NAMMCO

Report of the

NAMMCO-JCNB
Joint Scientific Working Group
on Narwhal and Beluga

8-11 March 2017
Copenhagen, Denmark

This report contains the views of the Working Group, and does not necessarily represent the view of the NAMMCO Scientific Committee and/or the Council, which will review the report at the next meeting.

EXECUTIVE SUMMARY

A Joint Meeting of the NAMMCO Scientific Committee Working Group on the Population Status of Narwhal and Beluga in the North Atlantic and the Canada/Greenland Joint Commission on Conservation and Management of Narwhal and Beluga Scientific Working Group was held in Copenhagen, Denmark, during 8-11 March 2015. The group reviewed new information on the biology of narwhals and belugas, and updated the assessments and catch advice based on new information. To accommodate some invited participants and for the efficiency of the meeting the JWG decided to discuss narwhals and belugas together for some topics, and that organization is reflected in the meeting report and this summary.

Life History Parameters

The JWG reviewed new and updated information on life history parameters for belugas and narwhals.

Belugas

The JWG reviewed the summary table of life history parameters for belugas in Hobbs et al (2015). These discussions informed the JWG's decisions made on the values to be used in the population modelling (see Item 2.3).

Narwhals

The JWG reviewed available life history parameters for narwhal. These discussions reviewed recent advances in age estimation and results from samples collected from hunted animals that were informed by these age estimates.

The JWG noted that beluga and narwhal racemization rates for aspartic acid in the eye lens appear to be different, and the cause of this is unknown. However, the narwhal results from two different labs using two different methods were similar, lending confidence that these reflect the accurate ages.

The JWG **agreed** to use the life history information to inform the priors and the age structure for the model input.

Review of the population models

The JWG reviewed the priors used in past assessment models and discussed whether to use uniform priors or fit alternative distributions (e.g., beta, gamma) that represented our current understanding of the distributions for these priors. The JWG identified four priors that should be updated: 1) adult survival rate (p), 2) first year survival rate ($p0$), 3) birth rate (b), and 4) age at maturity (a_m) or first reproduction.

The JWG changed the prior distributions on adult survival (p), the maximum birth rate (b), and the age of the first reproductive event (a_m). In earlier analyses, uniform distributions had been used for the prior distributions of p and a_m, these were changed to symmetric hump-formed beta distributions (a=b=2) that allocated more weight of the centre of the distributions, with the assumed minimum and maximum values of the two parameters being 0.95 and 0.995 for adult survival for both beluga and narwhal, and 6 and 14 years for a_m in beluga, and 7 and 15 years for a_m in narwhal.

The prior on the birth rate was then changed to a single value instead of a distribution in order to reduce the number of parameters to be estimated by the model. This value was set to 0.31 for beluga in West Greenland in accordance with the observed pregnancy rate Heide-Jørgensen and Teilmann (1994), and it was set to 0.33 for all narwhal populations to reflect a three-year calving interval.

Belugas

Stock structure
The JWG were informed of a large biogeographical study of belugas using whole-genome sequencing to elucidate the genetic differentiation among geographic regions and stocks.

The JWG encouraged this work, especially to help 1) identify an individual animal to a stock, 2) delineate between stocks, and possibly 3) provide a basis to identify genetic changes in response to climate change, noting that for this type of analysis, gene expression would be used, but would require samples collected to preserve RNA which is logistically challenging for most field conditions.

Hunt removals

Canada
Ferguson presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/12 that included the catch statistics from select Nunavut communities for the past five years (2011-2015; Table 1, Appendix 4). Catch reporting for the 2016-2017 harvest year was incomplete. The JWG discussed variation and uncertainty in the catch statistics.

The JWG noted that the catches have not been corrected for struck and lost. The JWG **recommended** that these catches be corrected for struck and lost.

There is uncertainty around whether the catches from Kugluktuk are from the Beaufort Sea or Somerset stock. The JWG decided not to include the catches from Kugluktuk in the modelling. The JWG also noted that catches from Kugluktuk were not included in the Beaufort Sea stock assessment. The JWG **recommended** that genetic analysis should be conducted on the catches from this area to clarify the stock identity of these catches.

There is some interannual variability in the catches from Igloolik, and it is uncertain whether these catches are from the Somerset Island stock. Canada informed the JWG that explained that seasonality of the hunt explained some allocations and that samples for genetics have been collected and the lab work has been completed, but the results have not been analysed. The JWG **recommended** that the analysis of the existing genetic results be completed.

The JWG **recommended** conducting a genetic comparison between Cumberland Sound belugas to the old West Greenland stock, using samples from the Danish Natural History Museum. If genetics indicate a linkage, the JWG further recommended a modelling exercise of these two stocks using historic population size and including catches from the old WG stock from pre-1930.

Greenland
Garde presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/06 (See Tables 2 and 3, Appendix 4). Catches declined during 1979-2016 to levels below 300 whales per year after 2004 (except

for 2013 where a catch of 304 whales were reported). All catches are assumed to be taken from the Somerset Island summering stock of belugas and all the catches in West Greenland are presumably taken from the fraction of that stock that winters in West Greenland. The exception is the winter catches in Qaanaaq (approx. 5% of annual catches in Qaanaaq) that likely are taken from the fraction that winter in the North Water. It is unknown which stock is supplying the summer hunt in Qaaanaq (approx. 15% of annual catches in Qaanaaq). A few confirmed catches (and sightings) of belugas have been recently been reported from East Greenland.

The JWG noted that the catches in Qaanaaq are variable. The JWG has previously recommended that summer catches in this area be prohibited due to the lack of knowledge on the stock identity of these catches. Small numbers of catches in the summer continue to occur. Genetic analysis of catches from Qaanaaq would be informative, however the JWG recognizes that sample collection is logistically challenging from all catches in West Greenland.

The JWG **accepted** these catch numbers for use in the assessments. The JWG further noted that the recent catches are below the quota. This is likely because with the recent ice conditions, as belugas have been observed (during aerial surveys) further from the coast, and are therefore it has become more difficult for the hunters in small boats to access the belugas. Additionally, a new cod fishery may be taking away some incentive to take marine mammals, although the price for maktak remains high in Greenland.

Recommendations

The JWG **recommended** genetic analysis for stock identity of the summer takes in Greenland.

The JWG reiterated its past **recommendation** that more accurate, and recent, struck and lost data is needed. Struck and lost is likely different for hunting method, season, etc., and the JWG recognizes that it is difficult to collect data on loss rates. However, knowing struck and lost rates is more important in areas where the quotas are small, and these hunts could be prioritised for data collection.

Abundance
No new abundance data was available to the meeting. Canada presented a database of abundance and trends of Canadian Arctic beluga whale and narwhal stocks for long-term monitoring and sustainable harvest management. The database contained 34 records for beluga whale surveys conducted between 1965 and 2015, and 22 records for narwhal surveys conducted between 1975 and 2013. The database is complete to 2015. The database can be updated as future surveys are completed and analysed. This type of database is currently planned for in Greenland, and the JWG **agreed** that it would be helpful for Greenland and Canada to cooperate on creating a consistent database.

Allocation of shared stocks
Belugas taken in West Greenland are believed to be from the Somerset Island stock.

Stock assessments and management advice

<u>Canada</u>
The subsistence harvest of Pangnirtung, Nunavut, is directed towards a single stock of belugas in Cumberland Sound, which forms a separate stock among belugas in the Canadian Eastern Arctic. A population model incorporating harvest statistics (1920–2015) was fitted to four

aerial survey estimates using Bayesian methods, resulting in a current estimated population of 1,000 (rounded to the nearest 100) animals. The management objective is to achieve a population of 5,000 animals by 2091. This could be expressed as an interim target of 1,235 animals within a decade (2026). At current reported harvest levels of 41 animals, the probability of the population declining over a 10-year period is 1. The probability that the population would increase to the interim target was 0.3, 0.25 and 0.1 for reported harvests of 0, 6, and 25 animals respectively.

This paper provides an example of the type of modelling that Canada is conducting. This is for information for the JWG, in case this stock would be included in the future for management advice. The JWG **recommended** genetics analysis for stock identity.

The JWG noted that the were more conservative than the potential biological removal (PBR) calculations with a 0.5 recovery factor, and if the results presented in this paper correctly represented the population, the PBR was not sufficiently conservative to recover the stock.

Another survey is planned for this area during summer 2017.

West Greenland Assessment

An updated assessment for West Greenland beluga with new catch data and the new priors as agreed by the JWG. The model estimated a decline from 21,180 individuals in 1970 to a minimum of 8,470 in 2004, and it projects an increase to an expected 11,610 individuals in 2023 (assuming post 2016 catches of 225). These results are similar to those of the last assessment, and the JWG **agreed** to re-iterate the previous advice, which remains valid until 2021.

Traditional Knowledge

The Government of Nunavut’s Department of Environment completed a Nunavut Coastal Resource Inventory (NCRI) in Pond Inlet in 2016. Local Inuit knowledge, both spatial and anecdotal, collected on narwhal and beluga in this area may be relevant for the JWG and will be compiled and presented for the next meeting.

Narwhal

Stock Structure

The JWG reviewed papers on narwhal biology, including studies on updated life history parameters of narwhals from Greenland and Canada, effect of ice entrapments on the Eclipse Sound narwhal stock, assessment of the winter range of Baffin Bay narwhals, long-term tag retention on narwhals, identification of seasonal foraging areas by examining the spatial distribution of dive data from Canadian populations and the comparison of migration patterns, diving behavior, site fidelity, travel speed, size of wintering grounds of satellite tracked narwhals from East and West Greenland.

Information in these papers were not used to update the assessment and advice at this meeting, but they contribute to the overall knowledge of narwhal biology.

The JWG were informed of a large biogeographical study using whole-genome sequencing to elucidate the genetic differentiation among geographic regions and stocks. A SNP-array (single

nucleotide polymorphism) could be developed for the Baffin Bay region as a tool for the joint management of narwhals.
The JWG were informed on the science review of the environmental impact statement addendum for the Baffinland Mary River project.

Catch Statistics and Struck and Lost
Information on catch statistics and struck and lost was presented from both Greenland and Canada.

Greenland presented a time series that provides realistic catch levels from West Greenland during 1862-2016, which was constructed with catches split into hunting grounds and corrected for under-reporting detected from purchases of mattak (low option), for periods without catch records (medium option) and from rates of killed-but-lost whales (high option). Struck and lost rates have been estimated using factors such as community, season, hunting method, direct observations and these estimates are included in the catch history that is used in the assessment model.

Canada presented a reconstructed catch history from 1970-2015 which was constructed with catches from each hunting community that hunt narwhals from the Baffin Bay population. Hunt statistics by community were divided into catch seasons with the average from the following 10-year catch statistics for years with missing catch report. Catches were divided into 6 different hunting regions where different struck and loss corrections by period, type of hunt and community where then assigned.

The JWG noted that ideally there would be monitoring programmes occasionally for struck and lost that could be used to update the values but recognised that there are no plans for this in the near future.

Surveys and Abundance
New abundance estimates based on aerial surveys were presented from the High Arctic Cetacean Survey of narwhals in Baffin Bay, Jones Sound and Smith Sound that was conducted in Canada in August 2013 (Doniol-Valcroze 2015a,b). Density in off shore strata and fjord strata were analyzed independently and the JWG recommended reanalyzing the data so high density coastal fjord areas would not be incorporated into, and hence inflate, the large off shore strata. Comparison of photographic data and visual data will be presented at the next JWG meeting. Abundance estimates were corrected for availability bias by using information on the diving behavior of animals satellite tagged in the area. Fully corrected abundance estimates were 12,664 (cv=0.33) for the Jones Sound stock, 16,360 (cv=0.65) for the Smith Sound stock, 49,768 (cv=0.20) for the Somerset Island stock, 35,043 (cv=0.42) for the Admiralty Inlet stock, 10,489 (cv=0.24) for the Eclipse Sound stock and 17,555 (cv=0.35) for the East Baffin stock. The JWG agreed to provisionally accept the abundance estimates but provided recommendations to investigate the current use of correction factors (satellite tagging and dive cycle) to improve the analysis.

New abundance estimates for narwhals in East Greenland based on aerial surveys were presented and these fully corrected estimates of 288 (cv=0.44) in the Tasiilaq management area and 476 (cv=0.38) for the Scoresby Sound area were accepted by the JWG for use in the assessment. Adding an off shore narwhal component from a survey in 2015 increased the estimate for Tasiilaq management area to 797 (0.69). The JWG noted that no narwhals were seen in south of the Kangerlussuaq fjord.

Re-analysis of survey data from a previous survey in 2008 decreased the abundance estimates from 2008 (1098 (cv=0.63) for the Tasiilaq management area and 1176 (cv=0.29) for the Scoresby Sound area. The JWG accepted these changes for use in the assessment.

The JWG recommended that previous surveys from 1983 and 1984 should be re-analyzed and discussed at the next JWG meeting.

The JWG reviewed new studies on the effects of tagging on narwhals (Heide-Jørgensen et al). The JWG noted that recaptured individuals equipped with satellite transmitters showed a low degree of inflammation and that it decreased with increasing thickness of epidermis around the attachment pins. The JWG noted that this information is relevant due to the expressed concerns of satellite tagging from Inuit in Nunavut. The JWG discussed that information provided by satellite tags remains critical in the use of correction factors for aerial surveys and that information from these tags contribute to the knowledge of stock structure, distribution and movement of narwhals.

The JWG reviewed the results of a satellite tagging project in the southern hunting region in Kangerlussuaq Fjord, East Greenland where a single whale was equipped with a satellite tag. The whale moved north and entered the Scoresby Sound hunting region. The movement of the whale demonstrated the connectivity between two areas in East Greenland that are considered two separate management units. The JWG recommended that satellite tagging in Kangerlussuaq Fjord should be continued.
The JWG agreed to recognize the hunting areas in East Greenland, Tasiilaq, Kangerlussuaq and Ittoqqortormiit, as three separate management areas. Maintaining these areas as three stocks is a more precautionary approach and hence is more likely to avoid local depletion.

East Greenland
Assessment
The updated assessment suggests a lower catch than the previous advice for both the Tasiilaq and Ittoqqortormiit area. The JWG recommends this lower quota. The JWG also recommends recognizing three management areas for East Greenland (Tasiilaq, Kangerlussuaq and Ittoqqortormiit). The JWG noted that the stock structure in East Greenland is unclear and that more information is needed. The JWG noted that the distribution of narwhals may be changing due to environmental changes and the JWG recommends more information on distribution and movements.

Management advice
The JWG agreed that catches should be reduced to less than 10 narwhals in both Kangerlussuaq and Ittoqqortormiit management areas. The JWG recommends that no catches are taken south of 68°N. The JWG noted that the harvest may be causing a population decline. This decline was confirmed by the model estimates, independent of the aerial surveys results, lending more evidence of a real decline.

Recommendations

- Re-evaluation of the Larsen et al (1994) survey
- Aerial survey in Scoresby Sound in 2017
- Stock identity of the Scoresby Sound winter hunt

Baffin Bay narwhal stocks

The JWG discussed the request from Canada to incorporate PBR into the catch allocation model and that the TJW intends publication of a peer-reviewed paper describing the catch allocation and assessment model which may help address concerns with implementing the model in Canada. The JWG recommends continuing using the catch allocation model for our advice.

Habitat concerns

The JWG was informed on planned studies of the short-term effects of seismic exploration on narwhals. The recent interest for oil exploration in both East and West Greenland has stressed the importance of conducting studies that assess the environmental impacts of disturbance to marine life in Greenland. Of special concern are the effects of seismic exploration, specifically the effects of the sounds produced by airguns used during seismic surveys. Airgun pulses have high sound amplitudes, which may injure mammalian ears at close ranges and are audible over great distances resulting in disturbance effects far away (e.g., tens of km) from the sound source. Narwhals are considered particularly susceptible to disturbance and are one of the least studied cetaceans when it comes to effects of anthropogenic activities. This study will assess the short-term effects of sound from airgun pulses on narwhals in a closed fjord system in East Greenland to provide an empirical basis for regulation of activities linked to seismic exploration in areas with narwhals

Based on the few studies we anticipate that narwhals will react vigorously to anthropogenic disturbance. Narwhals dive to depths exceeding 1000 m and airgun sounds may affect their diving behaviour. A sound-mediated disturbance may cause a change in migration path or displacement from a feeding area and could increase the risk of ice entrapment**.** The JWG expressed concern over seismic activities in narwhal habitat. More information on the JWG's concerns regarding habitat of both narwhal and beluga is in Item 13.

Traditional Knowledge

The Aboriginal Traditional Knowledge Subcommittee of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is planning an aboriginal traditional knowledge gathering project for narwhal. Updates on the progress of this project and results will be provided upon availability.

The Government of Nunavut's Department of Environment completed a Nunavut Coastal Resource Inventory (NCRI) in Pond Inlet in 2016. Local Inuit knowledge, both spatial and anecdotal, collected on narwhal and beluga in this area may be relevant for the JWG and will be compiled and presented for the next meeting.

The Canadian HACs (see Item 11) used input from local Inuit on locations that should be included in the survey.

Habitat Concerns for both narwhals and belugas

Baffinland Mary River Mine

The JWG expressed concern regarding development of mining activities and associated ship traffic on the Eclipse Sound narwhal stock. No similar example of such a high level of shipping and development has occurred in a high density narwhal habitat so there is little precedent to inform an assessment of the impacts. Of particular concern are:

1. Narwhal response to shipping activities is not well understood and may include threshold responses in which the narwhals abandon the disturbance area rather than habituate to the disturbance. In this case an irreversible loss of habitat may occur if the narwhals leave and do not re-inhabit the area even in the absence of shipping activity.
2. Ship strikes, lethal and sub-lethal effects of shipping activity may take significant numbers of narwhals. DFO (2014) estimated as many as 123 narwhal would be in the path of ships each year and be at risk of ship strike. Sub-lethal effects include disruption of feeding and communication, with potential consequences to energetics and reproduction. These impacts may negatively affect the sustainable removal levels of the Eclipse Sound stock which is shared between Greenland and Canada.
3. Risk of an oil or toxic spill in a high latitude area is compounded by the presence of ice and the remoteness from the necessary facilities and personnel for cleanup. It is poorly understood how a high arctic ecosystem would respond to an oil spill, the effects of which are likely detrimental and possibly irreversible.

Shipping/Icebreaking in Baffin Bay

The JWG expressed concern regarding shipping and icebreaking activities in the wintering grounds of narwhal and beluga in Baffin Bay where winter time shipping is unprecedented. Ship noise and icebreaking activities will disturb deep diving narwhal during a critical feeding period and may result in unpredictable response and displacement from preferred habitat of both species. Ice breaking will disrupt the distribution and condition of sea ice which may lead to ice entrapments. The risk from oil spill discussed above applies here as well and the JWG noted that there is no available method for cleaning up an oil spill in ice covered waters. A recent gas leak in Cook Inlet, Alaska has demonstrated the difficulties of responding to such an event.

The JWG also expressed concern that cumulative effects should be considered when new shipping and icebreaking activities are proposed for narwhal and beluga habitat areas.

Climate change impact on management advice

Workshop

Various aspects of climate change may be impacting certain populations of belugas and narwhals. One example is the lack of sightings of narwhals in the southern areas in East Greenland, which may indicate a shift in distribution and/or loss of range. The JWG recommends a workshop to address concerns over changes in management advice in response to the non-hunting takes and changes in distribution resulting from development and warming of the arctic. This workshop would take place over 1-2 days and could be joined with the next JWG (in 2019). The workshop will focus on the populations in West Greenland and Canada, but should include experts involved with changes in marine ecosystems and higher trophic animals in relation to climate change in the North Atlantic and Canadian Arctic (polar bears, walrus, etc.)

The Terms of Reference for the workshop will be to:

- Identify specific effects of climate change on belugas and narwhals
    - Request papers on changes in distribution, population dynamics, etc. resulting from climate change in Canada/Greenland waters

    - The focus will be less on the mechanism of the effects, and more on identifying simple predictors and possible consequences

- Identify specific ways that the JWG's advice may be informed by these effects
    - Climate change may affect timing and distribution of hunted populations.
    - Climate change may affect population model parameters used for assessment.
    - Development in the arctic may result in changes in habitat and carrying capacity as well as increased anthropogenic disturbance which may require changes in assessment models.

<u>Other Business</u>

Discussion/workshop on small populations
The JWG discussed the observations that small beluga populations appear to not recover once their abundance is below around 2000 individuals. Possible issues are limited mate selection, loss of "cultural" knowledge within the population or loss of habitat from a contraction of range. Modelling exercises could shed light on the causes of the lack of recovery, identifying other issues which should be examined for these small populations when even 0 catches do not result in recovery. This could be a one day workshop for a future JWG meeting.

Focus of the meeting
The participants noted that work procedures of the JWG should be discussed at a future meeting, of particular concern was the proportion of time given to reviewing general beluga and narwhal science and discussion and review of management advice. The concern being that the management advice is late on the agenda and may not be getting the time and consideration necessary.

Rapporteur
Rapporteuring has been done by NAMMCO although it is a joint working group of NAMMCO and JCNB. The JWG suggested that a second rapporteur be provided by the JCNB so that duties are shared between the two organizations in future meetings.

<u>Review of Report</u>

A draft version of the report was reviewed during the meeting, and the final version of the report was accepted via correspondence on 20 April 2017.

<u>Next Meeting</u>

The JWG agreed that the next meeting should be held in March 2019 and will be hosted by Canada.

NAMMCO-JCNB
Joint Scientific Working Group
***on* Narwhal and Beluga**

8-11 March 2017
Copenhagen, Denmark

Main Report

1. Opening Remarks

Chair Hobbs opened the meeting and welcomed the participants (Appendix 1).

1.1. Adoption of Joint Agenda

The agenda (Appendix 2) was adopted without changes, but the order that the points were taken were rearranged during the meeting due to availability of the relevant participants. These rearrangements were accepted by the JWG.

1.2. Appointment of Rapporteurs

Prewitt acted as rapporteur, with help from participants as needed.

1.3. Review of Available Documents

Hobbs reviewed the documents that were available to the meeting (Appendix 3).

2. Life History Parameters

The JWG reviewed new and updated information on life history parameters for belugas and narwhals.

2.1 Belugas

The JWG reviewed the summary table of life history parameters for belugas in Hobbs et al (2015). These discussions informed the JWG's decisions made on the values to be used in the population modelling (see Item 2.3).

For birth rates, it was noted the values in Hobbs et al (2015) were often based on the number of females seen with calves, and that the high numbers should be treated with caution because of possible sexual segregation of the population, and low numbers also should have caution because of possible lower detection of calves. Despite the caveats, this table provided a range of values that are in the literature to inform the JWG decisions.

2.2 Narwhals

Age estimation
Matthews presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/11 which provided age estimates for narwhal using embedded tusks and aspartic acid racemization (AAR).

There has been long-standing difficulty in generating accurate age estimates of narwhal (*Monodon monoceros*). Recently, the ratio of the D to L-isomer of aspartic acid in eye lens nuclei has been used to estimate cetacean ages. L-aspartic acid converts to D-aspartic acid at a constant rate over time (racemization), and age can be estimated from the D/L ratio of metabolically inert tissue when the initial aspartic acid D/L ratio and racemization rate are known. We collected paired eye lens and embedded tusk samples from 20 narwhals to calibrate a species-specific aspartic acid racemization (AAR) rate for narwhals. Ages were estimated from counts of annual growth layer groups (GLGs) in dentine of embedded tusks, while aspartic acid D/L ratios in eye lens nuclei were measured using HPLC-MS/MS. Occlusion of the embedded tusk root by acellular cementum, which prevented dentine deposition beyond that point, limited absolute age estimates to tusks aged ≤ 14 years (n = 7). Linear regression of aspartic acid D/L ratios against the estimated age of these seven whales showed estimated age to be a significant predictor of aspartic acid D/L ratios, with a slope and intercept of 0.00211 and 0.0688, respectively. This relationship corresponds well to that previously determined using eye lens nuclei and erupted tusks of older narwhals (0.00229x + 0.0580, respectively). Similar results from this study, which included much younger animals, extends the age range over which aspartic acid racemization rates in narwhals have been determined, and indicates AAR can be reliably used to generate age narwhal age estimates.

Discussion

The beluga and narwhal racemization rates appear to be different, and the cause of this is unknown.

The narwhal results from two different labs using two different methods were similar, lending confidence that these reflect the accurate ages.

Life History Parameters

Garde presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/16 which provided updated life history parameters for narwhals.

Biological information and samples from narwhals (n=57) were collected during field operations in Scoresby Sound (Hjørnedal), East Greenland, in the years 2011 – 2016 and in Melville Bay, West Greenland, in 2012. Eyes from 22 narwhals were available for age estimation using the AAR technique. Two tusks were collected for age estimation by counting of growth layer groups and AAR. Information on reproductive status, measures of body mass, body length, tusk length, circumference and heart mass were also collected and stomach content analysed. Asymptotic body mass and body length was estimated to be 1428 ± 69 kg and 457 ± 13,2 cm for males from East Greenland, respectively. Male narwhals from West Greenland have an asymptotic body mass of 1645 ± 55 kg and are thus heavier as adults compared to males from East Greenland. It is estimated that female narwhals become sexually mature at an age of 8 ± 1,60 – 10 ± 1,65 yrs, a body length of ~340 cm and a body mass from 550 kg – 610 kg. First parturition occurs at 9 ± 1,63 – 11 ± 1,68 yrs. Male narwhals become sexual mature at ages between 12 ± 1,70 – 16 ± 1,84 yrs, body lengths from 350 – 400 cm, and body masses between >700 kg – <870 kg. Pregnancy rate for East Greenland narwhals was estimated to be between 0.29 – 0.31 and for West Greenland 0.36. Tusk mass (kg) versus age (yrs) show a linear relationship. The longest living narwhal of 107,7 ± 8,8 yrs were recorded – previous record was 101 yrs.

<u>Discussion</u>
The difference in weight between males in West Greenland and East Greenland should be examined to see if season of collection could explain these differences.

The JWG **agreed** to use the life history information to inform the priors and the age structure for the model input.

2.3 Review of the population model

As background information to the discussion of the population modelling used by this JWG for belugas, Hobbs presented the population model for Cook Inlet belugas (Hobbs et al 2015). Ditlevesen presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/09 which provided examples of different options for distributions that could be used for prior distributions in a Bayesian analysis. Witting reviewed the population model for beluga that has been used in this JWG.

Discussion of priors used for the Bayesian assessment model
The JWG reviewed the priors used in past assessment models and discussed whether to use uniform priors or fit alternative distributions (e.g., beta, gamma) that represented our current understanding of the distributions for these priors. The JWG noted that priors that were too broad could introduce bias by allowing the model to use parameters that were outside the range of biological observations. Priors that were too narrow would limit the range of outcomes on which the advice is based and may make it less conservative. The JWG identified four priors that should be updated: 1) adult survival rate (*p*), 2) first year survival rate (*p0*), 3) birth rate (*b*), and 4) age at maturity (a_m) or first reproduction. The JWG discussed the *p0* and *b* which multiply together to determine the number of belugas at age 1 in the model. This suggested that the model could be simplified somewhat by fixing the *b* at observed values for populations where this information was available and allowing the *p0* to vary.

Priors
Based on discussions the JWG decided to change the prior distributions on adult survival (*p*), the maximum birth rate (*b*), and the age of the first reproductive event (a_m). In earlier analyses, uniform distributions had been used for the prior distributions of *p* and a_m, these were changed to symmetric hump-formed beta distributions (a=b=2) that allocated more weight of the centre of the distributions, with the assumed minimum and maximum values of the two parameters being 0.95 and 0.995 for adult survival for both beluga and narwhal, and 6 and 14 years for a_m in beluga, and 7 and 15 years for a_m in narwhal.

The prior on the birth rate was then changed to a single value instead of a distribution in order to reduce the number of parameters to be estimated by the model. This value was set to 0.31 for beluga in West Greenland in accordance with the observed pregnancy rate Heide-Jørgensen and Teilmann (1994), and it was set to 0.33 for all narwhal populations to reflect a three-year calving interval.

3. Stock structure beluga

Eline Lorenzen and Mikkel Skovrind from University of Copenhagen presented information on a large biogeographic study of narwhal and beluga, using whole-genome sequencing to elucidate the genetic differentiation among geographic regions and stocks, which has so far not been possible with population genetic data in the form of microsatellites and mitochondrial control region data. These high-resolution data will hopefully uncover biogeographically informative genomic regions in the form of SNPs (single nucleotide polymorphisms). By combining these in a custom-designed SNP-array for each species, it will be possible to provide a cost-effective and relatively easy way to discern narwhal and beluga stocks, which could potentially be run in any lab with suitable equipment. If there is an interest in such a genetic tool for the joint management of narwhal and beluga stocks in Canada and Greenland, Lorenzen and Skrovind will prioritize developing a SNP-array for the region.

Lorenzen and Skovrind informed the JWG that they are also collecting samples for analysing the microbiome from the whales (swabs from the digestive and respiratory tracts) to look at possible differences between the stocks.

<u>Discussion</u>
The JWG identified a few areas that could be prioritized

- Include the samples collected during the tagging in major summer aggregation areas of western Hudson Bay to provide stock id for catches in this area that are not available from hunting areas.
- Summer catches in West Greenland (see Recommendations under Item 4).
- Comparison between Cumberland Sound and the extinct West Greenland stock using old WG beluga samples in the museum

The JWG encouraged this work, especially to help 1) identify an individual animal to a stock, 2) delineate between stocks, and possibly 3) identify genetic changes in response to climate change. Lorenzen noted that genomic analysis will not be able to identify changes within the last 50 years. For this type of analysis, gene expression could be used, but would require samples collected to preserve RNA which is logistically challenging for most field conditions.

3. Hunt removals beluga

Canada
Ferguson presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/12 that included the catch statistics from select Nunavut communities for the past five years (2011-2015; Table 1, Appendix 4). Catch reporting for the 2016-2017 harvest year was incomplete.

In Baffin Bay the harvest remains relatively low, likely because hunters in Nunavut prefer narwhal. There is no quota for beluga but Hunters and Trappers Organizations do provide catch statistics. Igloolik reported a relatively large take in 2011-2012, but no reports were available for recent years.

<u>Discussion</u>
The JWG noted that the catches have not been corrected for struck and lost. The JWG **recommended** that these catches be corrected for struck and lost.

In Table 1 (Appendix 4), “NR” means that a report was not received, not a zero catch.

There is uncertainty around whether the catches from Kugluktuk are from the Beaufort Sea or Somerset stock. The JWG decided not to include the catches from Kugluktuk in the modelling. The JWG also noted that catches from Kugluktuk were not included in the Beaufort Sea stock assessment. The JWG **recommended** that genetic analysis should be conducted on the catches from this area to clarify the stock identity of these catches.

There is some interannual variability in the catches from Igloolik, and it is uncertain whether these catches are from the Somerset Island stock. Canada informed the JWG that catches in Igloolik, and nearby Hall Beach, occur in August and September if the belugas come close to the villages, which is variable from year to year, thus explaining the variability. There are also belugas in Foxe Basin throughout the summer. Catches in this area are taken mostly in the summer and fall, with rare catches in winter and spring. Samples for genetics have been collected and the lab work has been completed, but the results have not been analysed. The JWG **recommended** that the analysis of the existing genetic results be completed.

The JWG decided to continue to leave Pangnirtung out of the modelling until there is evidence that it is a shared stock between Canada and Greenland. Movements of tagged animals indicate that the belugas remain in Cumberland Sound, suggesting that it is not currently a shared stock. When this stock was larger, there is a possibility that it could have been a shared stock (possibly related to the now-extirpated West Greenland stock), and if the stock abundance were to increase in the future, it could become a shared stock. The JWG noted that there have been a few catches in south Greenland. The JWG **recommended** conducting a genetic comparison between Cumberland Sound belugas to the old West Greenland stock, using samples from the Danish Natural History Museum. If genetics indicate a linkage, the JWG further recommended a modelling exercise of the historic population size, including catches from the old WG stock from pre-1930.

Greenland

Garde presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/06 (See Tables 2 and 3, Appendix 4). Catches declined during 1979-2016 to levels below 300 whales per year after 2004 (except for 2013 where a catch of 304 whales were reported). All catches are assumed to be taken from the Somerset Island summering stock of belugas and all the catches in West Greenland are presumably taken from the fraction of that stock that winters in West Greenland. The exception is the winter catches in Qaanaaq (approx. 5% of annual catches in Qaanaaq) that likely are taken from the fraction that winter in the North Water. It is unknown which stock is supplying the summer hunt in Qaaanaq (approx. 15% of annual catches in Qaanaaq). A few confirmed catches (and sightings) of belugas have been recently been reported from East Greenland.

<u>Discussion</u>

The JWG noted that the catches in Qaanaaq are variable. This is an opportunistic hunt that takes advantage of belugas passing near the village, which does not occur regularly.

The JWG has previously recommended that summer catches in this area be prohibited due to the lack of knowledge on the stock identity of these catches. Small numbers of catches in the summer continue to occur. Genetic analysis of catches from Qaanaaq would be informative, however the JWG recognizes that sample collection is logistically challenging from all catches in West Greenland.

Previous studies have accounted for past underreporting, and it is not believed that underreporting is a significant problem with the more recent catch reporting. Greenland has implemented a special form that hunters must complete with various information (e.g., hunting method, length, etc.) that is used to track removals during the hunting season in relation to the quota within the year.

Belugas taken from to ice entrapments are not included in the quotas, and are considered to be utilizing animals that would have been lost from the population due to natural mortality.

The JWG **accepted** these catch numbers for use in the assessments. They noted the improved reporting system in Greenland, and the attempts to account for each take. The JWG further noted that the recent catches are below the quota. This is likely because with the recent ice conditions, as belugas have been observed (during aerial surveys) further from the coast, and are therefore it has become more difficult for the hunters in small boats to access the belugas. Additionally, a new cod fishery may be taking away some incentive to take marine mammals, although the price for maktak remains high in Greenland.

Recommendations

The JWG **recommended** genetic analysis for stock identity of the summer takes in Greenland.

The JWG reiterated its past **recommendation** that more accurate, and recent, struck and lost data is needed. Struck and lost is likely different for hunting method, season, etc., and the JWG recognizes that it is difficult to collect data on loss rates. However, knowing struck and lost rates is more important in areas where the quotas are small, and these hunts could be prioritised for data collection.

2. Abundance- belugas

No new abundance data was available to the meeting. Ferguson presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/10, where information from the literature was summarized on abundance and trends of Canadian Arctic beluga whale and narwhal stocks for long-term monitoring and sustainable harvest management. Metadata in the database includes area studied, time frame, survey type, uncorrected and corrected (if available) abundance estimate, measures of variability around the point estimate (confidence intervals, coefficient of variation), types of corrections for availability and perception bias, trends in abundance estimates, and limitations and sources of uncertainty. The database contained 34 records for beluga whale surveys conducted between 1965 and 2015, and 22 records for narwhal surveys conducted between 1975 and 2013. The database is complete to 2015. The database can be updated as future surveys are completed and analysed.

Discussion by JWG

The JWG noted this work, and discussed that a possible next step is to create a database of the survey data, including sightings, effort, sea state, etc. For older surveys in Canada, some of this information is not available. This type of database is currently planned for in Greenland, and the JWG **agreed** that it would be helpful for Greenland and Canada to cooperate on creating a consistent database.

3. Allocation of shared beluga stocks

Belugas taken in West Greenland are believed to be from the Somerset Island stock.

4. Stock assessments and management advice belugas

Matthews presented Marcoux and Hammill (2016). The subsistence harvest of Pangnirtung, Nunavut, is directed towards a single stock of belugas in Cumberland Sound, which forms a separate stock among belugas in the Canadian Eastern Arctic. A population model incorporating updated information on harvest statistics (1920–2015) was fitted to four aerial survey estimates using Bayesian methods, resulting in a current estimated population of 1,000 (rounded to the nearest 100) animals. The management objective is to achieve a population of 5,000 animals by 2091. This could be expressed as an interim target of 1,235 animals within a decade (2026). At current reported harvest levels of 41 animals, the probability of the population declining over a 10-year period is 1. The probability that the population would increase to the interim target was 0.3, 0.25 and 0.1 for reported harvests of 0, 6, and 25 animals respectively.

Discussion

This paper provides an example of the type of modelling that Canada is conducting. This is for information for the JWG, in case this stock would be included in the future for management advice. The JWG **recommended** genetics analysis for stock identity.

The JWG noted that the results presented in Marcoux and Hammill (2016) were more conservative than the potential biological removal (PBR) calculations with a 0.5 recovery factor, and if the results presented in this paper correctly represented the population, the PBR was not sufficiently conservative to recover the stock.

Another survey is planned for this area during summer 2017.

Assessment of West Greenland belugas

NAMMCO/SC/24-JCNB/SWG/2017-JWG/13 updated the assessment for West Greenland beluga with new catch data and the new priors as agreed by the JWG. The model estimated a decline from 21,180 (90% CI:15,370-29,620) individuals in 1970 to a minimum of 8,470 (90% CI:6,016-11,890) in 2004, and it projects an increase to an expected 11,610 (90% CI :6,320-19,520) individuals in 2023 (assuming post 2016 catches of 225). These results are similar to those of the last assessment, with a total annual removal of 310 individuals from 2017 to 2022 ensuring a 70% chance of an increase in the population over the period.

Discussion

The JWG noted that the changes in the priors (see Item 2.3) did not have a strong influence on the assessment.

This is an updated analysis, and the JWG **agreed** to re-iterate the previous advice, which remains valid until 2021.

5. Habitat Concerns belugas

See discussions for habitat concerns for both belugas and narwhals in Item 13.

6. Traditional Knowledge belugas

The Government of Nunavut's Department of Environment completed a Nunavut Coastal Resource Inventory (NCRI) in Pond Inlet in 2016. Information is collected on land and marine use by the community, fisheries resources and habitat, fish species, bird species, community infrastructure, marine mammals, aquatic plants, shellfish harvesting, etc. Local Inuit knowledge, both spatial and anecdotal, collected on narwhal and beluga in this area may be relevant for the JWG and will be compiled and presented for the next meeting.

7. Stock structure narwhal

7.1. Genetics

Lorenzen and Skovrind informed the JWG on their project(s) involving genetics in beluga and narwhal. See Item 3 for information on this project.

Discussion
The JWG is interested in being able to assign an individual animal (e.g. hunted) to a specific stock.

The JWG noted that for stock identity, Lorenzen would need to know the date of kill/sample collection, specifically prioritizing summer samples (defined as the last week of July, first 3 weeks of August).

7.2 Tagging and Movements

The JWG discussed Heide-Jørgensen et al (2017) "Long-term tag retention on two species of small cetaceans":

> Abstract:
> The effects of tagging on small cetaceans are difficult to assess due to logistical difficulties in recapturing the whales. In this study two narwhals, *Monodon monoceros*, and five harbor porpoises, *Phocoena phocoena*, were recaptured between 297 and 767 days after instrumentation with satellite transmitters. The transmitters were mounted by pins that were pushed through the fins of the porpoises or the backs of the narwhals. Overall body condition seemed unaffected by the instrumentations. Macroscopical examination revealed that umbilicalization of the tissue surrounding the pins was almost complete. On one of the narwhals the reepithelialization created a closed tunnel where the pins were isolated from the subdermal tissue, however the reepithelialization was incomplete around the middle of the pin and a low-grade inflammation increased with decreasing thickness of epidermis. The inflammation consisted of mononuclear cells, mainly lymphocytes. With increasing inflammation the number of neutrophils and macrophages increased. In the lymphoid follicular hyperplasia macrophages and a few neutrophils were found, in one case accompanied by Splendore-Hoeppli material with radiating eosinophilic clubs and Gram-positive cocci. Immunohistochemical staining of the cocci for *Staphylococcus aureus* was positive. The observations from the recaptured cetaceans suggest that the instrumentations caused only temporary and low-grade inflammatory responses.

Discussion
This information is relevant to our discussions of tagging for investigations of movements of individual whales.

Hobbs indicated that the US is planning a workshop in fall 2017 to review impacts of current tag attachments on cetaceans and to discuss design improvements.

The satellite tagging of narwhal and beluga remains a sensitive issue in Nunavut and Inuit have expressed concerns about invasive methods. Efforts to minimize the impacts of satellite tags on individuals is ongoing including the adoption of new technologies. The information provided from these devices remains critical in the use of correction factors that contribute to the generation of abundance estimates from aerial surveys. The information from these tags also contributes to the knowledge of stock structure, distribution and movement of narwhals.

East Greenland movements
Heide-Jørgensen presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/05, and also discussed relevant results in Heide-Jørgensen et al (2015) as background information.

One adult female narwhal (345cm) was tagged in Kangerlussuaq in East Greenland on 24 August 2016. The purpose was to investigate the stock identity of narwhals in fjord systems in East Greenland and especially those that are supplying the hunt in Tasiilaq and Ittoqqortormiit.

The narwhal was tagged with a Wildlife Computers SPOT6 backpack transmitter that was duty cycled to transmit every day.

The whale remained inside the Kangerlussuaq fjord system until it departed from the fjord on 6 October. It took a north-going coastal course along the Blosseville Coast where it visited almost every inlet and bay until it reached Kap Brewster on 21 October at the entrance to Scoresby Sound. It moved as far east as Føn Fjord (5 November) as far north as Bjørne Øerne (28 November). It spent most of its time in Gåse Fjord and it departed from Scoresby Sound (passing Kap Brewster) on 9 December. It spent the winter (through 24 February) on the East Greenland shelf area off the Blosseville Coast.

The movements of the whale demonstrated the connectivity between two areas in East Greenland that are considered separate management stocks. Narwhals in Kangerlussuaq are only hunted by hunters from Tasiilaq and hunters from Scoresby Sound never venture that far south along the uninhabited Blosseville Coast. The whale nevertheless spent November in Scoresby Sound in areas where narwhals are hunted although infrequently that late in the year.

After the relatively late departure from Scoresby Sound in December the whale stayed in the same areas where narwhals tagged in Scoresby Sound have remained in winter (Heide-Jørgensen et al. 2015).

More tagging of narwhals in Kangerlussuaq is needed to determine if the timing of their fall visits to Scoresby Sound coincides with the hunting season for narwhals in that area.

Discussion
Narwhals in East Greenland are hunted in Tasiilaq, Kangerlussuaq, and Ittoqqortormiit. Previously, the animals hunted in Kangerlussuaq have been assigned to the Tasiilaq quota. However, the only animal tagged in Kangerlussuaq moved north to Scoresby Sound. The JWG **agreed** to recognize these hunting areas as three separate management areas (Tasiilaq, Kangerlussuaq and Ittoqqortormiit). Maintaining these areas as three stocks is a more precautionary approach as it is more likely to avoid local depletion.

The JWG also discussed the possible connection between the East Greenland and Svalbard stocks. Of 29 animals tagged in Greenland, none went to Svalbard. There are sightings of narwhals in the Greenland Sea between East Greenland and Svalbard, but the JWG considered that there could be two populations that are not connected – a coastal population in East Greenland and a coastal Svalbard population.

Greenland informed the JWG that a survey will be flown in northern East Greenland (Northeast Water Polynya) in spring 2017. There will also be another survey in summer 2017 in south East Greenland.

8. Hunt removals narwhal

Canada

Ferguson presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/08, a reconstructed catch history from 1970-2015 (See Table 4, Appendix 4).

Abstract

Catch statistics from 1970-2015 for 13 Canadian communities that hunt narwhals from the Baffin Bay population are reviewed. Detailed statistics by community are missing from some of the communities, particularly before quotas were implemented in 1977. In these cases, an average value calculated from reported hunts in the following 10 years is used as approximation. Many catches were reported with date of kill which allowed a separation of hunt statistics across seasons. Catches were then divided into seasons for all years. When date of kill was not reported, as with total catch, we averaged catches over the next 10 years to estimate catch by season. Finally, catches were attributed to 6 different hunting regions in Canada, including Grise Fiord, Central Canadian Arctic, Arctic Bay, Pond Inlet, Baffin Island Central, and Baffin Island South and assigned different struck and loss corrections by period (1979-1989, 1990-2004, and 2005-2015), and when possible by type of hunt (open water, ice edge/crack), and community. The results can be used for data modelling purposes and thereby provide more reliable estimates of sustainable hunt management advise.

Discussion

The JWG noted that 10 years is a long time for using an average to fill in the missing data, but for this older data it has little influence on the results of the modelling.

Self-reporting rates from hunters were similar to rates reported by observers, suggesting that hunter self-reporting may be sufficient.

The JWG thanked Canada, especially Watt, for providing this work which fulfils the request from the last meeting (see NAMMCO 2016). The JWG **agreed** to use these catch numbers for the analysis.

Greenland

Garde presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/07, in which information and statistics including some trade statistics on catches of narwhals (*Monodon monoceros*) in Greenland since 1862 are reviewed (See Tables 5 and 6, Appendix 4). Since 1993 catches have declined in West Greenland especially in Uummannaq and Disko Bay where the decline is significant. In East Greenland there has been an increase of 5% per year since 1993.

Discussion

The JWG **agreed** to use these catch numbers from West and East Greenland in the model. The East Greenland information provided updated catches since 2010 and were corrected for struck and lost (30%, based on direct observations).

9. Habitat Concerns narwhal

Ferguson presented Richard et al (2013). Published tracking studies of narwhals have delimited two winter home ranges in Baffin Bay and Davis Strait for the Baffin Bay population of narwhals. One centres in northern Davis Strait and southern Baffin Bay, the "southern narwhal over-wintering area", which is in large part within Canadian waters, and contains Canadian narwhal summering stocks from Admiralty Inlet and Eclipse Sound, and the Greenland narwhal stock from Melville Bay. New tracking data from narwhals tagged in Admiralty Inlet suggest that the narwhals that summer there use the southern wintering area annually. Animals in the southern wintering area forage at depths over 1,000 m and it appears that a large part of their diet is Greenland halibut. The second wintering area referred to as the "northern narwhal over-wintering area" is largely inside Greenlandic waters of central Baffin Bay and is used by narwhals from the Somerset Island summering stock. The Division 0A Narwhal Overwintering and Coldwater Coral Protection Zone (fishing closure) includes an area of particularly high Ecological or Biological Significance and requires the provisions to protect and manage fishing activities in such areas.

<u>Discussion</u>
The JWG **recommended** maintaining the closure in this area.

Ferguson presented Watt et al. 2017:

> Abstract: In Canada, narwhals (*Monodon monoceros* L., 1758) are divided into the Baffin Bay (BB) and northern Hudson Bay (NHB) populations. Satellite tracking of 21 narwhals from BB and NHB provided information on their diving behaviour and was used to identify foraging regions. Previous research from hunted narwhals indicated that narwhals in both populations depend on benthic prey to meet their dietary needs. To evaluate home ranges and define areas important for benthic foraging, we conducted kernel density analysis on narwhal locations and focused on areas where deep diving occurs, as a proxy for foraging, in the winter, spring, and migratory periods. These analyses revealed important areas for foraging for BB narwhals on the summer grounds in Eclipse Sound, and the winter grounds in Davis Strait, as well as on the migratory pathway between regions. Similarly, important areas were identified for the NHB narwhal population in northwestern Hudson Bay in summer, in NHB and Hudson Strait on the migration, and to the east of the entrance to Hudson Strait in the winter. This, along with an analysis of the absolute dive depths, provides information on seasons and regions important for foraging, which is particularly relevant with increasing industrial activities in the Arctic.

<u>Discussion</u>
The "deep dives" described in this paper are deep relative to the bottom. The JWG noted that the depth measurements are not very precise, thus it is uncertain whether the deep dives actually made contact with the bottom, or were mid-water foraging dives.

Satellite tracks show that narwhals remain close to shore in summer, and are not diving frequently. Tracking of both killer whales and narwhals suggest that narwhals are remaining near shore to avoid the killer whales.

Plans for research in Eclipse Sound
Matthews presented updated information on recent research in Eclipse Sound.

An aerial survey of the Eclipse Sound and Admiralty Inlet narwhal stocks was conducted in August 2016 to update estimates obtained from surveys conducted in 2013. Photographic surveys were flown along pre-determined transect lines over nine days between August 7-21, including repeats of Tremblay Sound (n=7), Milne Inlet & Koluktoo Bay (n=4), and Eclipse Sound (n=3). Unfortunately, Admiralty Inlet was only partially surveyed once (August 13) due to poor sea state conditions which persisted throughout the survey period. Photos are currently being analysed, with a goal of producing abundance estimates from four replicate surveys (August 9, 10, 15, and 21) of the Eclipse Sound beluga summering range. Count data from Admiralty Inlet will not be used to estimate stock abundance due to incomplete coverage of the area.

A satellite telemetry study of Eclipse Sound narwhals was also conducted during August 2016 to provide information on 1) stock discreteness, 2) migratory pathways, winter range, feeding and diving habits, and 3) changes in behaviour in the presence of marine vessels and other industrial activity. A field camp was established in Tremblay Sound from Aug 11-31. To capture narwhals for tag deployment and sample collection, 50-m mesh nets were set perpendicular to the shore and were monitored at all times. Captured narwhals were brought to shore, where they were restrained and equipped with a satellite transmitter attached onto their dorsal ridge. Blood, morphometric measures, and other biological samples (e.g. blubber) were taken before the whale was released. Six narwhals were captured, including a juvenile that was not tagged. The five tagged whales included three females (one with a tusk) and two males. Two of the tags stopped transmitting early after deployment (one whale was shot by a hunter a few days after tagging), and one tag stopped transmitting while in the Eclipse Sound area. Two of the tags continued transmitting as the whales moved along the known migration route to wintering grounds in Baffin Bay, and stopped transmitted on November 10 and 17, respectively.

Trace elements were measured in skin samples of 188 narwhals from five Canadian summer stocks of the Baffin Bay narwhal population (Admiralty Inlet, n = 49; East Baffin Island, n = 16; Eclipse Sound, n = 63; Jones Sound, n = 45; Somerset Island, n = 15). Trace elements can be useful for stock delineation because the concentrations of trace elements in the marine ecosystem are related to underlying geology (e.g. lead [Pb] and strontium [Sr]), which can lead to regional differences in baseline marine food web trace element concentrations that are ultimately reflected in animal tissues. Additionally, trace element concentrations can reflect certain dietary preferences (e.g. cadmium [Cd] is elevated in marine mammals feeding largely on cephalopods; Bustamente et al. 2004; Lahaye et al. 2005). Preliminary principle components and discriminant analyses of the 31 trace elements measured in the narwhal skin samples show separation among the Baffin Bay narwhal stocks.

Discussion

The updated abundance estimate for Eclipse Sound are expected in a CSAS document in fall 2017, and will be available at the next JWG meeting.

General discussion on habitat concerns

Heide-Jørgensen updated the JWG on planned studies of the short-term effects of seismic exploration on narwhals. The recent interest for oil exploration in both East and West Greenland has stressed the importance of conducting studies that assess the environmental impacts of disturbance to marine life in Greenland. Of special concern are the effects of seismic exploration, specifically the effects of the sounds produced by airguns used during seismic surveys. Airgun pulses have high sound amplitudes, which may injure mammalian ears at close ranges. These high amplitudes also mean that the pulses will generally be audible over great distances and can therefore result in disturbance effects far away (e.g., tens of km) from the sound source. Even though all marine mammals can be considered vulnerable to some extent to sounds from airgun pulses, narwhals are considered particularly susceptible to disturbance. Narwhals are also one of the least studied cetaceans when it comes to effects of anthropogenic activities. This includes in particular short-term reactions to airgun pulses, which might lead to longer-term effects on populations. In this study it is planned to assess the short-term effects of sound from airgun pulses on narwhals in a closed fjord system in East Greenland, to acquire knowledge about narwhal movements in response to airgun pulses that can be applied to disturbance scenarios in both East and West Greenland as well as in offshore areas and to provide an empirical basis for regulation of activities linked to seismic exploration in areas with narwhals

The current lack of information on narwhals makes it impossible to predict the type and level of disturbance that airgun sounds would cause in areas with high densities of narwhals. Based on the few studies we anticipate that narwhals will react vigorously to anthropogenic disturbance. Narwhals dive to depths exceeding 1000 m and airgun sounds may affect their diving behaviour. A sound-mediated disturbance may cause a change in migration path or displacement from a feeding area. If a displacement occurs when they are in areas with heavy ice coverage or an area about to freeze over, then they could get trapped in ice.

Discussion
The JWG expressed concern over seismic activities in narwhal habitat. More information on the JWG’s concerns regarding habitat of both narwhal and beluga is in Item 13.

10. Traditional Knowledge narwhal

The Aboriginal Traditional Knowledge Subcommittee of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is planning an aboriginal traditional knowledge gathering project for narwhal. Updates on the progress of this project and results will be provided upon availability.

The Government of Nunavut’s Department of Environment completed a Nunavut Coastal Resource Inventory (NCRI) in Pond Inlet in 2016. Information is collected on land and marine use by the community, fisheries resources and habitat, fish species, bird species, community infrastructure, marine mammals, aquatic plants, shellfish harvesting, etc. Local Inuit knowledge, both spatial and anecdotal, collected on narwhal and beluga in this area may be relevant for the JWG and will be compiled and presented for the next meeting.

The Canadian HACs (see Item 11) used input from local Inuit on locations that should be included in the survey.

11. Abundance

Correction factors
Riisanger-Pedersen presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/17 which deals with developing depth correction factors for aerial surveys. One of the technical challenges to using line transect aerial surveys is the development of an appropriate depth correction factor, which represent proportion of time that the animals are visible for the observers. To estimate this six

narwhals were instrumented with time-depth recorders. Five animals carried an Acousonde and one carried a SPLASH tag from Wildlife Computers. Sensor inertia, causing parts of the dive profiles to be displaced, were corrected for each single dive using the compensation setting in the software program MTdive.

Discussion

The issues with the instrument not recording the surface correctly may be due to a delay in the sensor resulting from a change in the water temperature as the tag approaches the surface so that a short period of time is required for the sensor to reach the ambient temperature at the surface.

The JWG discussed that the method of choosing where to start and end applying the compensation could introduce bias in the proportion of time at the surface. Although this bias may be small, the effects of adjusting the method of compensation should be examined. One possibility for examining when to start the compensation is to use the Acousonde sound recording to verify when the animal is actually surfacing. This would be labour intensive, so a first step would be to test a subsample of the data.

The JWG discussed whether there could be variation in the error between instruments, e.g., are they consistently wrong. The JWG recommended that this be investigated further.

Tervo presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/19. Thirty-two harbour porpoises were instrumented with satellite linked time depth recorders (TDR) in Western Greenland off Maniitsoq in 2013-2014. Four of them were retrieved in 2016 and three of them had sufficient data allowing comparisons between the transmitted time-at-depth (TAD) data and the archival TDR data. Comparisons between temporal resolution, time at surface (at depths >= -2) and time at different depth categories between the two datasets were made. Only daytime data between 07:00:00 and 18:59:59 were used. The transmitted TAD data had 159 (39 %) fewer transmission days compared to the raw TDR data. Time spent at surface was underestimated by the TAD datasets for all the three individuals (in average 6.1 ± sd 1.7 hours/12 hours and 4.5 ± sd 2.4 hours/12 hours, respectively). The trends in both datasets and for all individuals were comparable with a decreasing tendency in time spent at the surface with progressing season, however it is possible that some of the change observed is the result of progressive instrument failure. For time spent at depth, in average all depth bins apart from bin 2, were underestimated by the TAD data.

The reasons for the discrepancies in the two datasets are unknown. Time spent at surface is an important component in the correction factor used in the analysis of abundance data from surveys. Using TAD data alone for calculating availability will result in an underestimation and can thus lead to an overestimation of abundance.

Discussion

The JWG discussed what the mechanism is behind the decline in the data. There is likely an issue with the programming. One possibility is the compression algorithm is losing some of the data at uplink.

There may also be issues with the sensor, possibly due to accumulation of "crud" or corrosion on the sensor. These issues may not be a problem for larger, slow moving species, but for quick, fast moving species, it is possible that they are not at depth for a long enough time for the sensors to detect the surfacing.

The JWG **agreed** that SLTDR data should be used with caution when developing correction factors. The TDR data appears to be more trustworthy than the TAD data. Alternatively the experimental results presented could be used to develop a correction for the TAD data.

Angle measurements during aerial surveys
Hansen presented information on a new device for measuring angles during aerial surveys, the Geometer. Aerial surveys employing distance sampling techniques are widely used in estimating the abundance of marine mammals and other wildlife. Distances are estimated using the declination angle from the observer to the sighting, which is either estimated by the observer or measured using an analogue forestry inclinometer. Angle estimation is imprecise and inaccurate, while using analogue inclinometers is cumbersome, slow and requires manual transcription of recorded data. A new device, called a geometer, was therefore developed in Iceland for the NASS 2015 survey. The geometer is a handheld, USB-connected device that measures pitch, roll and yaw and records these measurements with date and time when the user depresses a button. The observer simply aims the device at the sighting using a red-dot rifle sight, and depresses the button to record these data to a computer. The associated software also facilitates the recording of GPS data, voice and video. Up to four or more geometers can be recorded simultaneously on a single computer. The major advantages of the geometer over other measurement devices are: 1) ease of use, reducing observer training time and enabling faster measurements in high-density areas; 2) no recording or transcription error; 3) accurate timing of observations, improving the precision of distance measurements and duplicate identification; and 4) elimination of time-consuming data transcription. Extensive testing has shown that angle measurements are at least as accurate and precise as those taken by other methods, with no calibration drift over time. To date geometers have been employed successfully in two aerial surveys in Iceland and one in Greenland.

Discussion
The JWG noted that this device adds great precision to angle measurements critical to distance sampling analysis.

Database of Abundance Surveys in Canada
Ferguson presented paper NAMMCO/SC/24-JCNB/SWG/2017-JWG/10 which gave information on a database of abundance surveys belugas and narwhals in Canada. See Item 5 for more information.

East Greenland survey
Hansen presented NAMMCO/SC/24-JCNB/SWG/2017-JWG/18. A visual aerial survey of narwhals was conducted in fjords and bays along the coast of East Greenland in August 2016. A total of 66 unique sightings of narwhal groups were recorded in 9 strata, with more than half of the sightings occurring in the Scoresby Sound region, primarily in the tributary of Nordvestfjord.

The uncorrected individual abundance estimate was 237 (CV=0.318, 95% CI= 128-437) narwhals. A new availability correction factor was developed based on archival instruments deployed on six narwhals in Scoresby Sound in 2013-16. The average surface time from the whales that provided data was 0.31 (SE=0.064, cv=0.08) during daylight hours. The fully corrected individual abundance estimate was 765 (CV 0.33; 95% CI: 409–1430). The disaggregated estimates for the Tasiilaq management area was 288 (CV=0.44, 95%CI 125-663) and 476 (CV=0.38, 95%CI 232-977) narwhals for the Scoresby Sound area.

A survey in 2015 covered areas off the coast of East Greenland and including the estimate from that survey increases the abundance estimates to 1268 (0.48; 95% CI: 519–3098). Adding the offshore estimate to the Tasiilaq management area gave 797 (0.69, 95%CI 236-2686) narwhals in that area alone. Recalculation of the 2008-survey with corrected transect lengths, new stratum areas and the new availability correction factor gave an estimate of 2274 (cv=0.53, 95%CI 862-6002) narwhals in 2008. The disaggregated estimates for the Tasiilaq management area was 1098 (0.63, 95%CI 351-3437) and 1176 (0.29, 95%CI 661-2094) narwhals for the Scoresby Sound area in 2008.

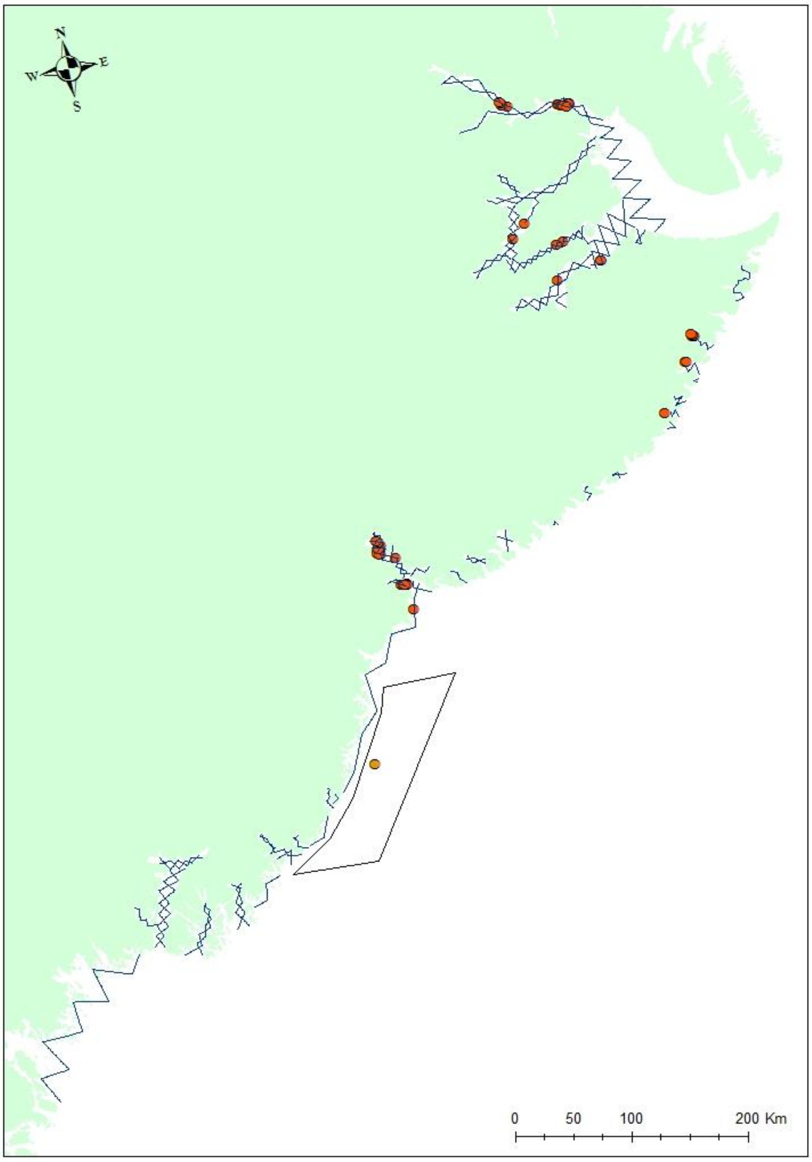

Figure 1. Transect lines in ss<3 and sightings of narwhals. The offshore strata is from 2015.

Discussion

The correction factor presented in NAMMCO/SC/24-JCNB/SWG/2017-JWG/17 was applied to the data from this survey. Only one of the fjords in this area is muddy, so these data were not corrected for different detectability in murky water.

The northeast part of Scoresby Sound was not covered because both the satellite tracks and the 2008 survey have not shown that narwhals use this area.

The 2016 survey had the same number of sightings as the 2008 survey, however the distribution was different. The most important difference between the surveys was the expected group size. The use of the geometer (see NAMMCO/SC/24-JCNB/SWG/2017-JWG/O20) might have changed the estimates of group size because the observers had more time during the sightings, and therefore "clumped" the groups less.

During the 2016 survey, no narwhals were seen in the southern areas, whereas during the 2008 survey there were 3 sightings of narwhals.

2008 re-analysis
The changes in the transect lines (km instead of nm) and strata both decrease the abundance estimate. The re-analysis also included the application of the new availability correction factor. The biggest issue is the availability of 0-2m, as there is uncertainty in the depth at which narwhal can be seen. The JWG noted that the re-analysis halved the abundance estimate.

The JWG **accepted** these changes to the 2008 analysis and agreed to use the new numbers in the assessment. However, the JWG recognizes that there may be further analysis that could be done with the availability correction factor in the future (review of depth of visibility, detection depth).

2016 estimate
The 2016 survey included an added "offshore" strata. There could be an "offshore" component of the population, or an influx from the northern area. The JWG **agreed** to the addition of the offshore strata, as these animals could be part of that population.

The JWG **agreed** to use these estimates in the assessment, while recognizing that continued analysis may refine the results. While continued analysis is not likely to change the results drastically, possible areas of future analysis include looking at the truncation, correction factors, etc.

The JWG noted that this area has been/is being heavily impacted by climate change. There have been many observations of new species (dolphins, humpback whales, killer whales), and it is looking less like narwhal habitat. The ecosystem changes in this area are having uncertain impacts.

Canadian High Arctic Cetacean Survey
Doniol-Valcroze presented (via Skype) information on the 2013 High Arctic Cetacean Survey (HACS) of narwhal stocks in Baffin Bay, Jones Sound and Smith Sound (Doniol-Valcroze et al 2015a,b; DFO 2015; Pike and Doniol-Valcroze 2015).

DFO conducted the High Arctic Cetacean Survey (HACS) in August 2013 to estimate abundance of all four Canadian Baffin Bay narwhal summer stocks as well as putative stocks in Jones Sound and Smith Sound. This is the first survey to count all of the narwhal stocks in the Canadian High Arctic during one summer (Fig. 2).

Narwhal abundance was estimated using a double-platform aerial survey. Three aircraft were used simultaneously to cover the vast survey area within a short time frame. Each stock range was divided in several strata, based on geographic boundaries as well as observed densities of narwhals from past surveys. Distance sampling methods were used to estimate detection probability away from the track line. Mark-recapture methods were used on the sighting data from two observers on each side of the aircraft to correct for the proportion of narwhals missed by visual observers (i.e., perception bias).

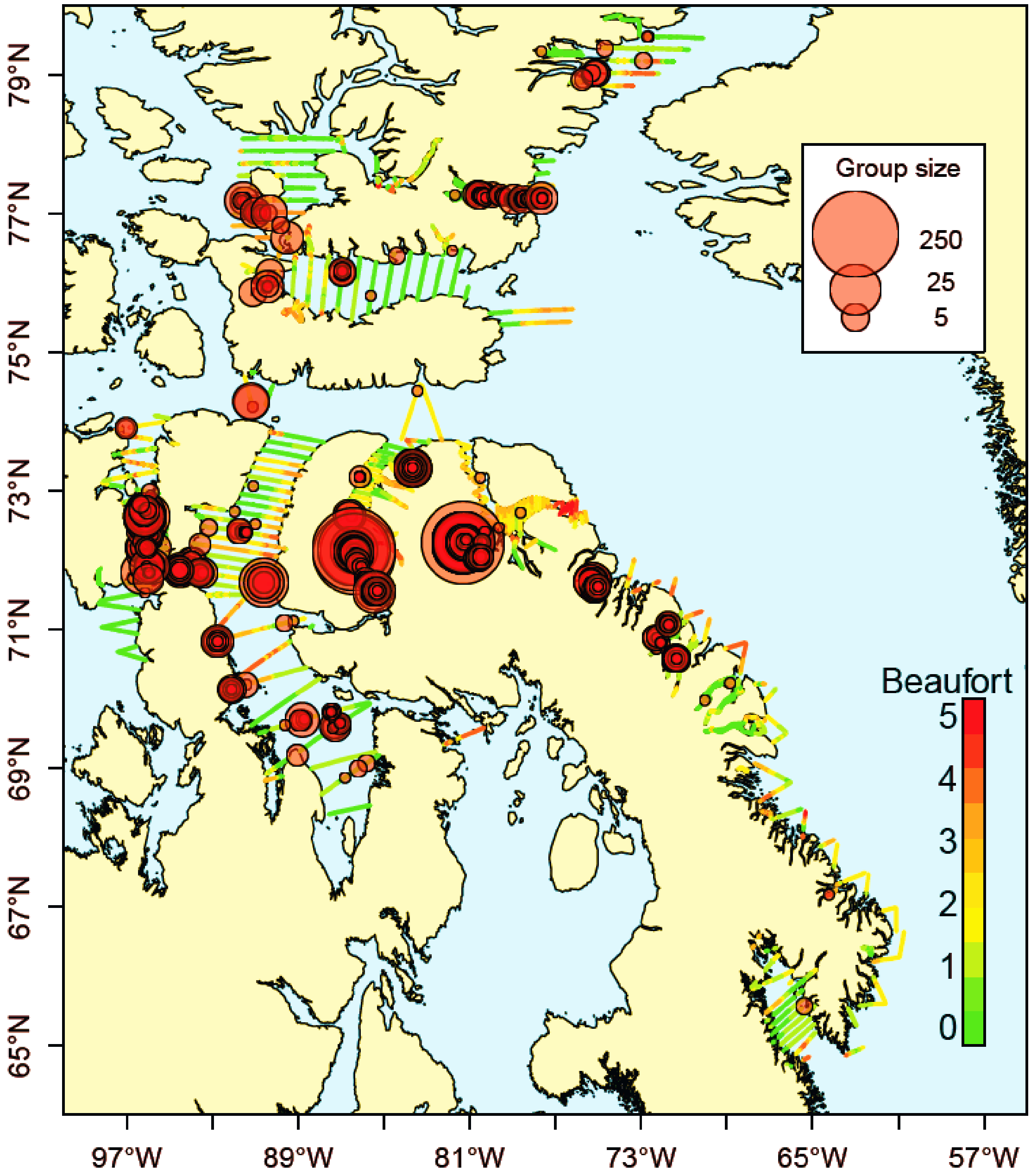

Figure 2. Unique sightings of narwhal groups made during the 2013 High Arctic Cetacean Survey (red circles). Lines represent realized effort with color scale showing Beaufort conditions.

Duplicate sightings (NAMMCO/SC/24-JCNB/SWG/2017-JWG/O06)
One of the key assumptions of distance sampling is that all animals on line are detected by observers. Double-platform methods have been developed to address situations of incomplete detection at the track line, but they require the identification of sightings seen by both observers. However, there is no means to independently and unequivocally determine whether or not a given pair of sightings is in fact a duplicate pair, or to select the most likely duplicate among a set of candidate sightings observed in close proximity. Most previous studies have used ad-hoc methods and arbitrary thresholds. Here, we develop a data-driven approach to identify single and duplicate sightings made during the 2013 High Arctic Cetacean Survey (HACS). We make use of four covariates to compare sightings made by front and rear observers: difference in time of sighting, difference in declination angle, difference in group size and difference in species identity. To estimate the relative weights of these covariates, we compared two datasets in a logistic regression framework: a set of sighting pairs that contain both duplicates and non-duplicates and a similar dataset known to contain no true duplicates (the observations made at the same time but on the other side of the plane). This allowed us to determine which combinations of factors were most successful at discriminating duplicates and to rate each candidate pair within the same-side data with an index of dissimilarity. Candidates with the lowest scores were identified as duplicates using two different methods and a range of threshold values for each covariate. Depending on the procedure used, 19% to 30% of narwhal sightings in the HACS dataset were seen by both observers, whereas 36% to 50% of bowhead whale sightings were seen by both observers. However, the aggregated nature of the sightings and particularly the relatively high proportion of missing primary data such as declination and group size made the identification of duplicates uncertain in many cases.

Density in Fjords (NAMMCO/SC/24-JCNB/SWG/2017-JWG/O05)
Previous studies have shown that narwhals spend time inside narrow inlets and fjords on their summer distribution range. Thus, any surveying effort must include these areas to provide a credible abundance estimate. Estimating abundance in fjords, however, creates logistical and statistical difficulties because of their narrow complex shapes and high cliffs, preventing the use of conventional distance sampling based on systematic transects. To address these issues, we used a two-stage cluster sampling design in which fjords designated as primary sampling units were selected in a way that maintained equal probability and systematic coverage. Within each fjord, we estimated density and abundance of narwhals using spatial density modelling. Density surface models do not require track lines to be designed according to a formal survey sampling scheme, and accommodates both non-random and unequal coverage. Moreover, the resulting variance of the abundance estimate incorporates both the variance from the detection function and that of the spatial model. Because no observations were made in West Ellesmere fjords, no abundance estimate was produced. Sightings of narwhals in the other fjords during HACS were highly variable. After expanding the abundance estimates to unsurveyed fjords, total (surface) abundance estimates were 45 for Jones Sound fjords (CV 94%), 1,916 (CV 45%) for Smith Sound fjords, 143 (CV 85%) for Admiralty Inlet fjords, 1,135 (CV 19%) for Eclipse Sound fjords, and 3,799 (CV 35%) for east Baffin Island fjords. Abundance estimates for the fjord strata will be added to other strata estimated via conventional distance sampling.

Discussion
The JWG discussed whether the density modelling could have been used for the entire area, rather than the traditional distance sampling. Density modelling is a new approach and there was some reluctance to use it for the entire survey. Rather, it was seen as a solution for the challenge of the fjords, not for use in the whole area.

The selection of which fjords to survey was done randomly, however certain fjords are known to be very important areas to survey. For the HACS, Makinson Inlet happened to be selected randomly, but if it had not been, this likely would have been problematic since it was the highest density strata (Fig. 3). One possibility would be to sub-stratify. Post-stratification was not seen as an option because there was limited previous knowledge of narwhal distributions in this area, and there was hesitation in making any assumptions.

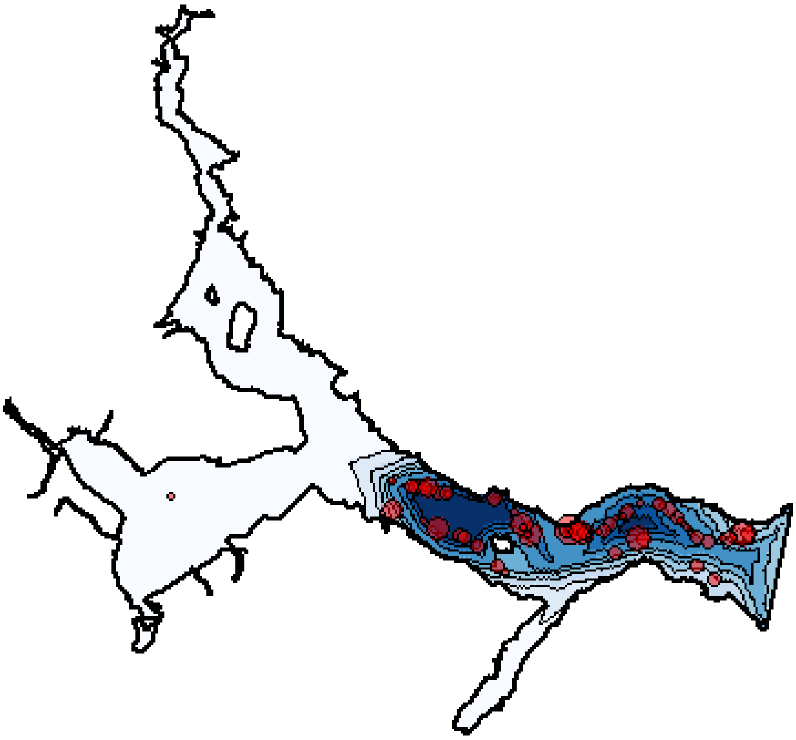

Figure 3. Spatial density surface of narwhal abundance in Mackinson Inlet (Smith Sound fjords stratum). Red line: track of aircraft. Red circles: sightings of narwhal groups. Darker shading indicates higher predicted density.

The JWG discussed the definition of the fjord strata, and that the strata as defined are potentially inflating the estimate. The JWG suggested creating a “near-shore” strata.

The comparison of the photographic data and the visual data has not been finalized, but preliminary results indicate close agreement in the estimates. The results of this comparison will be presented at the next JWG meeting.

<u>Abundance estimates</u>
Doniol-Valcroze et al (2015) contains the abundance estimates from the HACS.

Abundance estimates were obtained for each stock by combining standard Mark-Recapture Distance-Sampling estimates for off-shore strata and density spatial modelling estimates for fjord strata. Estimates were corrected for availability bias (narwhals that are not available for detection because they are submerged when the plane passes overhead) using a new analysis of satellite-linked time depth recorders transmitting information on the diving behaviour of narwhals in August.

Fully corrected abundance estimates were 12,694 (Coefficient of Variation [CV] 33%) for the Jones Sound stock, 16,360 (CV 65%) for the Smith Sound stock, 49,768 (CV 20%) for the Somerset Island stock, 35,043 (CV 42%) for the Admiralty Inlet stock, 10,489 (CV 24%) for the Eclipse Sound stock, and 17,555 (35%) for the East Baffin Island stock. Sources of uncertainty arise from the high level of clustering observed, particularly in Admiralty Inlet, Eclipse Sound and East Baffin Island, as well as the difficulty in identifying duplicate sightings between observers in large aggregations.

Discussion

The time in view was developed using 3 tags that classified dives starting at 8m, and these likely should not be used for the development of the correction factor. There is a need for data on the dive cycle. This will impact both the photographic and visual surveys.

The group size defined by observers can differ among observers for the same group and is likely influenced by the density of whales.

The JWG noted a similar problem in the HACS as the previously discussed 2016 survey in East Greenland, with the drop in the 0-100 meter bin of the detection function. This is likely not due to movement away from aircraft as the animals may have time to dive, but probably not enough time to swim away from trackline. Rather, the detection function is probably because it is difficult to see directly below the plane, and it is not always possible to look in every direction. Additionally, the speed of the sightings going by the plane at close distances means that there is less time for the observers to see the whales. Another possibility is the HACS was also a bowhead whale survey, and the observers may have been looking further from the plane to be able to detect bowhead whales. The HACS analysis accounted for this issue by using gamma curves fitted to the detection function, which better captures how observers see sightings.

The previously discussed problems with using SLTDRs for developing correction factors affects these results as well.

The JWG **agreed** to provisionally accept the HACS results, but provided recommendations to improve the analysis.

Recommendations:

- Investigate the issues surrounding the devices used to develop correction factors
    - Availability based on SLTDR
    - Time in view based on 8m dives
- Create a “near-shore” strata in Smith Sound. In the current analysis, the stratification of the fjords was too restricted, and the JWG recommended post-stratification to account for this. This would alleviate the issue of extrapolating high densities observed in coastal waters near the entrance of fjords to the large “offshore” strata.

12. Stock assessments and management advice narwhal

1983-84 Abundance estimate

The JWG discussed Larsen et al (1994) which discussed an aerial survey conducted in Scoresby Sound for narwhals in 1983 and 1984. The results of this survey have not been previously used in the assessments because it was a simple line-transect survey with no correction factors applied. The uncorrected numbers in Scoresby Sound fluctuated between ca 100-300. If corrected for perception and availability, the estimate is around 1000, which provides some agreement with the modelling of past abundance. The JWG **recommended** that the re-scaling of this estimate should be discussed fully at the next meeting.

East Greenland

NAMMCO/SC/24-JCNB/SWG/2017-JWG/14 examined the ability of the age structure from the East Greenland hunt (NAMMCO/SC/24-JCNB/SWG/2017-JWG/16) to update the estimates of annual survival and population dynamics growth. It showed that the assessment model is updating primarily the population dynamic growth rate, with an estimated annual production of 2% (90% CI:0-4%). A strong updating of the survival rate is dependent on a constrained growth rate. Given an assumed growth rate of zero, the model would update the survival rate. The associated estimate, however, is only 0.95 (90% CV:0.94-0.95), while the estimate from the more realistic model where the growth rate is estimated, is 0.97 (90% CI:0.96-0.99). This may explain why some earlier estimates of annual survival in beluga and narwhal from age structured data are lower than expected.

NAMMCO/SC/24-JCNB/SWG/2017-JWG/15 updated the assessment of East Greenland narwhal, given the new abundance estimates from 2016, the updated estimates from 2008, the updated age structure, and the new prior distributions that were agreed by the JWG. For both the Ittoqqortormiit and Kangerlussuaq fjords, the assessment estimates an annual production of 1% (90% CI: 0-3%). The decline in abundance that is suggested by the surveys in 2008 and 2016 is supported by the assessment even when the trend information of the abundance data was removed from the assessment. This suggests that the decline is real, and that the current catch levels are unsustainable.

The model estimates a continuous decline in the summer aggregation of Ittoqqortormiit from 1,420 (90% CI:920-2,120) individuals in 1980 to 580 (90% CI:330-980) individuals in 2017, and a somewhat smaller decline in Kangerlussuaq from 1,890 (90% CI:1,260-3,000) individuals in 1980 to 1,140 (90% CI:500-2,560) in 2017. Yet, the latter model is over estimating the abundance to some degree because the uncertainty of the abundance estimates is forcing the lower percentiles of the model against the boundary of extinction. In conclusion, the assessment estimates that total removals of no more than two to five individuals for Ittoqqortormiit, and of more than 10 to 13 individuals for Kangerlussuaq, are required to ensure a 70% chance of increase over the next five-year period.

Discussion

As discussed under Item 7.2, the JWG **agreed** to recognize three management areas for East Greenland (Tasiilaq, Kangerlussuaq, and Ittoqqortormiit). However, the JWG noted that the stock structure in East Greenland is very unclear, and it is possible that it could be many small populations. It is possible that animals from further north are supplying the hunt in Scoresby Sound. The JWG noted that more information is needed on the stock structure of East Greenland narwhals.

During the 2016 survey, there were less calves than were expected to be seen, and this should be explored further for the 2008 survey. Additionally, there no sightings of narwhals south of Kangerlussuaq. Although there are a lot of uncertainties with this population, the JWG is certain that there are not many narwhals. The distribution may be changing due to environmental changes, and the JWG recommends obtaining more information on distribution and movements (e.g. satellite tagging).

Management advice
Based on the assessment, the JWG agreed that catches should be reduced to less than 10 narwhals in both Ittoqqortormiit and Kangerlussuaq. In addition, the advice for the southern hunting areas applies only to Kangerlussuaq fjord. The JWG recommended that no catches are taken south of 68°N.

The catch advice will be updated with new abundance estimates from surveys in 2017. The information that we have on abundance (including the re-analysis of the 2008 survey which halved the abundance estimate) indicates that the harvest may be causing a population decline. This decline was confirmed by the model estimates, independent of the aerial survey results, lending more evidence of a real decline.

Recommendations
- Re-evaluation of the Larsen et al (1994) survey
- Aerial survey in Scoresby Sound rather than the Tasiilaq area (2017) (continue with the planned NE Greenland survey)
- Stock identity of the Scoresby Sound winter harvest

<u>Assessment on Baffin Bay narwhal stocks</u>

Canadian review of catch allocation model
Previously, there was a request from Canada to incorporate PBR into the catch allocation model for data poor populations. The JWG noted that if Canada wants to use PBR and Greenland does not, this may cause conflicts. The risk based assessment model is more conservative in data poor populations or populations that are declining, thus the PBR assessment may allow a larger removal than the risk model. For shared stocks if Canada used the PBR and Greenland used the risk model result then allowable takes from that population in Canada would be reduced by the quota in Greenland and where there was significant difference between the two methods, the quota in Greenland might exceed the PBR for the population leaving no takes for Canada. The JWG briefly discussed two options for implementing this request: 1) Using the risk based assessment results for data rich populations and for data poor populations using PBR when it was less than the risk based result. As noted above this would require some agreement between managers in Greenland and Canada to insure equitable distribution of takes. 2) Modify the risk based assessment model to meet the assumptions and criteria of the PBR assessment model; this would require a major overhaul of the assessment model and it would no longer be a Bayesian risk based assessment. The JWG intends publication of a peer-reviewed paper describing the JWG's catch allocation and assessment model, which may help address concerns with implementation of the model in Canada.

The JWG **recommends** continuing to use the catch allocation model for our advice.

13. Habitat Concerns for both narwhals and belugas

Baffinland Mary River Mine

The JWG expressed concern regarding development of mining activities and associated ship traffic on the Eclipse Sound narwhal stock. No similar example of such a high level of shipping and development has occurred in a high density narwhal habitat so there is little precedent to inform an assessment of the impacts. Of particular concern are:

4. Narwhal response to shipping activities is not well understood and may include threshold responses in which the narwhals abandon the disturbance area rather than habituate to the disturbance. In this case an irreversible loss of habitat may occur if the narwhals leave and do not re-inhabit the area even in the absence of shipping activity.
5. Ship strikes, lethal and sub-lethal effects of shipping activity may take significant numbers of narwhals. DFO (2014) estimated as many as 123 narwhal would be in the path of ships each year and be at risk of ship strike. Sub-lethal effects include disruption of feeding and communication, with potential consequences to energetics and reproduction. These impacts may negatively affect the sustainable removal levels of the Eclipse Sound stock which is shared between Greenland and Canada.
6. Risk of an oil or toxic spill in a high latitude area is compounded by the presence of ice and the remoteness from the necessary facilities and personnel for cleanup. It is poorly understood how a high arctic ecosystem would respond to an oil spill, the effects of which are likely detrimental and possibly irreversible.

Shipping/Icebreaking in Baffin Bay

The JWG expressed concern regarding shipping and icebreaking activities in the wintering grounds of narwhal and beluga in Baffin Bay where winter time shipping is unprecedented. Ship noise and icebreaking activities will disturb deep diving narwhal during a critical feeding period and may result in unpredictable response and displacement from preferred habitat of both species. Ice breaking will disrupt the distribution and condition of sea ice which may lead to ice entrapments. The risk from oil spill discussed above applies here as well and the JWG noted that there is no available method for cleaning up an oil spill in ice covered waters. A recent gas leak in Cook Inlet, Alaska has demonstrated the difficulties of responding to such an event.

The JWG also expressed concern that cumulative effects should be considered when new shipping and icebreaking activities are proposed for narwhal and beluga habitat areas.

13.1. Climate change impact on management advice

Workshop

Various aspects of climate change may be impacting certain populations of belugas and narwhals. One example is the lack of sightings of narwhals in the southern areas in East Greenland, which may indicate a shift in distribution and/or loss of range. The JWG recommends a workshop to address concerns over changes in management advice in response to the non-hunting takes and changes in distribution resulting from development and warming of the arctic. This workshop would take place over 1-2 days and could be joined with the next JWG (in 2019). The workshop will focus on the populations in West Greenland and Canada, but should include experts involved with changes in marine ecosystems and higher trophic animals in relation to climate change in the North Atlantic and Canadian Arctic (polar bears, walrus, etc.)

The Terms of Reference for the workshop will be to:

- Identify specific effects of climate change on belugas and narwhals
  - Request papers on changes in distribution, population dynamics, etc. resulting from climate change in Canada/Greenland waters
  - The focus will be less on the mechanism of the effects, and more on identifying simple predictors and possible consequences

- Identify specific ways that the JWG's advice may be informed by these effects
  - Climate change may affect timing and distribution of hunted populations.
  - Climate change may affect population model parameters used for assessment.
  - Development in the arctic may result in changes in habitat and carrying capacity as well as increased anthropogenic disturbance which may require changes in assessment models.

14. Other Business

Discussion/workshop on small populations

The JWG discussed the observations that small beluga populations appear to not recover once their abundance is below around 2000 individuals. Possible issues are limited mate selection, loss of "cultural" knowledge within the population or loss of habitat from a contraction of range. Modelling exercises could shed light on the causes of the lack of recovery, identifying other issues which should be examined for these small populations when even 0 catches do not result in recovery. This could be a one day workshop for a future JWG meeting.

Focus of the meeting

The participants noted that work procedures of the JWG should be discussed at a future meeting, of particular concern was the proportion of time given to reviewing general beluga and narwhal science and discussion and review of management advice. The concern being that the management advice is late on the agenda and may not be getting the time and consideration necessary.

Rapporteur

Rapporteuring has been done by NAMMCO although it is a joint working group of NAMMCO and JCNB. The JWG suggested that a second rapporteur be provided by the JCNB so that duties are shared between the two organizations in future meetings.

15. Review of Report

A draft version of the report was reviewed during the meeting, and the final version of the report was accepted via correspondence on 20 April 2017.

16. Closing

The JWG agreed that the next meeting should be held in March 2019 and will be hosted by Canada.

Hobbs thanked the participants for their hard work and discussions.

The meeting was closed at 17:30 on 11 March 2017.

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AGENDA

Wednesday 8 March

1. Opening Remarks
    1.1. Adoption of Joint Agenda
    1.2. Appointment of Rapporteurs
    1.3. Review of Available Documents

2. Review of population model
    2.1. Review of life history priors for beluga
    2.2. Review of life history priors for narwhal

Thursday 9 March

3. Stock structure beluga
4. Hunt removals beluga
5. Abundance belugas
6. Allocation of shared beluga stocks
7. Stock assessments and management advice belugas
8. Implementation of earlier advice on belugas
9. Habitat Concerns belugas
10. Traditional Knowledge belugas

Friday 10 March

11. Stock structure narwhal
    11.1. Genetics
12. Hunt removals narwhal
13. Habitat Concerns narwhal
14. Traditional Knowledge narwhal
15. Abundance w/ teleconference to Tomas after 1pm

Saturday 11 March

16. Stock assessments and management advice narwhal
17. Implementation of earlier advice on narwhals
18. Other business
    18.1. Climate change impact on management advice (workshop?)
19. Review of Report
20. Closing

List of Documents

Working Documents

Number: NAMMCO/SC/24-JCNB/SWG/2017-JWG/XX	Title	Agenda Item
01	Draft Agenda	
02	Participants List	
03	Document List	
04	Lorenzen and Skrovind. Genomic identification of narwhal and beluga stocks	11.1
05	Heide Jørgensen. The East Greenland Connection: movement of a narwhal from Kangerlussuaq to Scoresby Sound	11
06rev	Heide-Jørgensen and Garde. Catch statistics for belugas in Greenland 1862 to 2016	4
07	Heide-Jørgensen and Garde et al. Reconstructing catch statistics for narwhals in Greenland 1862 to 2016	12
08	Watt and Hall. Catch Statistics for Narwhal in Canada from 1970-2015	12
08a	Catch tables (data for paper 08 Watt and Hall)	
08b	Copy of narwhal...(data for paper 08 Watt and Hall)	
08c	Kill dates by community... (data for paper 08 Watt and Hall)	
08d	Narwhal struck and lost (data for paper 08 Watt and Hall)	
09	Ditlevesen. Priors for Analysis of Belugas	2.1
10	Higdon & Ferguson. Database of aerial surveys and abundance estimates for beluga whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) in the Canadian Arctic	5, 15
11rev	Stewart B. Age estimates of narwhal (*Monodon monoceros*) derived from growth-layer groups (GLGs) in the dentine of embedded tusks–Developmental constraints and best practices.	2.2
12	Young & Ferguson. Canadian beluga harvest from Baffin Bay.	4
13	Witting, L. Assessment of West Greenland beluga – 2017	7
14	Witting. L. Age structure in East Greenland	16
15	Witting. L. Narwhals East Greenland	16
16	Garde and Heide-Jørgensen. Update on life history parameters of narwhals (*Monodon monoceros*) from East and West Greenland	2
17	Riisager-Pedersen et al. East Greenland narwhal depth correction factor for aerial surveys	15

Number: NAMMCO/SC/24-JCNB/SWG/2017-JWG/XX	**Title**	**Agenda Item**
18	Hansen et al. Abundance of narwhals at the hunting areas in East Greenland in 2008 and 2016	15
19	Tervo et al. Comparing satellite transmitted and archival depth data – TAD versus TDR	11

For Information Documents

Number: NAMMCO/SC/24-JCNB/SWG/2017-JWG/X	**Title**	**Agenda Item**
O01	Marcoux and Hammill. Model estimates of Cumberland Sound beluga (*Delphinapterus leucas*)	7
O02	Watt et al. Narwhal availability bias.	16
O03	Doniol-Valcroze et al. Abundance estimates of narwhal stocks in the Canadian High Arctic in 2013	15
O04	SAR2015 High Arctic Survey	15
O05	Doniol-Valcroze et al. Spatial modelling of narwhal density in fiords during the 2013 High Arctic Cetacean Survey (HACS)	15
O06	Pike and Doniol-Valcroze. Identification of duplicate sightings from the 2013 double-platform High Arctic Cetacean Survey	15
O07rev	Watt et al. Harvest allocation modelling for narwhal (*Monodon monoceros*) stocks shared between eastern Canada and West Greenland	16
O08	SAR2017 Harvest allocation modelling for Baffin Bay narwhal stocks	16
O09	Watt et al. Effect of the 2015 narwhal (*Monodon monoceros*) entrapment on the Eclipse Sound narwhal stock	16
O10	Richard et al. Assessment of the winter range of Baffin Bay narwhals	13
O11	NAMMCO-JCNB JWG March 2015 Report	many
O12	Heide-Jørgensen et al 2017. Long-term tag retention on two species of small cetaceans	3
O13	Garde et al. 2015. Life history parameters of narwhals (*Monodon monoceros*) from Greenland	2
O14	Watt et al. 2017. Spatial distribution of narwhal (*Monodon monoceros*) diving for Canadian populations helps identify important seasonal foraging areas	13
O15	Heide-Jørgensen and Laidre 2015. Surfacing time, availability bias and abundance of humpback whales in West Greenland	15

Number: NAMMCO/SC/24-JCNB/SWG/2017-JWG/X	**Title**	**Agenda Item**
O16	Garde et al. 2012. Aspartic acid racemization rate in narwhal (*Monodon monoceros*) eye lens nuclei estimated by counting of growth layers in tusks	2
O17	Hobbs et al. Viability of a Small, Geographically-isolated Population of Beluga Whales, *Delphinapterus leucas*: Effects of Hunting, Predation, and Mortality Events in Cook Inlet, Alaska	
O18	Heide-Jørgensen et al. The predictable narwhal: satellite tracking shows behavioural similarities between isolated subpopulations	
O19	Heide-Jørgensen et al. (2016) Rebuilding beluga stocks in West Greenland.	
O20	Geometer status update	
O21	CSAS 2013/024	
O22	NAMMCO/24/MC/8 Disturbance Symposium Report	
O23	Larsen et al 1994. Line-transect estimation of abundance of narwhals (*Monodon monoceros*) in Scoresby Sund and adjacent waters	

Catch Tables

Table 1. Landed catches of beluga whales *(Delphinapterus leucas)* reported by select Nunavut communities for the past five years (2011-2015). Catch reporting for the 2016-2017 harvest year will be complete by 31 March 2017.

			Landed Catches by Harvest Year º				
Beluga Population	Community	Quota ¥	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Baffin Bay	Arctic Bay	NRQ	0	2	0	0	0
	Clyde River	NRQ	0	0	0	n.r.	1
	Gjoa Haven	NRQ	10	4	5	n.r.	10
	Grise Fiord	NRQ	0	n.r.	0	3	3
	Hall Beach	NRQ	8	n.r.	0	19	7
	Igloolik	NRQ	42	n.r.	0	n.r.	n.r.
	Kugaaruk	NRQ	0	0	0	1	0
	Kugluktuk	NRQ	21	0	0	n.r.	0
	Pond Inlet	NRQ	0	0	0	n.r.	0
	Qikiqtarjuaq	NRQ	0	n.r.	n.r.	n.r.	0
	Resolute Bay	NRQ	4	6	76	8	4
	Taloyoak	NRQ	0	0	n.r.	n.r.	3
	Total						
			Landed Catches by Harvest Year				
Cumberland Sound	Community	Quota [1]	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
	Pangnirtung	41	42	41	41	41	18 §
	Total						

¥ NRQ = No Regulatory Quota

º n.r. = no record received

§ The large amount of ice present in Cumberland Sound during the summer of 2015 limited the beluga harvest in Pangnirtung.

Table 2. Catches of belugas in three areas in West Greenland with three options for corrections of catch numbers. 'North' includes Qaanaaq, Upernavik and Uummannaq, 'Central' includes Disko Bay with the municipalities Kangaatsiaq, Aasiaat, Qasigiannguit, Ilulissat and Qeqertarsuaq, and 'South' includes Sisimiut, Maniitsoq, Nuuk and Paamiut. Last column show the catches with ice entrapments subtracted from the Central area. For 1954-1974 a *low* and a *medium option* correct for lack of catch reports from Qaanaaq. For 1975-1985 a correction factor for unreported catches is applied to Upernavik (*low option*) and to all areas (*medium option*). For 1986-1992 a *low* and a *medium option* correct for lack of catch reports from Qaanaaq and Sisimiut. For 1993-2016 the high option was applied to catches in the North (10%), Central (30%) and South (30%).

	NORTH			CENTRAL			SOUTH			TOTAL			TOTAL WITHOUT ICE ENTRAPMENTS		
YEAR	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
1954	95	186	205	1774	1774	2306	23	23	30	1892	1983	2541	118	209	767
1955	31	122	134	275	275	358	12	12	16	318	409	507	318	409	507
1956	35	126	139	373	373	485	34	34	44	442	533	668	442	533	668
1957	35	126	139	391	391	508	95	95	124	521	612	770	521	612	770
1958	25	116	128	182	182	237	36	36	47	243	334	411	243	334	411
1959	42	133	146	243	243	316	42	42	55	327	418	517	277	368	467
1960	37	128	141	179	179	233	18	18	23	234	325	397	234	325	397
1961	53	53	58	219	219	285	73	73	95	345	345	438	345	345	438
1962	101	101	111	186	186	242	42	42	55	329	329	408	329	329	408
1963	105	105	116	93	93	121	31	31	40	229	229	277	229	229	277
1964	135	135	149	166	166	216	30	30	39	331	331	403	331	331	403
1965	223	223	245	214	214	278	51	51	66	488	488	590	488	488	590
1966	131	222	244	398	398	517	50	50	65	579	670	827	579	670	827
1967	118	209	230	369	369	480	127	127	165	614	705	875	564	655	825
1968	180	271	298	1013	1013	1317	84	84	109	1277	1368	1724	1043	1134	1490
1969	165	256	282	661	661	859	170	170	221	996	1087	1362	996	1087	1362
1970	357	357	393	1133	1133	1473	34	34	44	1524	1524	1910	474	474	860
1971	243	243	267	328	328	426	168	168	218	739	739	912	739	739	912
1972	336	427	470	362	362	471	161	161	209	859	950	1150	859	950	1150
1973	313	404	444	581	581	755	191	191	248	1085	1176	1448	1085	1176	1448
1974	231	231	254	512	512	666	170	170	221	913	913	1141	913	913	1141

	NORTH			CENTRAL			SOUTH			TOTAL			TOTAL WITHOUT ICE ENTRAPMENTS		
YEAR	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
1975	254	270	297	268	331	430	167	206	268	689	807	995	689	807	995
1976	157	172	189	953	1177	1530	120	148	192	1230	1497	1912	844	1259	191
1977	395	419	461	379	468	608	121	149	194	895	1036	1263	895	1036	1263
1978	192	207	228	452	558	725	99	122	159	743	887	1112	743	887	1112
1979	356	367	404	379	468	608	65	80	104	800	915	1116	800	915	1116
1980	366	396	436	412	509	662	155	191	248	933	1096	1346	933	1096	1346
1981	594	635	699	340	420	546	163	201	261	1097	1256	1506	1097	1256	1506
1982	550	584	642	313	386	502	108	133	173	971	1103	1317	871	1003	1217
1983	360	377	415	194	240	312	102	126	164	656	743	891	656	742	888
1984	447	456	502	352	435	566	42	52	68	841	943	1135	621	723	915
1985	428	474	521	177	219	285	50	62	81	655	755	887	655	755	887
1986	520	623	685	114	114	148	48	96	125	682	833	958	682	833	958
1987	579	682	750	29	29	38	60	108	140	668	819	928	668	819	928
1988	141	244	268	125	125	163	46	94	122	312	463	553	187	338	428
1989	445	548	603	30	30	39	86	134	174	561	712	816	561	712	816
1990	356	356	392	684	684	889	69	117	152	1109	1157	1433	609	657	933
1991	450	450	495	100	100	130	46	94	122	596	644	747	596	644	747
1992	677	780	858	26	26	34	46	94	122	749	900	1014	749	900	1014
1993	473	473	520	191	191	248	118	118	153	782	782	922	782	782	922
1994	231	231	254	239	239	311	148	148	192	618	618	757	618	618	757
1995	296	296	326	301	301	391	187	187	243	784	784	960	784	784	960
1996	114	114	125	244	244	317	183	183	238	541	541	681	541	541	681
1997	208	208	229	228	228	296	120	120	156	556	556	681	556	556	681
1998	275	275	303	304	304	395	135	135	176	714	714	873	714	714	873
1999	250	250	275	184	184	239	58	58	75	492	492	590	492	492	590
2000	332	332	365	202	202	263	78	78	101	612	612	729	612	612	729
2001	161	161	177	207	207	269	87	87	113	455	455	559	455	455	559
2002	246	246	271	149	149	194	35	35	46	430	430	510	430	430	510

Appendix 4.

	NORTH			CENTRAL			SOUTH			TOTAL			TOTAL WITHOUT ICE ENTRAPMENTS		
YEAR	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
2003	189	189	208	149	149	194	74	74	96	412	412	498	412	412	498
2004	24	24	26	96	96	125	73	73	95	193	193	246	193	193	246
2005	42	42	46	102	102	133	40	40	52	184	184	231	184	184	231
2006	53	53	58	49	49	64	35	35	46	137	137	168	137	137	168
2007	29	29	32	59	59	77	28	28	36	116	116	145	116	116	145
2008	217	217	239	58	58	75	12	12	16	287	287	330	287	287	330
2009	165	165	182	53	53	69	27	27	35	245	245	286	245	245	286
2010	121	121	133	60	60	78	7	7	9	188	188	220	188	188	220
2011	75	75	83	67	67	87	8	8	9	150	150	179	150	150	179
2012	148	148	163	58	58	75	5	5	7	211	211	245	211	211	245
2013	212	212	233	52	52	68	40	40	52	304	304	353	304	304	353
2014	176	176	194	71	71	92	24	24	31	271	271	317	271	271	317
2015	36	36	40	73	73	95	16	16	21	125	125	156	125	125	156
2016	95	95	105	79	79	103	29	29	38	203	203	246	203	203	246

Table 3. Catches of belugas in East Greenland. Data from 1955-1990 from Dietz et al. (1994) and data from 1993-2016 from Piniarneq.

Year	Ittoqqortormiit	Tasiilaq	All
1955			
1956	1	2	3
1957			
1958			
1959	2	3	5
1960	0	1	1
1961			
1962	0	1	1
1963	0	1	1
1964			
1965	5	0	5
1966	1	0	1
1967			
1968			
1969	2	0	2
1970	0	1	1
1971	0	1	1
1972	0	18	18
1973	1	2	3
1974	1	7	8
1975			
1976	0	1	1
1977	0	1	1
1978			
1979			
1980			
1981			
1982			
1983			
1984	15	0	15
1985			
1986	0	15	15
1987			
1988			
1989			
1990			
1991			
1992			
1993	0	8	8
1994	0	0	0
1995	0	0	0
1996	0	0	0
1997	0	1	1
1998	0	0	0
1999	0	0	0
2000	1	3	4
2001	0	1	1
2002	0	0	0
2003	0	12	12
2004	0	0	0
2005	0	1	1
2006	0	0	0
2007	0	1	1

Year	Ittoqqortormiit	Tasiilaq	All
2008	0	0	0
2009	0	0	0
2010	0	0	0
2011	0	0	2
2012	2	0	0
2013	0	0	0
2014	0	0	0
2015	0	0	0
2016	0	0	0

Table 4. Seasonal harvest of narwhals multiplied by a struck and loss factor for each hunting region in Canada. AB = Arctic Bay, GF = Grise Fiord, PI = Pond Inlet, CCA = Central Canadian Arctic (includes the communities of Kugaaruk, Hall Beach, Igloolik, Gjoa Haven, Resolute Bay, Creswell Bay, and Taloyoak), BIC = Baffin Island Central (includes the communities of Clyde River and Qikiqtarjuaq), and BIS = Baffin Island Sound (includes the communities of Pangnirtung and Iqaluit). Superscript F = fall, Sp = spring, S = summer, and W = winter.

Year	AB^{F}	AB^{Sp}	AB^{S}	GF^{F}	GF^{Sp}	GF^{S}	PI^{F}	PI^{Sp}	PI^{S}	CCA^{F}	CCA^{Sp}	CCA^{S}	CCA^{W}	BIC^{F}	BIC^{Sp}	BIC^{S}	BIS^{F}	BIS^{Sp}	BIS^{S}
1970	21	112	22	34	11	37	30	145	75	18	4	30	0	30	7	12	1	8	2
1971	21	112	23	17	6	19	30	141	74	21	4	32	0	43	10	20	3	26	4
1972	23	121	26	5	2	7	8	44	22	20	4	35	0	28	6	14	4	27	5
1973	33	183	37	12	3	18	60	264	136	30	4	62	0	11	3	6	0	0	1
1974	10	66	12	3	2	6	29	139	63	18	3	32	0	56	13	26	4	34	5
1975	30	220	35	3	2	6	25	107	46	19	6	36	0	17	4	12	4	34	4
1976	22	147	27	5	4	9	40	171	78	17	7	33	0	18	5	12	2	16	2
1977	19	23	22	0	0	0	34	144	69	36	0	13	0	111	0	14	0	6	0
1978	12	83	16	0	0	0	48	198	100	5	5	14	0	29	6	15	1	3	0
1979	8	42	6	19	0	2	0	118	97	15	0	4	0	23	25	6	3	23	27
1980	18	160	0	0	0	0	34	121	66	1	1	44	0	75	14	50	0	40	0
1981	20	113	34	0	0	0	29	101	58	86	0	20	0	77	15	52	23	53	8
1982	19	99	31	0	0	45	0	188	52	0	4	73	0	103	0	9	27	56	11
1983	14	141	18	2	0	3	78	81	71	29	0	64	0	36	38	42	0	4	2
1984	0	164	5	0	2	2	8	94	8	0	0	0	0	66	15	60	0	68	0
1985	0	183	0	2	7	6	62	141	27	8	11	18	0	5	8	78	0	36	2
1986	29	87	45	0	2	2	31	113	83	5	4	10	0	11	2	7	26	22	8
1987	7	22	11	0	2	2	17	57	44	6	4	11	0	65	9	35	0	0	0
1988	24	75	39	1	6	6	16	55	49	8	4	12	0	56	17	44	2	1	0
1989	27	86	46	1	4	4	25	74	74	11	7	21	0	74	15	47	34	28	9
1990	16	39	28	3	9	12	14	32	39	8	4	17	0	61	8	35	2	3	1
1991	26	65	49	3	10	13	21	46	55	15	4	18	0	66	10	40	5	3	2
1992	29	56	41	0	1	1	19	48	54	7	3	23	0	53	8	38	3	2	1
1993	22	46	36	1	5	6	15	38	43	10	5	30	0	65	9	43	15	12	5
1994	25	54	42	3	6	7	21	44	47	12	4	28	0	58	8	36	21	16	6
1995	16	33	9	2	5	5	0	90	0	12	3	26	0	61	8	34	4	3	1
1996	20	59	43	0	0	1	26	40	57	7	1	13	0	28	3	14	14	8	3
1997	13	40	29	0	0	1	21	28	43	12	2	21	0	57	5	26	1	1	0
1998	18	54	41	2	4	7	2	21	106	17	4	47	0	57	5	29	2	2	1

Year	AB_F	AB_{Sp}	AB_S	GF_F	GF_{Sp}	GF_S	PI_F	PI_{Sp}	PI_S	CCA_F	CCA_{Sp}	CCA_S	CCA_W	BIC_F	BIC_{Sp}	BIC_S	BIS_F	BIS_{Sp}	BIS_S
1999	16	49	45	2	8	11	39	17	106	8	3	12	0	79	1	29	25	14	4
2000	23	66	64	2	8	11	58	69	79	12	2	38	0	153	18	79	0	9	44
2001	24	67	71	3	12	16	21	27	32	37	6	54	0	108	13	53	14	11	1
2002	63	22	11	0	3	0	0	48	29	21	0	37	0	73	0	98	30	9	0
2003	15	60	84	0	0	10	10	32	40	2	4	32	0	105	12	73	1	36	0
2004	21	81	50	9	0	3	39	27	14	59	0	13	0	94	34	71	21	12	0
2005	1	83	93	0	1	0	20	26	25	26	0	43	0	133	14	10	6	0	0
2006	3	170	3	0	0	26	20	25	56	73	1	73	0	111	5	45	1	0	0
2007	5	90	72	0	4	21	32	8	35	12	0	44	0	120	10	31	0	4	1
2008	35	65	78	5	0	23	9	16	58	8	0	45	0	65	2	52	22	0	4
2009	1	23	150	0	5	1	21	24	6	46	3	22	0	93	9	25	40	10	0
2010	32	51	89	0	10	16	37	20	15	14	2	48	0	76	17	77	20	14	1
2011	26	38	112	2	14	10	3	45	81	4	8	51	0	125	7	23	4	2	0
2012	100	4	65	0	2	17	23	25	63	23	0	47	0	98	9	31	10	0	1
2013	4	43	167	4	5	0	58	30	82	23	1	33	0	143	11	9	18	3	1
2014	81	63	46	9	1	0	59	33	63	32	0	45	0	140	16	22	11	1	0
2015	165	20	107	0	0	9	94	28	97	38	0	43	2	111	0	52	0	0	0

Table 5. Construction of time series of catches of narwhals from 1862 through 2014 by provisional stock divisions. Catches during 1877-1886 and 1889-1891 were created as the average of five years before and two years after the period. Catches between 1894 and 1902 were set to the average of five years before and after the period. The period 1935-1948 was constructed as linear extrapolations of the catches before and after the period. Catches for the period for 1949-1954 and 1959-1960 were calculated as the average of the catches for the period 1955 to 1958 (minus ice entrapments). Catches for Inglefield Bredning was arbitrarily set to 25 whales per year for 1862 to 1899 and to 50 for 1900 to 1934. From 1935 to 1960 catches were increased linearly from 50 to 134 in Inglefield Bredning. For 1959 to 1974 catches were distributed between Upernavik, Uummannaq and Disko Bay in proportion to the relative change in catch levels before and after that period.
After 1983 catches in Savissivik in Qaanaaq municipality are allocated to the Upernavik-Melville Bay stock together with catches from Upernavik municipality. From 1993-2010 catches in Siorapaluk are subtracted from the catches in Inglefield Bredning as they are assumed to be from the Smith Sound stock, however in 2011 this practice was changed to allocate any catches from Qaanaaq with location data north of Siorapaluk to the Smith Sound. Catches from all areas south of Disko Bay are assumed to come from the Disko Bay stock. Ice entrapments are subtracted from catches. Values for years with no catch reporting are constructed as the average of three years before and after the missing year. In the *low option* catches from Inglefield Bredning and Melville Bay are corrected for underreportings needed to sustain the purchases of mattak. Before 1950 all catches under the high option are corrected for a loss rate of 5%. After 1950 catches in Inglefield Bredning and Smith Sound are under the *high option* corrected for a loss rate of 5%, catches in Melville Bay are corrected for losses of 15% and catches in Uummannaq and Disko Bay and corrected for a 30% loss rate. The quality of the data is assessed based on the amount of corrections needed where LQ=low quality, MQ=moderate quality, R=reliable and P=preliminary.

Stock	Quali	Smith Sound			Inglefield Bredning			Melville Bay			Uummannaq			Disko Bay and south		
Year	-ty of data	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
1862	LQ				25	25	26	29	29	30	4	4	4	45	45	47
1863	LQ				25	25	26	24	24	25	12	12	13	43	43	45
1864	LQ				25	25	26	42	42	44	30	30	32	70	70	74
1865	LQ				25	25	26	16	16	17	30	30	32	35	35	37
1866	LQ				25	25	26	32	32	34	20	20	21	72	72	76
1867	LQ				25	25	26	38	38	40	22	22	23	96	96	101
1868	LQ				25	25	26	17	17	18	11	11	12	55	55	58
1869	LQ				25	25	26	46	46	48	37	37	39	136	136	143
1870	LQ				25	25	26	23	23	24	80	80	84	106	106	111
1871	LQ				25	25	26	32	32	34	35	35	37	102	102	107
1872	LQ				25	25	26	22	22	23	46	46	48	103	103	108
1873	LQ				25	25	26	29	29	30	21	21	22	88	88	92
1874	LQ				25	25	26	32	32	34	13	13	14	106	106	111
1875	LQ				25	25	26	22	22	23	17	17	18	73	73	77
1876	LQ				25	25	26	24	24	25	23	23	24	80	80	84
1877	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1878	LQ				25	25	26	28	28	29	28	28	29	98	98	103

Stock Year	Quali-ty of data	Smith Sound			Inglefield Bredning			Melville Bay			Uummannaq			Disko Bay and south		
		LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
1879	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1880	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1881	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1882	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1883	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1884	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1885	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1886	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1887	LQ				25	25	26	32	32	34	38	38	40	117	117	123
1888	LQ				25	25	26	32	32	34	38	38	40	117	117	123
1889	LQ				25	25	26	29	29	30	35	35	37	105	105	110
1890	LQ				25	25	26	29	29	30	35	35	37	105	105	110
1891	LQ				25	25	26	29	29	30	35	35	37	105	105	110
1892	LQ				25	25	26	31	31	33	42	42	44	102	102	107
1893	LQ				25	25	26	31	31	33	42	42	44	102	102	107
1894	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1895	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1896	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1897	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1898	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1899	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1900	LQ				50	50	53	31	31	33	36	36	38	87	87	91
1901	LQ				50	50	53	31	31	33	36	36	38	87	87	91
1902	LQ				50	50	53	31	31	33	36	36	38	87	87	91
1903	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1904	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1905	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1906	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1907	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1908	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1909	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1910	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1911	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1912	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1913	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1914	LQ				50	50	53	50	50	53	62	62	65	112	112	118

Stock Year	Quali -ty of data	Smith Sound			Inglefield Bredning			Melville Bay			Uummannaq			Disko Bay and south		
		LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
1915	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1916	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1917	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1918	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1919	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1920	LQ				50	50	53	46	46	48	42	42	44	74	74	78
1921	LQ				50	50	53	46	46	48	42	42	44	74	74	78
1922	LQ				50	50	53	46	46	48	42	42	44	74	74	78
1923	LQ				50	50	53	46	46	48	42	42	44	74	74	78
1924	LQ				50	50	53	46	46	48	42	42	44	74	74	78
1925	LQ				50	50	53	43	43	45	55	55	58	58	58	61
1926	LQ				50	50	53	43	43	45	55	55	58	58	58	61
1927	LQ				50	50	53	43	43	45	55	55	58	58	58	61
1928	LQ				50	50	53	43	43	45	55	55	58	58	58	61
1929	LQ				50	50	53	43	43	45	55	55	58	58	58	61
1930	LQ				50	50	53	43	43	45	53	53	56	87	87	91
1931	LQ				50	50	53	43	43	45	53	53	56	87	87	91
1932	LQ				50	50	53	43	43	45	53	53	56	87	87	91
1933	LQ				50	50	53	43	43	45	53	53	56	87	87	91
1934	LQ				50	50	53	43	43	45	53	53	56	87	87	91
1935	LQ				53	53	56	42	42	44	50	50	53	83	83	87
1936	LQ				56	56	59	41	41	43	48	48	50	78	78	82
1937	LQ				59	59	62	40	40	42	45	45	47	74	74	78
1938	LQ				62	62	65	39	39	41	42	42	44	70	70	74
1939	LQ				66	66	69	38	38	40	39	39	41	65	65	68
1940	LQ				69	69	72	37	37	39	37	37	39	61	61	64
1941	LQ				72	72	76	36	36	38	34	34	36	57	57	60
1942	LQ				75	75	79	36	36	38	31	31	33	52	52	55
1943	LQ				78	78	82	35	35	37	28	28	29	48	48	50
1944	LQ				81	81	85	34	34	36	26	26	27	44	44	46
1945	LQ				84	84	88	33	33	35	23	23	24	39	39	41
1946	LQ				87	87	91	32	32	34	20	20	21	35	35	37
1947	LQ				90	90	95	31	31	33	17	17	18	31	31	33
1948	LQ				94	94	99	30	30	32	15	15	16	26	26	27
1949	LQ				97	97	102	29	29	30	12	12	13	22	22	23
1950	LQ				100	100	105	29	29	30	12	12	13	22	22	23

Stock	Quali	Smith Sound			Inglefield Bredning			Melville Bay			Uummannaq			Disko Bay and south		
Year	-ty of data	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
1951	LQ				103	103	108	29	29	33	12	12	16	22	22	29
1952	LQ				106	106	111	29	29	33	12	12	16	22	22	29
1953	LQ				109	109	114	29	29	33	12	12	16	22	22	29
1954	LQ				112	112	118	29	29	33	12	12	16	22	22	29
1955	LQ				115	115	121	23	23	26	2	2	3	14	14	18
1956	LQ				118	118	124	15	15	17	32	32	42	21	21	27
1957	LQ				122	122	128	55	55	63	11	11	14	8	8	10
1958	LQ				125	125	131	24	24	28	3	3	4	46	46	60
1959	LQ				128	128	134	25	25	29	11	11	14	21	21	27
1960	LQ				131	131	138	24	24	28	12	12	16	24	24	31
1961	MQ				134	134	141	29	29	33	15	15	20	26	26	34
1962	MQ				182	182	191	12	12	14	7	7	9	12	12	16
1963	MQ				275	275	289	16	16	18	10	10	13	16	16	21
1964	MQ				275	275	289	16	16	18	11	11	14	18	18	23
1965	LQ				210	210	220	35	35	40	25	25	33	40	40	52
1966	LQ				203	203	213	36	36	41	28	28	36	47	47	61
1967	LQ				196	196	206	33	33	38	28	28	36	50	50	65
1968	LQ				189	189	198	50	50	58	46	46	60	83	83	108
1969	LQ				182	182	191	37	37	43	37	37	48	82	82	107
1970	LQ				175	175	184	61	61	70	66	66	86	99	99	129
1971	LQ				168	168	176	39	39	45	46	46	60	103	103	134
1972	LQ				161	161	169	21	21	24	27	27	35	60	60	78
1973	LQ				154	154	162	46	46	53	64	64	83	92	92	120
1974	LQ				147	147	155	30	30	35	47	47	61	64	64	83
1975	LQ				140	140	147	54	54	62	11	11	14	51	51	66
1976	LQ				133	133	140	22	22	25	27	27	35	57	57	74
1977	LQ				126	126	133	62	62	71	113	113	147	31	31	40
1978	MQ				110	110	116	56	56	64	183	183	238	263	263	342
1979	MQ				120	120	126	22	22	25	132	132	172	103	103	134
1980	MQ				130	130	137	61	61	70	146	146	190	125	125	163
1981	MQ				160	160	168	83	83	95	140	140	182	268	268	348
1982	MQ				164	164	172	59	59	68	162	162	211	76	76	99
1983	MQ				135	135	142	72	72	83	164	164	213	68	68	88
1984	MQ				274	274	288	80	80	92	210	210	273	67	67	87
1985	MQ				115	115	121	34	34	39	39	39	51	68	68	88
1986	LQ				165	165	173	81	81	93	97	97	126	59	156	203

Stock	Quali	Smith Sound			Inglefield Bredning			Melville Bay			Uummannaq			Disko Bay and south		
Year	-ty of data	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
1987	LQ				155	155	163	145	145	167	334	334	434	26	156	203
1988	LQ				145	145	153	*85*	85	98	226	226	294	*35*	156	203
1989	LQ				136	136	142	37	37	43	288	288	374	7	156	203
1990	LQ				126	126	132	127	127	146	1019	1019	1325	11	156	203
1991	LQ				116	116	122	90	90	104	223	223	290	40	156	203
1992	LQ				106	106	111	37	37	43	288	288	374	7	156	203
1993	R	4	4	4	104	104	109	102	102	117	301	301	391	103	103	134
1994	R	2	2	2	90	90	95	150	150	173	297	297	386	156	156	203
1995	R	0	0	0	88	88	92	113	113	130	159	159	207	125	125	163
1996	R	0	0	0	37	37	39	77	77	89	405	405	527	172	172	224
1997	R	4	4	4	54	54	57	98	98	113	381	381	495	209	209	272
1998	R	3	3	3	68	68	71	128	128	147	344	344	447	227	227	295
1999	R	17	17	18	87	87	91	130	130	150	253	253	329	258	258	335
2000	R	20	20	21	85	85	89	154	154	177	106	106	138	196	196	255
2001	R	30	30	32	98	98	103	172	172	198	95	95	124	140	140	182
2002	R	23	23	24	58	58	61	177	177	204	180	180	234	125	125	163
2003	R	35	35	37	66	66	69	158	158	182	174	174	226	121	121	157
2004	R	52	52	55	111	111	117	68	68	78	67	67	87	76	76	99
2005	R	52	52	55	79	79	83	77	77	89	161	161	209	39	39	51
2006	R	19[a]	19	20	55[a]	55	58	80[b]	80	92	72[c]	72	94	56[c]	56	73
2007	R	0[d]	0	0	134[d]	134	141	107[e]	107	123	67[c]	67	87	66[c]	66	86
2008	R	7	7	7	122	122	140	92	92	120	87	87	113	47	47	61
2009	R	6	6	6	84	84	97	136	136	177	91	91	118	89	89	116
2010	R	9	9	10	99	99	114	40	40	52	42	42	55	45	45	59
2011	R	2	2	2	53	53	56	79	79	91	77	77	100	40	40	52
2012	R	3	3	3	128	128	134	83	83	96	42	42	55	55	55	72
2013	R	0	0	0	83	83	87	71	71	82	78	78	101	51	51	66
2014	R	0	0	0	102	102	107	113	113	130	69	69	90	50	50	65
2015	R	0	0	0	75	75	79	71	71	86	42	42	73	29	29	38
2016	P	0	0	0	81	81	85	91	91	105	120	120	189	56	56	73

a) Based on *special reports*
b) Based on *special reports* from Savissivik and *Piniarneq* from Upernavik
c) Based on *Piniarneq* – *special reports* too low.
d) Catches from Siorapaluk all assumed to be from Inglefield Bredning
e) Incl. five catches reported from Savissivik (*special reports*)

Table 6. Catches of narwhals in East Greenland. Data from 1955-1990 from Dietz et al. (1994) and data from 1993-2016 from Piniarneq. There was one ice entrapment in Tasiilaq in February 2008 that involved about 37 narwhals.

Year	Ittoqqortormiit	Tasiilaq	All
1955	18	6	24
1956	10		10
1957	9	5	14
1958	28	1	29
1959	17	9	26
1960	54	2	56
1961	12	4	16
1962		3	3
1963	8	21	29
1964	8		8
1965			0
1966	2	67	69
1967		20	20
1968		30	30
1969	6	17	23
1970	6	47	53
1971	5	33	38
1972	1	25	26
1973	4	18	22
1974	2	40	42
1975	2	2	4
1976	1	8	9
1977	5	14	19
1978	1	1	2
1979	10	20	30
1980	10	49	59
1981	15	128	143
1982	25	84	109
1983	43	12	55
1984	50		50
1985	28	21	49
1986		63	63
1987		19	19
1988	40	11	51
1989	70	19	89
1990	70	88	158
1991			
1992			
1993	9	16	25
1994	17	20	37
1995	34	35	69
1996	8	39	47
1997	9	42	51
1998	21	26	47

Year	Ittoqqortormiit	Tasiilaq	All
1999	19	99	118
2000	11	28	39
2001	52	70	122
2002	54	55	109
2003	6	87	93
2004	39	96	135
2005	50	68	118
2006	93	29	122
2007	39	40	79
2008	37 *	39	76
2009	12	0	12
2010	20	10	30
2011	30	15	45
2012	31	17	48
2013	47	19	66
2014	63	18	81
2015	74	20	94
2016	38	15	53

*All taken in ice entrapment in Sermilik