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Central and Arctic Region

Canadian Science Advisory Secretariat
Science Advisory Report 2015/046

ABUNDANCE ESTIMATES OF NARWHAL STOCKS IN THE CANADIAN HIGH ARCTIC IN 2013

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

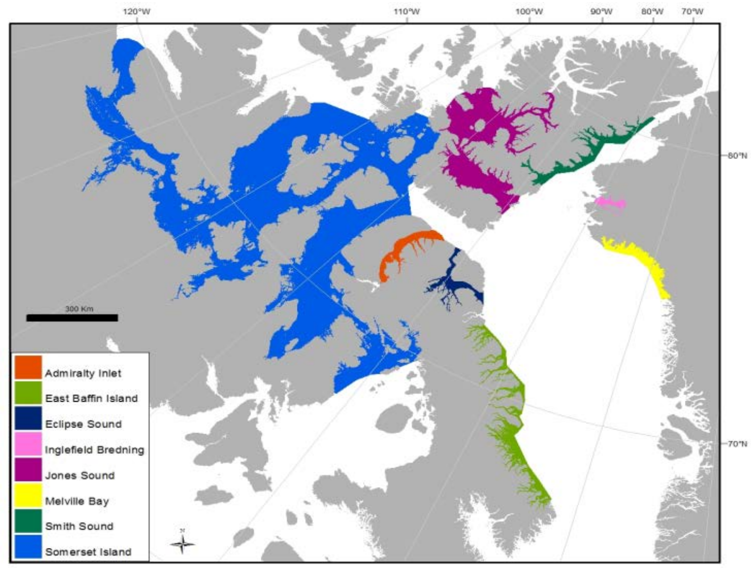

Figure 1. Map of the six Canadian narwhal summer aggregations as well as two aggregations in Greenland recognized as part of the Baffin Bay population by the Canada-Greenland Joint Commission on Conservation and Management of Narwhal and Beluga (source: NAMMCO/SC/21-JCNB/SWG/14-05).

Context:

In August 2013, a series of aerial surveys were conducted for the four recognized Canadian stocks of the Baffin Bay narwhal population as well as the putative Jones Sound and Smith Sound stocks. For the first time, abundance estimates for all of these stocks were made in the same year.

The Nunavut Wildlife Management Board (NWMB) establishes Total Allowable Harvest levels for narwhals in the Nunavut Settlement Area. Fisheries and Oceans Canada (DFO), in close collaboration with co-management partners, has implemented an Integrated Fisheries Management Plan for narwhals. DFO Ecosystems and Fisheries Management Sector asked for advice on sustainable harvest based on the 2013 surveys for the Nunavut narwhal summering stocks. This science advisory report presents information on the updated abundance estimates and advice on sustainable narwhal harvest based on the Potential Biological Removal method.

This Science Advisory Report is from the October 20-24, 2014 annual meeting of the National Marine Mammal Peer Review Committee (NMMPRC). Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

SUMMARY

- An aerial survey was conducted for six narwhal summering aggregations (hereafter referred to as stocks) in the Canadian High Arctic in August 2013. This is the first time that a survey counted all of the Canadian High Arctic narwhal stocks during one summer, and the first time for narwhals in Jones Sound and Smith Sound. The total estimate for the Canadian High Arctic was 141,909 (Coefficient of Variation, CV by stock ranged from 20 to 65%) narwhals.
- This survey combined two abundance estimation methods that were summed to produce an estimate of total abundance:
  1) spatial modelling was used to estimate densities in narrow fiords; and
  2) mark-recapture distance sampling was used to estimate narwhal density from line transects elsewhere.
- Total abundance estimates include a correction for perception bias (caused by observers missing narwhals present at the surface) estimated from duplicated sightings between the primary (front) and secondary (rear) observers.
- Abundance estimates were also corrected for availability bias (to account for the fraction of time diving whales are visible near the surface) computed from the percentage of time satellite-tagged narwhals spent within 2 meters of the surface (or 1 meter in fiords with murky waters). The correction for availability bias was 2.94 (and 4.53 in fiords of East Baffin Island).
- Stock specific abundances rounded to 500 were 12,500 for Jones Sound, 16,000 for Smith Sound, 50,000 for Somerset Island, 35,000 for Admiralty Inlet, 10,500 for Eclipse Sound, and 17,500 for East Baffin Island for a total of 142,000 narwhal in the Canadian High Arctic.
- Assuming fidelity of narwhals to six specific summering stocks and based on the abundances estimated in 2013, the Total Allowable Landed Catch (TALC) advice for the six summering stocks are 76 for Jones Sound, 77 for Smith Sound, 658 for Somerset Island, 389 for Admiralty Inlet, 134 for Eclipse Sound, and 206 for East Baffin Island for a total of 1,540 narwhals per year. If narwhals from the Eclipse Sound and Admiralty Inlet areas are considered as belonging to a single unit, the TALCs cannot simply be summed. The TALC advice for a combined unit would be 542 narwhals.
- Allocation of the catch to communities should be done in a way that accounts for the seasonal hunts of mixed stocks.

INTRODUCTION

In Canada, the Baffin Bay narwhal population is currently managed as four summering stocks, each represented by a different geographic aggregation, i.e., Somerset Island (SI), Admiralty Inlet (AI), Eclipse Sound (ES) and East Baffin Island (EB). A number of narwhal aerial surveys were conducted by DFO in the eastern Canadian Arctic from 1975 to 2011 to estimate the abundance of different stocks within the Baffin Bay population (DFO 2012, Doniol-Valcroze et al. 2015a). Most of the previous abundance estimates were known to be incomplete. Narwhals are also known to occur elsewhere in the Canadian High Arctic during summer (e.g., Parry Islands, Cambridge Bay), but no narwhal surveys have been conducted in these areas. In 2013, two narwhal aggregations provisionally identified as Jones Sound and Smith Sound stocks were surveyed. No previous survey has counted all of the known High Arctic narwhal stocks during one summer.

Narwhals summering in the Eastern Canadian Arctic are designated as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and are a priority fishery for DFO. Narwhal are listed on Appendix II of the Convention on International Trade in Endangered Species (CITES), and a non-detrimental finding (NDF) decision from the DFO Scientific Authority is required to obtain a CITES Export/Re-export permit to export narwhal products internationally. Harvested narwhals from Canadian management units are considered ineligible for international trade if the harvest exceeds the Total Allowable Landed Catch (TALC) recommendation for a population. Under CITES requirements, updated science and a documented management approach are required to confirm sustainable narwhal management to allow for international trade.

This Canadian Science Advisory Secretariat (CSAS) Science Advisory Report provides updated scientific advice regarding TALC levels for each of the Baffin Bay narwhal stocks, and for narwhals in Smith and Jones Sounds.

ANALYSIS

Survey methods

The survey was designed to cover the six known summering stocks of narwhal (Figure 1) in the Canadian High Arctic simultaneously (Doniol-Valcroze et al. 2015b). Narwhal are thought to exhibit strong site fidelity to their summering grounds. However, recent evidence suggests that limited mixing between summering areas does occur (Dietz et al. 2001, Heide-Jørgensen et al. 2002, Watt et al. 2012). Thus, the survey covered all six areas within one month using three aircraft to avoid double counting. Priority was given to Jones Sound, Smith Sound and Somerset Island areas because no previous surveys had been done in Jones Sound and Smith Sound in August and the Somerset Island abundance estimate was 17 years old.

Each stock range was divided into several strata (Figure 2), based on geographic boundaries as well as expected densities of narwhals inferred from past surveys. When such information was not available, traditional Inuit knowledge and/or observations from a reconnaissance survey flown in 2012 were used to determine survey strata. Survey transects were regularly spaced and oriented in a direction perpendicular to the longest axis of the stratum (Figure 2). A combination of parallel line transects and zig-zag transects was used to survey small areas with expected high narwhal densities (parallel lines) and large areas with expected low densities (zig zag). An effort was made to survey each stratum within 1-2 days.

Narwhals tend to aggregate in deep fiords when the ice melts in the summer (Dietz et al. 2001). Because most fiords are narrow, have complex shape and can be steep-walled, they cannot be surveyed using line transect methods and thus, standard distance sampling estimation methods cannot be applied. Therefore, separate survey and analytical methods were developed for the fiord strata (Doniol-Valcroze et al. 2015a) with each fiord considered a primary sampling unit and abundance estimated for each separately.

The survey was designed as a double-platform experiment with independent observation platforms at the front (primary) and rear (secondary) of the survey aircraft. Each of the three survey aircraft was assigned a team of four observers, and each observer was assigned a specific bubble window for the duration of the survey. The two observers stationed on the same side of the aircraft were visually and acoustically isolated to ensure independence of their detections. Each of the three survey teams included a trained Inuit observer, and when surveys were conducted close to a community, participation of a local hunter was encouraged. Overall, Inuit groups were intimately involved with survey planning and design.

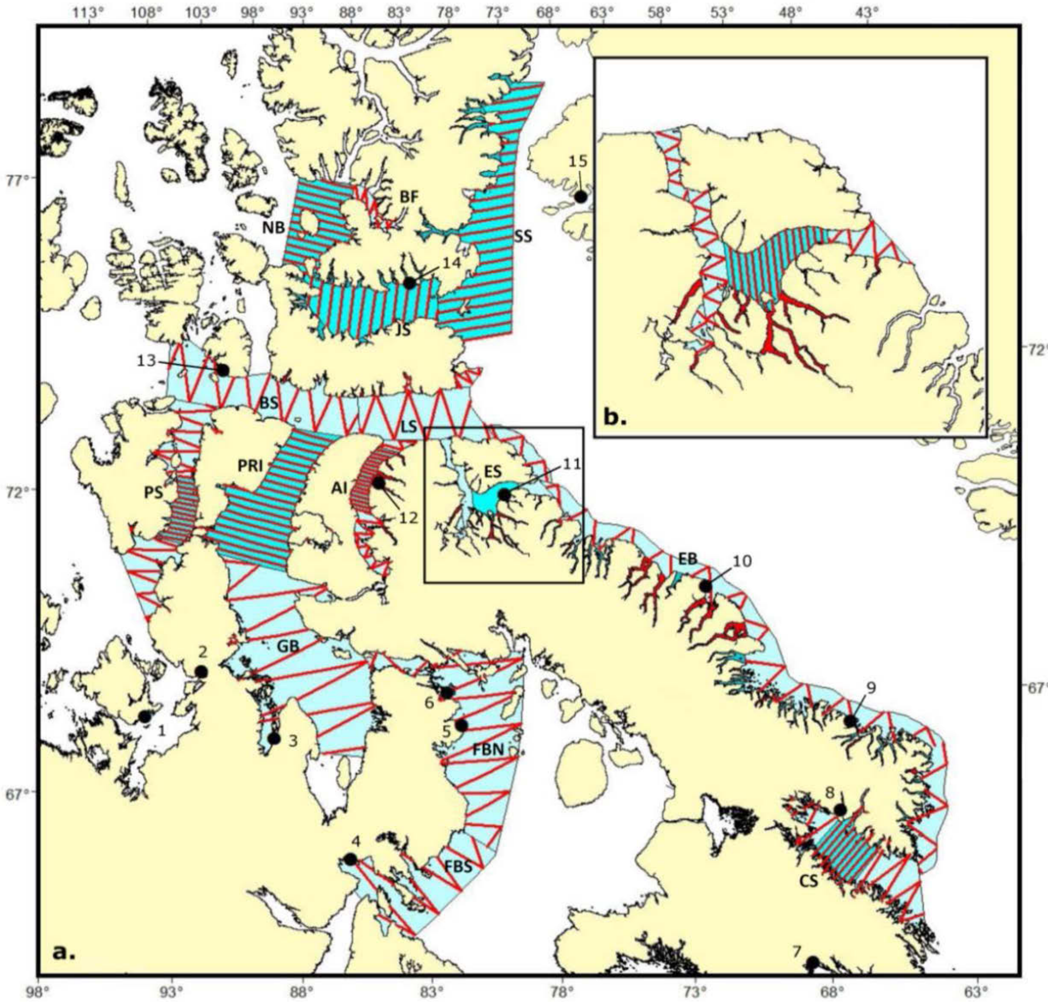

Figure 2. a.) Map of planned survey strata (blue polygons), transect lines (red lines), and fiord strata (red areas). AI: Admiralty Inlet. BF: Baumann Fiord. BS: Barrow Strait. CS: Cumberland Sound. EB: East Baffin Island. ES: Eclipse Sound. FBN: Foxe Basin North. FBS: Foxe Basin South. GB: Gulf of Boothia. JS: Jones Sound. LS: Lancaster Sound. NB: Norwegian Bay. PRI: Prince Regent Inlet. PS: Peel Sound. SS: Smith Sound. Communities (black dots): 1. Gjoa Haven; 2.Taloyoak; 3. Kugaaruk; 4. Repulse Bay; 5. Hall Beach; 6. Igloolik; 7. Iqaluit; 8. Pangnirtung; 9. Qikiqtarjuaq; 10. Clyde River; 11. Pond Inlet; 12. Arctic Bay; 13. Resolute; 14. Grise Fiord; 15. Qaanaaq (Greenland). b.) inset : zoom of the Eclipse Sound stratum (boxed area).

Observers recorded sightings on a hand-held recorder indicating the time at which a group of narwhal was first seen and the time at which the group was abeam of the aircraft. Additional information was recorded with the following priority:

1) number of narwhals in a group (defined as two or more narwhals within one or a few body lengths of each other and oriented in the same direction),
2) perpendicular distance to sighting; and
3) other variables (direction of movement, presence of young, number of tusks).

The position and altitude of the aircraft was recorded every 2 seconds.

Statistical analysis

Distance sampling methods were used to estimate the density of narwhals within the surveyed area. These methods assume that the probability of detecting a narwhal is a function of the distance from the track line. However, observers can miss narwhals present at the surface. Thus, a perception bias must be estimated (Marsh and Sinclair 1989). A mark-recapture method on duplicated sightings by two observers on the same side of an aircraft was used to estimate the perception bias (Laake and Borchers 2004). The identification of duplicate sightings is not obvious and a novel data-driven approach was developed to sort single and duplicate sightings made during the 2013 survey (Pike and Doniol-Valcroze 2015). While most previous studies used ad-hoc methods and arbitrary threshold for this task, the method used in this study was based on four weighted covariates.

A detection function was computed using perpendicular distance of all sightings (duplicates were removed) in all strata. Akaike Information Criteria were used to select the best-fitting detection function (Buckland et al. 2001) and associated environmental covariates (Marques et al. 2007) including ice cover, cloud cover, sea state and glare.

For the fiord strata, density and abundance were estimated using spatial modeling (Doniol-Valcroze et al. 2015a). The number of narwhals seen in surveyed segments of each fiord was modeled using Generalized Additive Models. The variables included in the models were distance from shore and distance from the mouth of the fiord. The best model for each fiord was selected based on maximum likelihood and used to predict the abundance of narwhals across the entire fiord. Density estimates were computed by dividing predicted abundance by the total area of the fiord. Total abundance for all fiord strata was computed by averaging the densities of all fiords weighted by their respective area, and multiplying it by the total area of all fiords in a given stratum.

Narwhals that were not at the surface of the water at the time of the survey could not be seen by observers causing an availability bias (Marsh and Sinclair 1989). Thus, the number of narwhals counted in the survey must be corrected for availability. Experiments with model narwhals showed that they could be detected on planes when they were within 2 m of the surface (Richard et al. 1994). However, in some fiords with murky waters, we assumed narwhal could only be detected down to 1 m. Based on data from 24 narwhals fitted with satellite tags near the communities of Arctic Bay and Pond Inlet every August from 2009 to 2013, narwhals spend 31.4 ± 1.1% of their time within 2 m of the surface, and 20.4 ± 0.8% within 1 m (Watt et al. 2015).

The Potential Biological Removal (PBR) method (Wade 1998), corrected to include hunting losses (i.e., animals that are struck and lost), was used to calculate the recommended TALC:

$$TALC = \frac{PBR}{LRC}$$

where,

$$PBR = 0.5 \times R_{max} \times N_{min} \times F_r$$

The hunting loss rate correction (LRC) was equal to 1.28 (Standard Error, SE=0.15, Richard 2008). R_{max} , the maximum rate of increase for the stock, was set to 0.04 (the default value for cetacean when unknown, Wade 1998). N_{min} is the 20th percentile of the log-normal distribution of N. The recovery factor for the population (F_r) was set at 0.5 for the Jones Sound and Smith Sound stocks (to account for uncertainty in stock structure and narwhal movements), and at 1.0 for the other stocks (value suggested for large populations).

Results

The timing of the ice break-up in the northern parts of the survey range during the summer of 2013 affected the timing and coverage of portions of the survey areas. Nevertheless, all stocks were completely surveyed with the exception of Smith Sound. The global average group size was 2.76 (CV 3.8%), and stratum-wide mean group sizes ranged from 1 to 3.08. Figure 3 shows the location of the individual sightings of narwhal groups. The estimated abundances for each stock are given in Table 1. The total corrected estimate for the Canadian High Arctic narwhal population was 141,909 narwhals (including 7,038 narwhals estimated in fiords). The weighted correction factor used was equal to 2.94 (CV 3.4%). This value, based on the recommended instantaneous correction factor of 3.18, is for survey strata occurring in clear waters (Watt et al. 2015) and was weighted for an average observer search time of 4.3 seconds. From these abundance estimates, the combined TALC for the Baffin Bay population was 1,540 narwhals. TALC for each summering stock is given in Table 2.

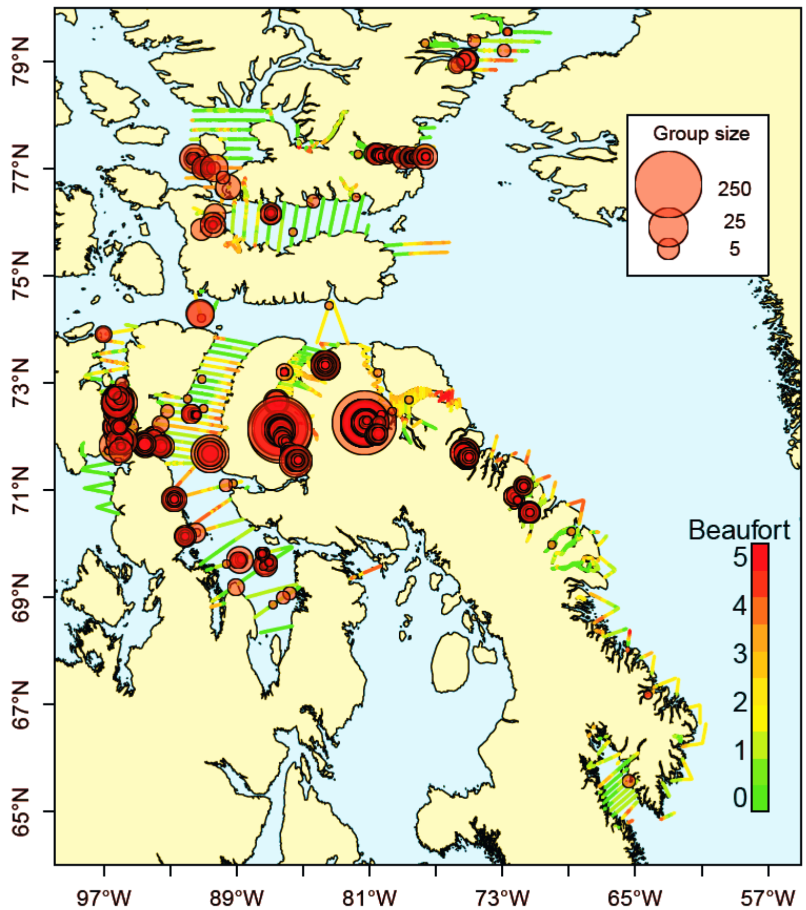

Figure 3. Unique sightings of narwhal groups made during the 2013 High Arctic Cetacean Survey (red circles). Lines represent transects flown with color scale showing Beaufort conditions.

Table 1. Area surveyed, survey coverage, narwhal sightings (surface abundance), and corrected abundance estimates by summer stock. The weighted correction factor used was 2.94 (CV 3.4%), except in East Baffin Island fiords where it was 4.53 (CV 3.8%).

Stock / Stratum	Area (km^2)	Percentage surveyed	Surface abundance	Abundance (corrected)	CV
Jones Sound	35,357	13%	4,316	12,694	0.33
Smith Sound	40,669	4%	5,563	16,360	0.65
Somerset Island	115,309	9%	16,921	49,768	0.20
Admiralty Inlet	9,419	26%	11,915	35,043	0.42
Eclipse Sound	8,459	26%	3,566	10,489	0.24
East Baffin Island	53,510	8%	3,799	17,555	0.35
Combined AI+ES	17,878	26%	15,481	45,532	0.33

Table 2. Total allowable landed catch (TALC) for the six Canadian summer stocks of narwhals in the Canadian High Arctic. The recovery factor (Fr) was set at 0.5 for the Jones Sound and Smith Sound stocks to account for uncertainty in stock structure and narwhal movements. Fr of 1.0 was set for the other stocks as suggested for large populations with additional stock assessment information.

Summer Stock	N_{min}	TALC
Jones Sound (/Fr=0.5)	9,714	76
Smith Sound (/Fr=0.5)	9,897	77
Somerset Island	42,081	658
Admiralty Inlet	24,895	389
Eclipse Sound	8,564	134
East Baffin Island	13,214	206
TOTAL	108,365	1,540
Combined AI + ES	34,716	542

Sources of Uncertainty

- An accurate abundance estimate of a population requires that the entire distribution range must be surveyed (Buckland et al. 2001). The summering range of narwhals in Smith and Jones Sounds is currently not well understood. For the Somerset Island stock, we chose not to survey the extreme western and southern parts of their distribution. We assumed these areas are used following ice melt in the core areas of Peel Sound and Prince Regent Inlet. Narwhals also occupy areas where they are not hunted and outside of the survey area (e.g., Parry Channel region). However, we assume they occur at low densities and would not impact community TALC.
- Narwhal sightings were extremely clustered in Eclipse Sound and Admiralty Inlet which increased uncertainty around the estimate (CVs) and could introduce bias.
- Although a pooled TALC is provided for AI and ES, connectivity between these stocks remains a source of uncertainty. There have been no new analyses to confirm new stock

structure. Future research is required to assess connectivity between the two stocks and is particularly relevant given the industrial activity and increased shipping occurring in the region.

- For the Jones Sound stock, relatively large numbers of narwhals were found in Norwegian Bay. Only a few narwhals were seen in the Jones Sound stratum itself, which is where most of the hunting takes place due to proximity to the community of Grise Fiord.
- Smith Sound could not be surveyed completely because of unfavorable weather conditions. The density estimate is based on relatively few lines in the northern part of the stratum, and therefore it cannot be extrapolated to the entire stratum. Instead, the density estimate was extrapolated to the area of the survey effort only. This resulted in an estimate that is more precise, but should be considered a minimum estimate of narwhal abundance in Smith Sound. We anticipate that this stock will be further sub-divided once more information is available on movements. The relationship between Smith Sound narwhals, the four recognized Baffin Bay stocks and the Inglefield Bredning stock in Greenland is unclear.
- The proportion of sightings made by both front and rear observers was relatively low during this survey, resulting in a low detection probability and a large precision bias correction. Surveys with low detection probability result in higher abundance estimates than surveys with high detection probability. Because the number of duplicate sightings between observers was relatively low the estimates from this survey might have been inflated.

CONCLUSIONS

This survey provided current abundance estimates for four Baffin Bay narwhal stocks in Canadian waters that improved their precision and resulted in new PBR estimates for each stock. Also, the first summer abundance estimates have been calculated for narwhals in the Smith Sound and Jones Sound areas. Concurrent, long-term telemetry studies of diving behaviour were critical to obtaining estimates of availability bias. Abundance estimates also were improved by implementing new analysis techniques to address specific challenges associated with narwhal use of fiords.

SOURCES OF INFORMATION

This Science Advisory Report is from the October 20-24, 2014 annual meeting of the National Marine Mammal Peer-Review Committee (NMMPRC). Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

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