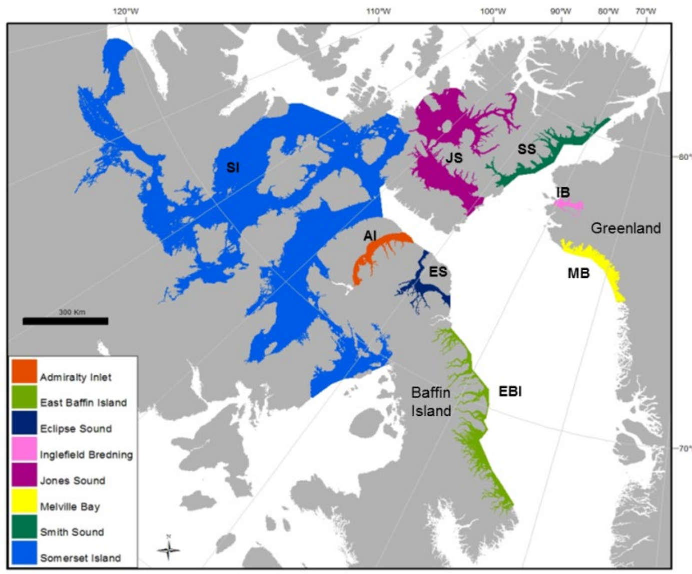

Figure 1. Map indicating the summering stocks of narwhals from the Baffin Bay population in Greenland and Canada.

Context:

*Narwhals (*Monodon monoceros*) are part of the subsistence harvest in Canada and Greenland. In Canada this harvest is currently managed using Total Allowable Landed Catch (TALC) advice from Fisheries and Oceans Canada (DFO) Science for each of the summering stocks of the Baffin Bay populations (Somerset Island, Admiralty Inlet, Eclipse Sound, East Baffin Island, Jones Sound and Smith Sound). These summering stocks, as well as the Inglefield Bredning and Melville Bay stocks from Greenland, may mix together during annual migrations in spring and fall, to and from their overwintering areas, and in the offshore in Baffin Bay and Davis Strait during the winter. The Canada/Greenland Joint Commission on the Management and Conservation of Narwhal and Beluga (JCNB) and the North Atlantic Marine Mammal Commission (NAMMCO), with the participation of DFO Science, has developed a two-step model (the stock exchange model and a population dynamics model) that combines expert opinion, harvest, tracking movement (satellite tagging), and abundance information since 1970 from both Greenland and Canada. The stock exchange model relates the number of narwhal in each stock to their availability to hunters in different hunting regions and seasons in order to allocate catches to the different stocks. The population dynamics model estimates abundance trajectories for the stocks, and incorporates uncertainty in a Bayesian framework to inform harvest allocation decisions for each narwhal stock. Resource managers have requested advice on using the JCNB model to support sustainable harvest recommendation allocations for Baffin Bay narwhal stocks in Canada.*

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SUMMARY

- Hunt management for Baffin Bay narwhal is based on summering stocks, but these stocks mix during migrations and in wintering areas, such that some stocks are harvested at multiple locations in both Canada and Greenland, and some locations harvest from multiple stocks.
- A two-step model was developed by the Canada/Greenland Joint Commission on the Management and Conservation of Narwhal and Beluga (JCNB) to allocate catches to different stocks (stock exchange model) and to analyze the impact of these catches on the dynamics of the eight narwhal stocks (population dynamics model). These models work together to define stock catch levels for all stocks. It is an improvement over previous models since it considers stocks shared between Canada and Greenland.
- The stock exchange model uses satellite telemetry data from Canada and Greenland, and expert opinion to determine the availability of narwhal stocks in the different hunting regions for each season.
- The population dynamics model combines available data on narwhal life-history, catches, and abundance from Greenland and Canada, but is limited by the available data for many stocks.
- The outputs of the population dynamics model for each stock should be evaluated using the precautionary approach framework developed for marine mammals in Canada.
- For stocks with sufficient input data, and where the population dynamics are captured by the model, the stock exchange and population dynamics models could be used to identify stock catch levels for Canadian communities based upon Canadian management objectives.
- If the level of stock knowledge is limited and the population dynamics not captured by the model, the Potential Biological Removal (PBR) for the stock should be estimated, and used with the stock exchange model to assign catches in relation to the availability of narwhals to the different hunting regions and seasons. This is consistent with the current approach for Data Poor species in Canada.
- We support continued development of this approach by JCNB with further consideration of how it can accommodate the Canadian Precautionary Approach Framework, particularly when the dynamics of a stock are not captured by the population dynamics model. Further sensitivity testing should also be conducted.

INTRODUCTION

Narwhals from the Baffin Bay population are part of the annual subsistence narwhal hunt and are hunted in communities throughout the year in northern Canada and West Greenland. Since narwhals are considered to return to the same fiords and inlets each summer, they have been divided into stocks based on their summering region. Narwhal hunts are managed based on the summering stocks, although these stocks overlap spatially during migration and on the wintering grounds. As a result some stocks are harvested at multiple locations in Canada and West Greenland, and some locations harvest from multiple stocks. By not considering hunting in multiple areas throughout the year this may pose a risk to some local narwhal stocks and therefore, a model which considers all hunting, in all seasons, across communities in Canada and West Greenland is needed.

The Canada/Greenland Joint Commission on the Management and Conservation of Narwhal and Beluga (JCNB) has developed an approach which considers mixing of stocks to ensure quotas are sustainable. The first component is the stock exchange model, which relates the number of narwhal in each stock to the availability of narwhals to hunters in hunting areas and seasons, and allocates catches to the different stocks. The second component is the population dynamics model, which analyzes the impacts of these catches on the stock dynamics of the eight narwhal stocks in Canada and Greenland.

ANALYSIS

The stock exchange model requires an availability matrix that estimates the portion of each stock that is available to hunters in different regions and seasons. Satellite telemetry data, phenology of occurrence and catches, and expert opinion are used to determine the proportional availability of each stock in the different hunting sites, for each season. This portion is then multiplied by the stock size to determine the number from that stock that are available to each hunt. The numbers from each stock are added together to determine the total number available at that location and the proportion of the hunt from each stock is the ratio of the number from that stock to the total. When there is uncertainty around the proportions of narwhals available to different regions, this uncertainty is quantified in the matrix using a mathematical description of the probability of these proportions (a probability distribution). The availability matrix can then be multiplied by the landed catches for different hunting regions to produce an estimate, with associated uncertainty, of the catches taken from the different stocks.

The population dynamics model produces abundance trajectories for each of the stocks. The model requires abundance estimates for each narwhal stock obtained from surveys, narwhal catches derived from the stock exchange model, and a number of inputs or assumptions. These include the upper bound on the carrying capacity for the stock, the adult yearly survival rate, the first year survival rate, the birth rate, the age of first reproduction, and the female fraction at birth for narwhals.

The population model run results in estimated trajectories for the eight summer stocks. The two models together provide total allowable landed catches for the different stocks with probabilities from 50% to 95% of meeting a given management objective. The associated probability that these takes, when projected into the future, will fulfil stock specific management objectives is also provided. There are 90% confidence limits around the probabilities of meeting management objectives to reflect uncertainty about which stocks are supplying a given hunt. Using the two models together it is also possible to test the probability of meeting stock specific management objectives when catches are allocated to different hunting regions.

Model Assessment

The stock exchange component of the model is an improvement over previous methods for catch allocation because it considers sharing of stocks between Canada and Greenland, and uses available telemetry data to estimate the availability of narwhals from different stocks to hunters in a given region. The model is also able to incorporate uncertainty in the allocations, and assign catches to the stocks with a given level of uncertainty.

The population dynamics model estimates the abundance trajectories for the different stocks based on uncertainty in the allocation of catches from the stock exchange model. The population model requires a number of inputs. Each stock has a different degree of information available (e.g., abundance estimates vary from 1–5 surveys), and the biological inputs for narwhals are largely unknown. As a result of this uncertainty, an evaluation of each individual stock within a precautionary framework should be conducted to determine if the population dynamics model used in this approach is an appropriate method for estimating abundance and assigning catches. If the stock has sufficient data, and the model captures the dynamics of the stock, the model could be considered for determining catch levels for the stock once management objectives have been defined. If, however, the stock has limited data (i.e., is considered 'Data Poor'), a PBR estimate should be used to determine the recommended catch levels for the stock in keeping with the Precautionary Approach Framework developed for marine mammals in Canada. The PBR can then be assigned to the different hunting areas through use of the stock exchange model.

Sources of Uncertainty

Satellite telemetry data are used to inform the stock exchange model. Four of the eight stocks (Smith Sound, Jones Sound, Inglefield Bredning, and East Baffin Island) have never had whales tagged. We know that these four stocks supply the summer hunts located in their respective regions, but it is unknown whether they are hunted in other communities in other seasons. In these cases, expert opinion was used to assign probabilities of whales encountering other hunting localities. For stocks where telemetry data are available, there are still relatively few narwhals tagged and we are inferring behaviour of the entire stock from these whales.

Not all stocks have sufficient data to determine population dynamics. In some cases there were few abundance estimates while some of the biological inputs for narwhals, such as the birth rate and age at first reproduction are uncertain. It is not clear if the uncertainty associated with these Data Poor stocks influence the results from data rich stocks.

A single struck and loss rate is currently applied to all Canadian catches, but rates specific to different communities and hunting types throughout the year for all hunting regions would improve the model output.

The model is currently set to assume a take of 50% females, but this may not be the case in all hunting regions and seasons. This may impact the catches estimated by the model.

There is uncertainty in the accuracy of historic catch records from 1970–1976 for Canadian narwhal stocks which will, in turn, impact the estimated population trajectories.

CONCLUSIONS

The JCNB approach is an improvement over previous methods since it takes into account the combination of information that Canada and Greenland have collected about the narwhal stocks. Together the two models integrate assessments of stocks that are shared by Canada and Greenland, with the composition of catches to provide an output of possible catch estimates assuming different probabilities of reaching the management objectives. However, because many of the narwhal stocks are considered to be Data Poor, the use of the current population dynamics model is not consistent with the precautionary approach framework used by Canada.

We encourage further development of the JCNB, including consideration of how differing management approaches and objectives from the two countries can be accommodated, particularly for stock where the population dynamics are not captured by the population dynamics model.

OTHER CONSIDERATIONS

The model can advise on catches on hunting grounds, but these catches may need to be further divided by communities that share the same hunting grounds.

The management objectives and the probability level of meeting these objectives needs to be defined since this can change the stock catches significantly.

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SOURCES OF INFORMATION

This Science Advisory Report is from the October 17–21, 2016 meeting on Baffin Bay Narwhal – Review of a harvest allocation model. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Watt, C.A., Witting, L., Marcoux, M., Doniol-Valcroze, T., Guldborg Hansen, R., Hobbs, R., Ferguson, S.H., and Heide-Jørgensen, M.P. 2019. Harvest allocation modelling for narwhal (*Monodon monoceros*) stocks shared between eastern Canada and West Greenland. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/031. iv + 27 p.

Witting, L. 2017. Meta population modelling of narwhals in East Canada and West Greenland. NAMMCO JCNB/SWG/2017-JWG. doi:10.1101/059691

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