SCIENTIFIC COMMITTEE
AD HOC WORKING GROUP ON NARWHAL IN EAST GREENLAND

24-27 September 2019
Greenland Representation, Copenhagen Denmark

REPORT

Please cite this report as:

NAMMCO-North Atlantic Marine Mammal Commission (2019). Report of the Ad hoc Working Group on Narwhal in East Greenland. September 2019, Copenhagen, Denmark.

Available at https://nammco.no/topics/sc-wg-reports/

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EXECUTIVE SUMMARY

The NAMMCO Scientific Committee has previously expressed concern over the status of narwhal stocks in East Greenland due to high catches continuing on a declining population. In 2018 it was decided to convene an Ad hoc Working Group on Narwhal in East Greenland. This ad hoc working group (WG) met at the Greenland Representation in Copenhagen from 24-27 September 2019.

The tasks for the WG involved reviewing data on stock structure, abundance and distribution; examining impacts from hunting, climate change and other anthropogenic stressors; and assessing the future sustainability of catches.

Three management areas had previously been recommended for narwhals in East Greenland. This was based on the known high degree of site fidelity, the observed distribution during summer, and a desire to facilitate a precautionary approach to management. The management areas considered by the WG were therefore: *Area 1* = Ittoqqortormiit, Scoresby Sound and Blosseville Coast south to 68°30'N; *Area 2* = Kangerlussuaq 68°30'N to 67°N; *Area 3* = Tasiilaq, south of 67°N.

Distribution & Stock Structure: Genetic analysis shows that East Greenland narwhals are genetically and ecologically distinct from animals in West Greenland and genetically distinct from those in Svalbard. The analysis is, however, not yet powerful enough to distinguish different stocks in East Greenland and requires additional samples to cover all management areas.

There is specific uncertainty regarding stock structure in management area 1 (Ittoqqortoormiit /Scoresby Sound). Specifically, whether this area is inhabited by two populations at different times of the year. This possibility is indicated by a bimodal distribution of catches and tracking data that shows all animals tagged in Hjørnedal moving out of the fjord system and staying in offshore areas south of Scoresby Sound between April and June, while catches are reported in Scoresby Sound during this time. Although there could be migration down from a population in the north (e.g. Dove Bay), there is currently no evidence to support this. Further work is required to resolve stock structure in this area.

Abundance: Estimates from recent aerial surveys and mark-recapture data were presented. Newly calculated correction factors were also applied to estimates from previous surveys. Abundance estimates for each management area are reported in the section on stock assessments below.

Non-lethal Impacts: Experiments were conducted exposing narwhals (fitted with satellite tags and acoustic-behavioral recorders) to noise from airguns. Impacts observed included movement towards the surface and a decrease in vocalisations related to foraging, despite the airguns being less powerful than those used in commercial activities and the level being within the range of background noise. Noise disturbance (from shipping and seismic exploration) has a clear potential to impact narwhals although the significance of this for small populations in decline requires further investigation.

Life History: Although not statistically significant, the pregnancy rate was observed to be declining in both hunter reports and biological sampling. This trend has further support from very few calves being seen in recent aerial surveys and the lack of young animals in recent live captures. Although the body condition of the whales appears to be good, the pregnancy rate is decreasing. This decline in fertility has significant implications for the population, although the exact cause is unknown.

Habitat Changes & Population Responses: Two major oceanographic changes have recently been observed in coastal areas of Southeast Greenland - a lack of pack ice in summer and increasing sea temperatures. This has had cascading effects on the marine ecosystem, as observed through changed fish fauna and the presence of a large number of boreal cetaceans either new to the area or now occurring in surprisingly large numbers (e.g. humpback, fin, killer, and pilot whales as well as white-beaked dolphins). Narwhals are endemic to the Arctic and depend on cold water. Their habitat range is therefore being restricted by the warming oceans. Since they primarily get rid of heat through the dorsal ridge and tail fluke, their ability to adapt to these warming temperatures is also limited. While there have recently been several sightings of narwhals in areas north of their traditional range (e.g. Dove Bay), evidence suggests that a combination of hunting and climate change is negatively impacting the long-term viability of populations in Southeast Greenland.

Stock Assessments: Various runs of the population assessment model used different parameter values and prior to test model structure and sensitivity to key parameters. The results of these runs are described in the report and the results of the final runs used for stock assessments presented below.

Ittoqqortoormiit (management area 1) The dIw model uses a birth rate fixed at the observed average of 0.31. The model estimates a small and depleted aggregation. With a historical population estimate of 2,290 (90% CI:1,750–2,840), and a current depletion to only 18% (90% CI:6%–40%) of this, the model estimates a 2019 abundance of 410 (90% CI:120–990) animals. With an annual growth rate estimate close to zero, it is unlikely that the aggregation can sustain any current removals. The estimated probability of increase is only 57% should a single individual be removed annually.

Kangerlussuaq (management area 2): The dKa model uses no age structured data and a birth rate fixed at 0.33 for a three year birth interval. The model estimates a small depleted aggregation. With a historical population estimate of 1,050 (90% CI:720–1,540), and a current depletion to 27% (90% CI:12%–59%) of this, the model estimates a 2019 abundance of 290 (90% CI:140–560) animals. This aggregation is so small that it is unlikely that it can sustain any current removals. The estimated probability of increase is 72% should 4 individuals be removed annually. This estimate is, however, considered to be too optimistic because demographic variation, allee effects, and other factors—which negatively affect small populations—were not included in the model but should be taken into account when considering the sustainability of the harvest.

Tasiilaq (management area 3): The dIa model uses no age structured data and a birth rate fixed at 0.33 for a three year birth interval. The model estimates a small depleted aggregation. With a historical population estimate of 820 (90% CI:580– 1,210), and a current depletion to 25% (90% CI:4%–74%) of this, the model estimates a 2019 abundance of 210 (90% CI:30–670) animals. This aggregation is so small that it is unlikely that it can sustain any current removals. The estimated probability of increase is 76% should two individuals be removed annually. This estimate is, however, considered too optimistic, partly because of a statistical bias (model abundance being slightly larger than the survey estimate), and partly due to factors negatively affecting small populations as outlined for Kangerlussuaq above.

The WG expressed significant concern that removals continue to take place in these small populations observed to be in decline and considers the urgency of the situation to now require immediate action.

Recommendations for Conservation and Management

- *The NAMMCO SC seek an immediate response from managers to the information that current removal levels are unsustainable*
- *The NAMMCO SC develop guidance on a standard or principle-based approach for how to manage small stocks and harvest advice*
- *Data on struck and lost be obtained to inform assessments of sustainability if any harvest continues*
- *Reports of any landed animals include length measurements in addition to age category and presence of a foetus*
- *Hunters receive payment for assisting scientific research to clarify stock structure and abundance (e.g. through tagging animals)*
- *Ways to improve the reporting of user observations (e.g. on struck and lost, pregnancies, stomach contents, and seasonal presence) be investigated to inform future assessments*
- *The negative impact of climate change on narwhals be recognised and included in management decision-making on all stocks*

Recommendations for Research

- *Perform further analysis of the study on the effects of noise disturbance on narwhals in Scoresby Sound*
- *Conduct further research on the impact of increasing sea temperatures and the thermal regulation of narwhals*
- *Carry out further research to clarify stock structure, especially in the Ittoqqortoormiit management area (Scoresby Sound), e.g. through tagging animals in the spring, a spring survey and ongoing genetic analysis.*
- *Estimate a plausible maximum population size in Tasiilaq from the 2016 survey*
- *Investigate the possibility of calculating the detection function for the most recent survey and assess whether applying it to previous surveys has a significant impact*
- *Include the collection of data on calves in future surveys*
- *Develop predictive models of narwhal habitat and project changes over time*
- *Further evaluate the feasibility of using mark-recapture data for estimating abundance*
- *Expand the knowledge available regarding narwhal diets and trophic roles*

MAIN REPORT

1. CHAIRMAN WELCOME AND OPENING REMARKS

The Chair of the Working Group, Roderick Hobbs, welcomed participants to the meeting and noted that the topics for discussion included not just the impacts of hunting on narwhals in East Greenland, but also environmental and other anthropogenic impacts. This meant that recommendations could be made on measures for environmental management as well as on the sustainability of catches.

The Chair also noted that although the NAMMCO-JCNB Joint Working Group on Narwhal and Beluga has regular meetings to discuss the management of these species, an ad hoc working group focused on narwhal in East Greenland was deemed necessary by the NAMMCO Scientific Committee because this stock is not shared with Canada and there are a unique set of issues to be considered in this region.

The terms of reference for the meeting and the available working documents were reviewed. The terms of reference were:

1. Review the latest information on surveys in East Greenland including options for updating the surveys from the 1980s.
2. Review information on satellite tracking of narwhals in East Greenland
3. Present the latest information on genetic discrimination of stocks in East Greenland
4. Assess the importance of climate change on the distribution of narwhals in East Greenland
5. Compile hunting statistics and information from hunters on availability of narwhals
6. Assess the future sustainability of catches

The Chair proposed that the order of items on the agenda be amended slightly so that anthropogenic impacts would be discussed before distribution & abundance. This was to accommodate plans to have one of the working papers presented remotely and the time difference involved. The agenda was adopted with this minor amendment.

The NAMMCO Scientific Secretary, Fern Wickson, was appointed as rapporteur for the meeting.

2. DISTRIBUTION & ABUNDANCE

2.1 REVIEW OF MOVEMENTS AND DIVE BEHAVIOUR DATA

2.1.1 Satellite tracking studies

Timing and direction of the spring migration of narwhals entering Scoresby Sound

Summary (Working Paper 14)

A total of 64 narwhals have been instrumented with satellite transmitters in Hjørnedal, Scoresby Sound, between 2010 and 2018. Eleven of the whales (6 males and 5 females) provided positions after 1 April in the subsequent year, three gave positions in May, two in June and one in July (which stopped transmitting in October). In April-June all whales remained outside Scoresby Sound either on the wintering ground or along the Blosseville Coast south of Scoresby Sound (Heide-Jørgensen et al. 2015). None of the whales were even close to the ice edge outside Ittoqqortoormiit where hunting occurs in April-June. In July 2016, one whale that was still transmitting provided positions every 7th day that showed that the whale entered Scoresby Sound along the southern coast of Volquart Boons coast before entering Gåsefjord, where it stayed until the end of the month. The whale continued to give positions through October where it remained in the inner part of Scoresby Sound in the same areas that narwhals tagged in Hjørnedal traditionally occupy.

Discussion

The tracking data from animals caught in Hjørnedal shows all of them moving out of the fjord system to the south, and the few animals that are tracked until April and June stay in the offshore areas south of Scoresby Sound where they would not be available to hunters. The reported catches in Ittoqqortoormiit north of Hall Bredning when the tagged whales were offshore indicates that the area may be visited by animals from a different population at this time. This could be from a northern population migrating down (such as from Dove Bay) although there is no current evidence to support this. The WG agreed that the question of whether the animals being caught in Ittoqqortoormiit between April-June are coming from northern stocks is an important question that is difficult to answer with the data currently available. This means the stock structure in this area requires further work to resolve. This could include genetic analysis of samples from the spring hunt, tagging of animals in the spring hunt area, or a new survey conducted during the spring.

Although the effort of the satellite tagging program to catch narwhals has remained constant over time, few animals were caught this year. More may have been caught if the fieldwork had been extended as the animals appear to be entering the area later in the season.

Whether any of the captures included tuskless males or females with tusks was asked. It was noted that although this was rare, one tuskless male and one female with a tusk had been captured in Scoresby Sound. Genetic samples were available for both animals. It was confirmed that despite these rare occurrences, fieldwork with narwhals typically assumes that animals with tusks are males and those without are females.

A mark-recapture abundance estimate from Scoresby Sound in 2019

Summary (Working Paper 18)

A total of 66 narwhals have been instrumented with recorders and satellite transmitters in Hjørnedal, Scoresby Sound, since 2010. The instruments leave a permanent scar on the skin of the whales that is easily recognizable by the hunters and personnel involved in the live capturing operations. In August-September 2019 a total of four whales (three with scars and one with a satellite transmitter) were recaptured from the Greenlanders' hunt of 50 whales and the live capturing operation. This is an unprecedented large number of recaptures for monodontids with a tagged population. Together with the large number of recaptures in previous years (2010-2018; n=4) this raises concerns about the size of the narwhal population in Scoresby Sound. The estimated abundance in 2019 from mark-recapture was 669 whales (95% CI: 179-1158).

Discussion

Since this work was not initially designed as part of a formal mark-recapture exercise, the ability to use the data to generate an abundance estimate was discussed. It was noted that although the tagging was all done in one location, the recaptures took place in different areas and this may bias the results. The extent to which this work could generate an abundance estimate for all of Scoresby Sound was also discussed. It was noted that although the animals were recaptured relatively close to the tagging site, those tagged in Hjørnedal were shown to use the entire fjord system, which meant that it may be reasonable to use the data to estimate the population in this area. However, if Scoresby Sound is indeed used by two populations (see discussion on working paper 14 above), the recapture estimate would only represent the fall population.

Regarding the reliability of the recapture numbers, whether hunters would necessarily always report catches of whales with tags or recognise scars from tags was discussed. It was noted that since there are only 5-6 hunters operating in this area and all have been involved in the tagging efforts, all are likely to be aware of the program and the indicators of past tag presence.

Following the discussion, the WG concluded that given the concerns regarding the sampling, it should not be included in the assessment at this time. However, the work was considered valuable and the WG recommended that it continue and that further analysis be presented at future meetings.

2.1.2 Local knowledge observations

Bits of Local Knowledge on narwhals in Southeast Greenland

Summary (Working Paper 19)

This working paper presented a summary of conversations with locals from the Tasiilaq area knowledgeable about narwhals. According to the informants, narwhals avoid anthropogenic sound and swim close to shore when frightened. They also favour glaciers and fjords with ice. An increase in the numbers of skiffs with outboard engines and a reduction of glaciers due to climate warming have resulted in narwhals changing distribution, so that that they are now rare in some of the previous hunting grounds. Locals believe that narwhals are still common in areas south and north of the villages around Tasiilaq. They do not believe that there are less narwhals than before, but rather that distribution has changed. There is some struck and lost associated with the kayak hunt, as evidenced by the harpoon wounds observed on some animals caught in nets in Kangerlussuaq. There is a widespread suspicion that some hunters catch more narwhals than they report.

Discussion

Documentation that some areas with previously high numbers of narwhals are no longer populated was discussed as being partly due to environmental changes but also to other factors. For example, there is now a halibut fishery in the Tasiilaq area, which has brought more money to the region and lead to the presence of more small fast boats and therefore more engine noise. Although the number of hunters in Tasiilaq does not seem to have changed, the number of hunters with boats has increased. The exact numbers of boats in the area is not known but this information should be possible to obtain. It was noted that most of the hunters from Tasiilaq are now going north to Kangerlussuaq and if there are no narwhal there, they go further to Nansen fjord (just north of Kangerlussuaq). Narwhal hunters in around Tasiilaq go out in boats and use rifles while those going north to hunt in Kangerlussuaq tend to use kayaks. The different methods used impact struck and lost rates since in the former hunt, the hunters shoot the animal first and then have catch up to secure it before it sinks, while in the latter method, the animal is secured by harpooning first.

Although illegal hunting is talked about as occurring in the Tasiilaq area, it is difficult to prove. There are certainly many boats hunting for a small quota and there are no wildlife officers in the area. This may mean that there is an underreporting of the number of narwhals being taken by hunters from Tasiilaq (i.e. in management areas 2 & 3, see Figure 1).

Hunters today tend to take just the mattaq and tusks but leave the meat as there is little demand for it. Some of the meat is taken for personal use but it is rarely sold. There are fewer dogs in East Greenland due to the presence of large amounts of open water in the winter now and this also reduces the need for narwhal meat. The price paid to the hunter for mattaq is 150-200kr per kilo. Sometimes the mattaq is sold before it is caught, which can create challenges for adapting to quotas. It is also often sold individual to individual (e.g. via social media channels).

The WG emphasised that it is very important that there is reliable data on total removals for generating management advice. This means that it is important to have information on the rates of struck and lost and the degree of underreporting that may be taking place.

Research conducted on user practices would provide useful information to help ensure data is accurate and reliable. It may be useful to perform a robust interview study and/or conduct biological sampling of catches. Biological samples could be taken when hunters come back to the village or from the market as a way to trace the origin and number of catches. There is a clause in the law that the government can ask for biological samples as a requisite for getting a license. This is currently done for polar bears and minke whales, although it does not provide 100% coverage of all catches. While both approaches have potential challenges and financial implications, the WG agreed that a combination of such efforts would improve the data available to inform future management advice.

2.2 REVIEW OF AERIAL SURVEYS IN EAST GREENLAND

Abundance of narwhals in Scoresby Sound in 1983 and 1984

Summary (Working Paper 06)

Aerial line transect surveys of the abundance of narwhals were conducted in Scoresby Sound (including areas along Liverpool Land and in Kong Oscars Fjord) in September 1983 and 1984 (Larsen et al. 1994). The surveys used a Partenavia Observer (twin engine plane), with two observers and one recorder, flying at a target altitude and speed of 183 m and 167 km/h. A total of 1747 km and 1973 km was covered in 1983 and 1984, respectively. The surveys covered the entire fjord system of Scoresby Sound and used a systematic design with east-west or north-south going transect lines, except in the inner parts of the fjord systems where a zig-zag design was applied. The achieved abundance are estimates of the number of narwhals detected by one observer platform at the surface. No corrections were applied for submerged whales or whales missed by the observers.

Hansen et al. (2017) used a double platform experiment to estimate the perception bias (i.e. whales missed by both observers) and data from time-depth-recorders to estimate availability bias (i.e. whales that are submerged below 2 m during the passage of the plane). The estimate of perception bias from two sets of observers in a Twin Otter with bubble windows flying at a target altitude of 213 m and a target speed of 168 km/h was 0.82 (cv=0.08). Data from time-depth-recorders deployed on narwhals in Scoresby Sound revealed that the whales were available to observers 31% (cv=0.31) of the time.

If the correction factors developed for the surveys in 2008 and 2016 (Hansen et al. 2017) are applied retrospectively to the surveys in 1983 and 1984, corrected and larger estimates of 1180 and 401 whales are obtained. It is uncertain if the correction for perception bias can be applied to a different survey plane flying at a slightly higher altitude in a different decade, however, it is reasonable to assume that some sightings are missed and the correction of 0.82 must in this respect be considered conservative. Also, the availability correction of 0.31 is conservative compared to most other estimates that range between 0.21 and 0.30.

Larsen et al. (1994) ascribe the large difference between the two abundance estimates in 1983 and 1984 to either annual variability in the presence of narwhals in Scoresby Sound or to earlier ice formation in the fall of 1984 compared to 1983. However, from satellite tracking of narwhals Heide-Jørgensen et al. (2015) found that the main exodus in Scoresby Sound was not until late October and November.

Discussion

In discussing whether this recalculation could be considered valid, the WG acknowledged that correction factors are often applied across different areas and time periods and found no specific reason to discard the estimates generated in this case. It was therefore agreed that the corrected data from the two surveys could be used in the assessment.

Abundance of narwhals at the hunting areas in East Greenland in 2008 and 2016

Summary (Working Paper 05)

A visual aerial survey of narwhals was conducted in fjords and bays along the coast of East Greenland in August 2008. Recalculation of the derived abundance estimates was deemed necessary as there was an error in transect lengths. 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 in 2016 was 676 (CV=0.32; 95% CI: 363–1261). The disaggregated estimates for the Tasiilaq management area was 256 (CV=0.46, 95% CI: 109-600) and 421 (CV=0.40, 95% CI: 198-895) narwhals for the Scoresby Sound area. Recalculation of the 2008-survey with corrected transect lengths, new stratum areas and the new availability correction factor gave an estimate of 2636 (CV=0.48, 95% CI: 1074-6465) narwhals. The disaggregate estimates, corrected for perception bias and availability bias, for the Tasiilaq management area was 645 (CV=0.65, 95% CI: 200-2078) and 1991 (CV=0.57, 95% CI: 709-5590) for the Scoresby Sound area including the Blosseville Coast.

Abundance of narwhals summering in East Greenland and narwhals wintering in the North Water and Northeast Water polynyas

Summary (Working Paper 04)

Relatively few detections of narwhals were obtained during the surveys in East Greenland. A common detection function was fitted from combining sightings from seven aerial surveys. Five visual aerial line transect surveys of narwhals were conducted at the summering grounds in East Greenland between 2016 and 2018 and two surveys were conducted in March/April 2017 (the Northeast Water polynya) and in March/April 2018 (the North Water polynya). Detection function parameters were estimated by maximizing likelihood Equation conditional on the fitted hidden Markov models (HMMs) for animal availability. HMMs were fitted to 12 days of depth tag data, using only data from between 6am and 6pm when the visual surveys were conducted. There were approximately 5000 narwhals inhabiting East Greenland in summer with a distribution from Norøstrundingen and south to and including Kangerlussuaq fjord.

Discussion (Working Papers 4 & 5)

It was noted that the 2008 and 2016 estimates are from surveys that cover Scoresby Sound and some of the coastline, while the 2017 survey and those from the 1980s are only from the Scoresby Sound fjord system. Furthermore, the estimate for the Greenland Sea comes from a unique 2017 survey that only covered parts of the Greenland Sea. It is important that these differences are accounted for in the assessment.

Whether the individual abundance estimates could be used in the assessment, the appropriateness of combining data from different survey methods, and the ability to apply recently determined correction factors to older surveys were all topics of discussion. The WG agreed that if the surveys were done with the same planes, the same observers, and the same sea states, it was reasonable to combine their data.

It was noted that the behaviour of the animals (e.g. dive behaviour and therefore the availability of the animals to the observers in the fjords vs offshore) may vary and therefore also the correction factor for availability bias in the different areas. The WG acknowledged the assumptions being made in combining different surveys but agreed that due to the limited information available, a combined correction factor was suitable for use in this instance. It was also noted that the correction factors had been developed in the areas that were of most interest in this case (Scoresby Sound/Ittoqqortoormiit) and therefore any bias arising was most likely to affect estimates in the northern areas not subject to hunting.

The WG proposed that it may be informative to calculate the detection function for the most recent survey (where good data is available) and assess whether applying it to previous surveys has a significant impact. That is, to compare the impact of using a detection curve from an individual survey vs a global curve.

Re-calculations of abundance of narwhals to three management units in East Greenland

Summary (Working Paper 20)

Currently the management area for narwhals in East Greenland is divided by Kangerlussuaq Fjord. Hunters from Ittoqqortoormiit have traditionally hunted along the northernmost fjords of Blosseville Coast, whereas hunters from Tasiilaq have hunted in Kangerlussuaq Fjord. Since the abundance of narwhals south of Kangerlussuaq Fjord is too low to be detected by aerial surveys, it has previously been suggested to divide the management areas into three areas so that there is an option to adopt a precautionary approach and protect the low number of narwhals south of 67°N. The three management areas are proposed as: Scoresby Sound and from the entrance to Scoresby Sound south along the Blosseville Coast to 68°30'N (management area 1), Kangerlussuaq 68°30'N to 67°N (management area 2) and Tasiilaq, south of 67°N (management area 3).

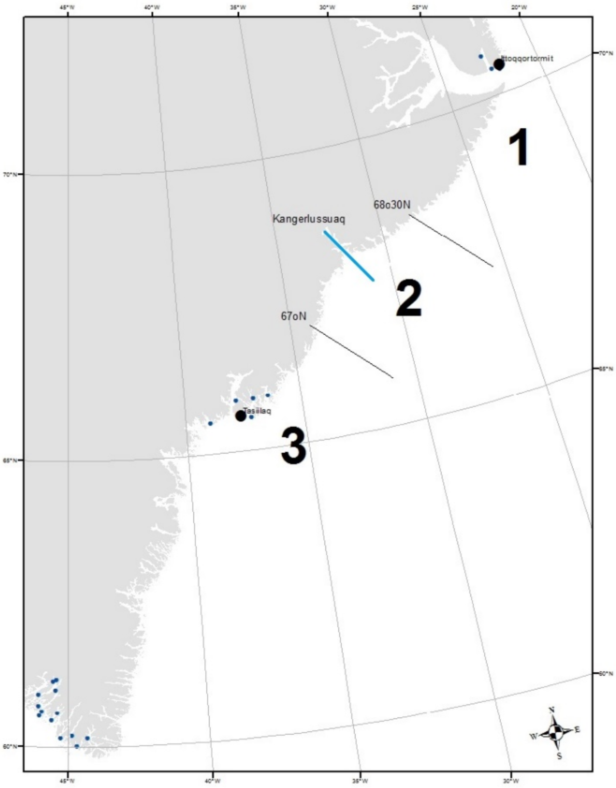

Figure 1: Suggestion for three management areas for narwhals in East Greenland. Ittoqqortoormiit & Scoresby Sound (area 1), Kangerlussuaq (area 2) and Tasiilaq (area 3). Blue line indicates the previous segregation of two management areas. Blue dots represent settlements, with Tasiilaq and Ittoqqortoormiit superimposed

Discussion

In working paper 20, abundance in management area 3, Tasiilaq, in 2016 no animals were seen during the aerial survey. However, the WG acknowledges that a lack of sightings does not mean that the population is 0. The WG therefore recommends that a maximum plausible population size is determined (see Doniol-Valcroze and Hammill 2012).

The WG re-examined the rationale for separating management areas 2 and 3 (Kangerlussuaq and Tasiilaq) rather than simply moving the border of the existing area to 68.5˚N. The site fidelity of narwhals supports the potential existence of separate aggregations in the different fjord systems, making three management areas a practical division that facilitates the precautionary approach to managing small and declining populations.

Given that so few narwhals have been sighted in Tasiilaq in recent surveys, the WG was concerned about the survival of the population. If there are two separate populations inhabiting management areas 2 and 3 and they are managed together as one unit, then there is a high risk that the more southern population in Tasiilaq will be overexploited. If, however, the area is managed as two areas (i.e. management areas 2 & 3), the risk of overexploitation of a potential small southern population around Tasiilaq is reduced. Furthermore, if the animals have a form of cultural memory that helps guide them back to particular grounds, their elimination from a particular area will reduce the possibility of their recovery and return to this area. Therefore, the WG reemphasised the relevance of creating three management areas.

The WG agreed that the more specific details provided at this meeting were useful in defining more clearly the borders of the three management areas.

3. ANTHROPOGENIC IMPACTS

3.1 HUNT REMOVALS

Catch statistics for East Greenland narwhals 1955-2019

Summary (Working Paper 15)

The objective of this paper was to provide a catch record (1955–2019) of the narwhal hunt in East Greenland and calculate total removals (including struck-but-lost whales) of narwhals in Tasiilaq and Ittoqqortoormiit. Almost complete catch statistics for narwhals in East Greenland, split on the two communities on the East coast, Tasiilaq and Ittoqqortoormiit, were compiled from 1955–2019. From 1955–1992 the catch reporting system ("Fangstlistesystemet") was based on appointed locals in each settlement keeping track of hunting in the settlement. In 1993, the new catch reporting system "Piniarneq" started to provide statistics including information on hunting date and community (i.e. where the hunter was settled). In 2009, with the installation of quotas, the hunters in East Greenland have also been asked to fill out "Special Reports" that provide more detailed information about the hunt. The catch statistics in this paper were compiled from these three systems. Observations of losses in the open water hunt in Scoresby Sound were collected during live-capturing operations of narwhals in Hjørnedal 2010–2019 and used for estimation of retrieval (0,69) and loss rates (0,31).

The total catch for Tasiilaq + Ittoqqortoormiit during 1955–2019 was 3841 narwhals and total removals was estimated to be 4696 narwhals. The catches taken in Tasiilaq and Ittoqqortoormiit (for 2011-2019) were split into geographical locations (Tasiilaq or management area 3 and Ittoqqortoormiit or management area 1) and divided by season (Ittoqqortoormiit). This was done to distinguish the hunts from Kangerlussuaq fjord and adjacent fjords, which has been proposed as a separate management area and to separate the spring from the summer hunt as the whales present in spring versus summer could come from two separate populations (in Ittoqqortoormiit, management area 1). For Ittoqqortoormiit, it was found that catches were separated by location and season and that sexes of whales were skewed towards males in the spring hunt, although this was not statistically significant.

The distribution of males and females in both the hunt in Tasiilaq and the summer hunt in Ittoqqortoormiit was approximately 60% males and 40% females. The annual percentage of females in the catch has decreased in recent years in both communities and the percentage of pregnant females in the hunt in Ittoqqortoormiit show a decreasing trend.

Discussion

It was noted that there is no data from special reports on catches in 2009 and 2010 – although the reason for this is unclear.

The correction factor (1.44) for struck and lost whales estimated based on losses in Scoresby Sound is applied to the open water hunts in both Ittoqqortoormiit and Tasiilaq. No observations on struck and lost have been made in Tasiilaq. A lower correction (1.05) is used for kayak hunting in Tasiilaq (Garde et al. in press).

Differences in the hunting methods used in the two areas were highlighted. In Ittoqqortoormiit (i.e. management area 1) some narwhals are taken using nets, while in Tasiilaq (management area 3), kayaks and speedboats (i.e. any small craft with an outboard motor, including dingies, skiffs etc) are used but no nets. In nets it is normal to get 1-2 animals, and although one hunter reported a catch of 5, this was considered exceptional. It was noted that although it was previously forbidden to take females with calves, because this was impossible to enforce in net-based catches the law was changed. When kayaks are used, the whale is first harpooned, with a line attached to a buoy, and once these are attached, the animal is shot. When the hunt is done from a speedboat rather than a kayak, the sequence is often reversed, with the rifle shot taking place first and this can result in a greater risk of losing the animal. Hunting narwhal from kayak requires significant skill that must be learned and this practice has not been retained in all regions.

Spring and summer hunts take place in Ittoqqortoormiit and animals are caught in different places during these times. In the spring, the animals are caught more towards the north of the fjord system while they are caught further to the south in the summer. This is further evidence that two populations may occupy the area at different times.

The strength of the empirical evidence for the declining trend in pregnancy rate as observed in hunter reports was discussed. It was noted that although the sample sizes are quite small, pregnancy rates have been calculated based on both hunter reports and analysis of biological samples. Although the biological samples indicate a higher pregnancy rate than that reported by hunters, the declining trend is the same. Potential causes for this trend were discussed, including: pollution affecting fertility (not considered likely in this case), pregnant animals moving to other areas (also not considered likely), nutritional or other stressors prohibiting pregnancy or provoking abortion, altered age structure of the population etc. Although several factors may be involved, the WG agreed that having hunters record the length for all animals caught (in addition to reporting age class) would improve the value of the reports. Requiring hunters to provide skin and blubber samples could also be considered as is already done for polar bears and minke whales.

3.2 OTHER REMOVALS

3.2.1 Fisheries by-catch or entanglement data

There are no records of by-catch of narwhals in East Greenland. The only fishery overlapping with areas inhabited by narwhals is for halibut, which is a line fishery. There are no set or drift net fisheries in the area. Given that narwhals are very closely associated with the ice and there is no overlap with net fisheries, no significant by-catch is expected in this region.

3.2.2 Vessel strikes

No information was available on vessel strikes of narwhals in East Greenland.

3.3 NON-LETHAL IMPACTS

Preliminary results on short-term effects of airgun pulses on the acoustic behaviour of narwhals

Summary (Working Paper 08)

Underwater noise pollution from anthropogenic activities has in recent decades been recognized as an increasing threat to marine life. One of the last pristine marine soundscapes, the Arctic, has during the last decade been exposed to increasing anthropogenic activities due to the climate induced decrease in sea ice coverage. We combined movement and behavioral data from animal-borne tags in a controlled sound exposure study to describe the reactions of narwhals *Monodon Monoceros*, a high-Arctic species, to airgun pulses. In August 2017 and 2018, 8 East Greenland narwhals were live-captured and instrumented with satellite tags and Acousonde acoustic-behavioral recorders and exposed to airgun pulses. The sound pressure levels of airgun pulses were also measured using stationary recorders. The data clearly demonstrate that narwhals react to airgun pulses – all individuals decreased their echolocation rates and 7 out of 8 whales decreased their buzzing rates during exposure. In addition, 1 individual increased and 2 individuals decreased the calling rates significantly. The estimated sound exposure level at which the buzzing and clicking rates halved was ~ 105 - 132 dB re 1 μPa^2 -s and the sensitivity of the individuals to exposure varied. This is the first description of the effects of airgun pulses on narwhals and we suggest that effects of anthropogenic disturbance should be taken into consideration when assessing the resilience of a population, especially in the Arctic.

Discussion

Whether it was possible to distinguish observed effects from the airgun and from the ship itself was discussed. Analysis allowing for such a distinction in the current study has not yet been performed although there is data available to do this type of work in the future. Since impacts from the noise of the large ship carrying the airgun could not be excluded at this stage though, the data presented can be interpreted as demonstrating effects from a combination of the airgun and the ship. From audits of the recordings, sounds from the airgun could be picked up but not the noise of the ship. One explanation for the lack of detection of the ship was the broadband flow noise at the hydrophone when the whale was moving. The WG agreed that this does not mean the animal cannot hear the ship noise.

It was noted that the ship used for the airgun experiments emits a lower frequency noise than that emitted by speedboats and that this experiment did not examine the impact of speedboats on the behaviour of narwhals. Furthermore, although the 2018 experiment used a louder airgun, the airgun used is still significantly smaller than those used for commercial purposes so the reaction distances observed can be expected to be larger for louder airgun arrays. Interestingly, although many environmental impact assessments on commercial developments talk about narwhals being more attuned and sensitive to high frequency sounds and having poor low frequency hearing, this experiment demonstrates sensitivity to low frequency sounds.

The analysis has not yet looked at whether narwhal vocalisations became louder in the presence of the disturbance. There has also been only preliminary work done on whether the narwhal change direction in response to the noise. There are some indications that the animals seem to move towards land and away from the noise. It was, however, also seen that in some areas with high background noise, it may be difficult for them to locate the source (e.g. they are seen turning around, potentially trying to locate the source). They also tend to come closer to the surface rather than dive deep as other species do in their reactions to noise. This may be due to the need to increase their oxygen stores in preparation for any flee or dive response.

It was noted that there was significant individual variation in the animals' reactions to noise disturbance and that the state of the animal and/or their past experiences may make a difference.

The WG discussed whether it is more appropriate to use the received sound exposure levels or the measured distance to the ship in looking at the reactions. It was noted that there is high resolution data from the GPS while the received sound levels can be very variable due the behaviour of the animal and environmental factors (ice presence, flow noise, oceanographic features etc). It was noted as particularly interesting that although narwhals live in a noisy environment and the range of the received sound exposure was within the range of the fluctuating background noise, the animals seemed to be able to distinguish anthropogenic/artificial sources of noise at long distances. That is, despite being in the same range as background noises, the narwhal reacted to the airgun and an impact was seen, particularly in terms of a decrease in vocalisations related to foraging.

Ceasing foraging or engaging in flight are energetically costly and may result in nutritional stress. The WG discussed the relative impact of nutritional stress occurring at different times of the year. It was considered relevant to do an analysis that quantifies effects in terms of behavioural change affecting energy usage and future work is planned on this.

Variation in vocalisation activity in different areas of the fjord system was also discussed – i.e. some areas seem to be used for feeding while others are used more as commuting areas (Blackwell et al. 2018). This makes the reduced vocalisation rates that seem to follow catching and tagging activities difficult to interpret as the area where tagging takes places is used for commuting. It does, however, seem relevant to include the location of the animals in the analysis of disturbance effects. Currently the trials are analysed according to three areas. However, their definition is the result of a subjective choice and more work is required to determine a distinction of areas that makes sense based on narwhal activity.

The WG agreed that seismic activity and other forms of noise disturbance from shipping have clear potential to impact narwhals (e.g. reducing foraging time). However, the significance of this type of disturbance for the animals (and particularly for small populations in decline) requires further investigation. The WG therefore recommends further research and ongoing analysis of the existing data. When the impacts of different forms of noise on foraging and energy use are better understood, this information may be used to generate relevant recommendations for conservation and management. It may also be relevant to consider the possible cumulative impact from increased shipping in terms of enhanced noise disturbance.

4. BIOLOGY

4.1 LIFE HISTORY

Life history parameters of narwhals from East Greenland

Summary (Working Paper 10)

This working paper compiles all previous data (2007–2016) with recently collected data (2017–2019) to estimate novel life history parameters for the East Greenland narwhals for use in assessments of sustainable hunting levels. Samples and measurements from narwhals (N=158; females 62; males 96) were collected in East Greenland during the years 2007–2019. Measurements of body length (cm), body mass (kg), tusk length (cm), circumference (cm) and heart mass (kg) were collected together with samples of eyes for age estimation using the AAR technique and sexual organs for estimation of reproductive status. Stomach content was sampled and investigated for assessments of narwhal diet.

Asymptotic body lengths were estimated for both females and males. Female asymptotic body length was estimated to be 406 ± 4,3 SE cm and 464 ± 10,0 SE cm for the males. Asymptotic body mass for the males was estimated to be 1496 ± 66,5 SE cm and asymptotic tusk length 197 ± 13,0 SE cm. There was not enough data to estimate an asymptotic body mass for the females.

No new data were collected on female reproduction during recent years (2017–2019). Previous estimates on female reproduction are therefore presented here. Age at sexual maturity (ASM) is reached between 8–10 years, at a body length of ~340 cm and body masses between 550 kg to 610 kg. First parturition occurs at ages between 9–11 years Garde et al. (2015, 2017).

It was previously observed that the oldest reproductively active female from East Greenland was 47 years (Garde et al. 2017). One female collected in 2017 produced milk and was estimated to be 65 years. This shows that narwhals in East Greenland reproduce at old ages, as also found for narwhals in West Greenland. No female narwhals have, however, been found to reproduce past the age of 69 (n=3 in East Greenland; n=5 in West Greenland) (Garde et al. 2015). Male narwhals have previously been estimated to become sexual mature at ages from 12–20 years (Garde et al. 2015, 2017). New information on male reproduction indicates that this estimate can be narrowed down to ages from ~15–17 years at body lengths of ~400 cm and body masses of ~900–1000 kg.

The pregnancy rate for East Greenland narwhals is updated using additional reproductive information on four females collected in 2017, where none were pregnant. This gives a new and lower estimation of the pregnancy rate compared to the previous estimate - current estimate 0.31 (based on samples from 2007-2017), previous estimate 0.42 (Garde et al. 2015). The data indicates that the fertility of East Greenland narwhals has decreased. The longevity record for narwhals in EGRL is still 107.7 years for females and 83.7 for males (Garde et al. 2017).

Discussion

When looking at the individual years, in both the biological samples and the hunter reporting, a downward trend in pregnancy rate is observed. The sample size is small, which makes it is difficult to interpret the significance and reliability. However further support for this trend is given by hunters own information on the presence of a foetus in hunted animals (see working paper 15 on catch statistics), the very few calves seen in recent aerial surveys (see working paper 11 on calf production, described below), and the few young animals present in recent live captures.

The WG noted that the body condition of the whales seems to be good – i.e. they are large and healthy - and yet the pregnancy rate and population is decreasing. Both density and productivity appear to be going down and this is difficult to explain. Less competition may explain why the animals are growing fatter, but not why productivity is declining.

A standard reproductive rate of 0.33, reflecting a three-year birth interval was assumed, as there is no evidence to indicate a 2 rather than 3 year breeding cycle (e.g. with females both lactating and pregnant at the same time).

Calf production of narwhals in Scoresby Sound

Summary (Working Paper 11)

The proportion of calves observed in aerial surveys fluctuates greatly between years and areas. This could be due to regional differences in calf production or different survey protocols. In 1983, a large number of both individuals and calves (24%) were recorded in Scoresby Sound, whereas this proportion was lower in recent years (between 0-11% calves from 2008-2017). The low recruitment in Scoresby Sound might be influenced by the increasingly warmer sea temperatures that could affect the reproduction rate of females in the region. At a survey in Inglefield Bredning where calf classification was prioritized, calves comprised 16% of the proportion of observations. Estimates higher than about 10% are unlikely as an average percentage of calves in populations of narwhals. It is, however, unclear whether the higher estimates are due to a lumping of calves and yearlings (where we can expect about 15%), or whether they reflect a year to year synchronization where a majority of adult females give birth in the same years.

Discussion

The observation of so few calves during recent surveys in Scoresby Sound make it desirable to have good records on calf production to enable comparisons over time. The work presented therefore represents the beginning of an effort to create a database on calf production (with ongoing data collection). The WG agreed that it is valuable and important to have data of the type presented, and also to encourage observers to record this type of information in the future. It was noted that standardisation of the detection range would also be important for future comparisons across years.

It was recognised that it is particularly difficult to compare different time periods when there is variation in the observers used. However, it was also highlighted that data from 2017, 2018, and 2019 can be compared as these surveys used the same observers. When comparing these surveys, stark differences are seen between the percentage of calves present in the different areas.

The lack of a clear discrimination between calves, yearlings and neonates in the current data collection was noted. The WG proposed that it might be best to have a single calf category rather than try and make distinctions within this group.

Although all of the data related to reproduction was recognised as having limitations and uncertainties associated with it, the WG noted the significance and importance of the fact that a range of different sources are all indicating a similar trend of declining productivity.

5. HABITAT EAST GREENLAND NARWHALS

5.1 HABITAT CHANGES

A regime shift in South-east Greenland

Summary (Working Paper 12)

Two major oceanographic changes have recently been observed in coastal areas of Southeast Greenland (SEG). The amount of drifting pack ice of polar origin that is exported from the Fram Strait and transported with the East Greenland Current (EGC) along East Greenland south to Cape Farewell has decreased significantly over the past two decades and has almost disappeared in the summer months in SEG. The Irminger Current that advects warm, saline Atlantic Water northward through the Denmark Strait to the East Greenland shelf has recently increased in strength in SEG and has been a major driver of increasing sea temperatures in the area. The lack of pack ice in summer, together with increasing sea temperatures, has had cascading effects on the marine ecosystem in SEG. This has manifested itself in a changed fish fauna and in the occurrence of a large number of boreal cetaceans - humpback whales, fin whales, killer whales, pilot whales and white-beaked dolphins - that are either new to this area of the Arctic or now occurring in surprisingly large numbers. At the same time there has been a reduction in the abundance and catches of narwhals in SEG and it is speculated that narwhals, that are endemic to the Arctic and depend on cold water, have been reduced in numbers due to excessive hunting in combination with habitat changes from increasing sea temperatures.

Discussion

The WG discussed that although sea surface temperature seems to be undergoing a gradual change, which may not necessarily indicate a regime shift, the dramatic loss of sea ice and the presence of large numbers of new species of marine mammals does suggest such a shift. The emergence and rise of the halibut fishery in the area also offers further support for a regime shift in the region.

The boreal cetacean species now entering the area are assumed to be chasing prey. The rise in humpback whales close to the coast in Greenland has, for example, been linked to shifting capelin distribution (a temperature sensitive species). This demonstrates that even small changes in sea temperature can have a significant impact on species distribution. The WG noted that the presence of these large predators is likely having top down impacts on other trophic levels so potential cascading effects on the rest of the food web may be worth investigating. Combining the data on marine mammals with information on the distribution of fish species would be interesting but comparisons across years may be challenged due to the way fish surveys are done. The WG noted that catches of the new cetacean species appearing in the Tasiilaq area could be replacing those of narwhal and highlighted that in Greenlandic, white beaked and white sided dolphins have the same name so the recorded catches may actually be a mix of the two.

5.2 NARWHAL RESPONSE TO CHANGES

Temperature dependent habitat selection by narwhals

Summary (Working Paper 13)

The narwhal (*Monodon monoceros*) is a high Arctic species inhabiting areas that are now experiencing increases in sea temperatures, which together with reduction in sea ice are expected to modify the niches of Arctic marine apex predators. The Scoresby Sound fjord-system in East Greenland is the summer residence for an isolated population of narwhals. The movements of 12 narwhals instrumented with FastLoc GPS transmitters were studied during summer in Scoresby Sound and during winter at their offshore wintering ground in 2017-2019. An additional four narwhals provided detailed information on the temperature profiles (down to 1000 m) on both the summering (284 profiles) and the wintering ground (263 profiles). Data on diving of the whales were obtained from deployments of 16 Acousonde™ recorders, and 10 satellite-linked time depth recorders deployed from 2010 through 2018. The Acousonde recorders furthermore provided information on the temperature and depth of buzzes during summer. The foraging whales targeted depths between 300 and 500 m in summer. At these depths the preferred areas visited by the whales had temperatures ranging between 0.6 and 2.0˚C with an average temperature at 300 m of 1.1˚C (0.6-1.8˚C, SD=0.25). The buzzing activity during summer was focused on depths between 284 and 405 m where the temperature was within 0.3-0.7˚C. In winter the whales targeted depths >500 m where the average temperature was 1.3˚C (range: 0.7-1.7, SD=0.29), a < 0.2 degree difference across seasons and geographic areas. It is unknown if the small temperature niche of whales while feeding is because prey is concentrated at these temperatures and are easier to capture at low temperatures, or because there are restrictions in the thermoregulation of the whales. In any case, the small niche requirements emphasize the sensitivity of narwhals to changes in the thermal characteristics of habitats.

Discussion

It was noted that the salinity of the water was not considered in this study but that this could be done and that there are peaks in the temperature break points, which may help predictions of where prey are located.

It was clarified that the temperature average presented in the study is an average from all the CTD station readings within the Scoresby Sound system. These were calculated spatially as averages of the readings per grid square in the area where the stations were distributed. The WG proposed that indications of variance in the CTD casts could be represented.

Preliminary assessment of the impact of rising sea temperatures on narwhals

Summary (Working Paper 07)

Arctic cetaceans are expected to exhibit behavioural adaptations in response to increasing temperatures and sea-ice loss associated with climate change. Using a unique, large dataset including 147 satellite tracked adult narwhals, Sea Surface Temperatures (SST) data spanning 27 years (1993-2019) and narwhal abundance estimates from 17 localities, we (1) assessed the thermal exposure of this species, (2) investigated the temperature trends at the summering grounds for narwhal populations across its distribution range from the Canadian Arctic Archipelago (CAA) to East Greenland, and (3) assessed the effect of increasing temperature on 36 narwhal abundance. The use of state-of-the-art ocean models showed a sharp SST increase Northwest, Mideast and Southeast of Greenland, whereas no change occurred in the CAA. Generalized Additive Models also indicated a temperature increase of 3°C in East Greenland compared to West Greenland. The largest abundance of narwhals was found in the CAA (>141,000 individuals) where the sea temperatures are the lowest and the most stable over time. In contrast when comparing different regions of Greenland, we found, lower abundances of narwhals in Mideast and Southeast Greenland (range: 50-238 individuals), resulting in a negative relationship between narwhal abundance and increasing SST. These results confirm the hypothesis that warming oceanic waters will restrict the habitat range of this cold-adapted species, further suggesting that narwhals from Mideast and Southeast Greenland may be under pressure to abandon their traditional Arctic habitats due to imminent global warming projections.

Discussion

The WG found it noteworthy that there have been several sightings of narwhals in areas north of their traditional range in recent years (e.g. in Dove Bay, Greenland Sea, Northeast water, and Petermann glacier front) where they have not been seen before and that the abundance estimates in some of these northern areas now are quite high.

It was noted that although it is not currently possible to distinguish between the impacts of catch and temperature change on the abundance narwhals in East Greenland, the data indicates that abundance has always been higher in the colder waters in Canada in comparison to the warmer waters in East Greenland. Whether sea temperature is the primary explanator of abundance being higher in Canada was discussed and it was noted that the relationship between temperature and prey presence is not clear.

Previously strong site fidelity has been documented for narwhals so it has been assumed that there is little plasticity in choice of summering grounds. Changes have, however, recently been observed in tagging studies (in both Canada and Greenland). One narwhal tagged in Tasiilaq was shown to move north in the fall into Scoresby Sound and then out to the offshore wintering grounds. These observations may indicate that narwhal could have more flexibility in their movements than previously thought. The WG noted that what is being observed may also be activity of a sub-population, which is just being noticed now due to enhanced tagging activities. The WG agreed that detecting changes in patterns of movement requires a decent sample size in the tagging and having tags last for a long time.

The primary places where narwhals can get rid of heat is through the dorsal ridge and tail fluke, which restricts their ability to adapt to warming sea temperatures. This means that even if there may be some flexibility in choice of summer grounds, the lack of plasticity connected to their need for cold water remains. Future research is planned that will look more closely at the heat loss capacity of narwhals and how this may affect their ability to respond to anthropogenic impacts.

5.3 SYNTHESIS OF POPULATION RESPONSE

The WG agreed that temperature appears to be operating as a proxy for prey and temperature increases may also be a physiological stressor as the animals may have greater difficulty shedding excess heat during periods of activity.

The WG agreed that hunting and the projected increases in sea surface temperature from climate change will negatively impact the long term viability of populations of animals in these management areas. Furthermore, a loss of sea ice is creating a longer open water season that allows increased vessel activity and industrial activities. This has the potential to increase noise disturbance and add to cumulative negative effects from anthropogenic stressors.

The WG therefore recommended that impacts from climate change be incorporated into future assessment models and management decision-making.

6. STOCK ASSESSMENTS

6.1 STOCK STRUCTURE

6.1.1 Genetics

Presentation Summary

Using 121 complete mitochondrial genomes, low levels of genetic structuring among localities across the narwhal range were found, and no marked geographic structuring of the well-differentiated genetic clades that are apparent in the phylogeny and haplotype network. East Greenland narwhals (all sampled in summer in Scoresby Sound) have for example haplotypes from several genetic clades. The different genetic clades have diverged since the onset of the last glacial period. As the well-differentiated clades lack any apparent geographical structuring in current populations, it is proposed that they might have diverged in allopatry during the last glacial period. After sea ice retreated and narwhals expanded northwards following the Last Glacial Maxima (LGM) (as inferred by species distribution model), potential isolated populations may have experienced more recent secondary contact, resulting in an admixing of divergent lineages. The female effective population size of narwhals was low and relatively stable from 150,000 years ago and then increased around threefold after the LGM, from around 9,000 years ago. The timing of the expansion is coincident with an increase and northwards shift in the amount of available suitable habitat after the LGM. The long-term small effective population size likely explains the very low genetic diversity recorded in narwhals.

Preliminary analyses using low coverage nuclear genomes (pre-filtering of the data) show genetic differentiation between East and West Greenland and Svalbard. Further stock structure in the East could not be investigated as samples are only coming from one sample site. Stock structure within West Greenland/Arctic has to be investigated with the filtered data.

Analyses of stable isotopes show long-term ecological differences between East and West Greenland. They also show differences between the ecological niches of males and females in East Greenland but not in the West. Females in East Greenland have a smaller and lower trophic niche than the males. East Greenland narwhals are thus genetically and ecologically distinct from West Greenland and genetically distinct from Svalbard.

Discussion

The WG discussed potential reasons for the difference observed in the trophic range between females and males in East Greenland. It was suggested that it may be useful to look at the size of the animals as larger animals may be feeding at higher trophic levels.

The WG acknowledged that the analysis presented provides some information on stock structure but it is not (yet) powerful enough to distinguish different stocks in East Greenland. Developing the potential to identify animals from different areas of East Greenland was, however, seen as very valuable and therefore the importance of continuing to develop this work was emphasised. Avenues for this future work included increasing the sample size to include all areas of East Greenland, as well including more filters (to remove bias or uninformative data). The development of markers was also emphasised as important because even now assigning an individual to a population from either East or West Greenland can only be done through sequencing the whole genome.

6.1.2 Seasonal Distribution

The WG was presented with data on movement and seasonal distribution of animals in Scoresby Sound in the working papers described above. Geographic separation and a high level of site fidelity has been demonstrated by the tagging program in Scoresby Sound, although there is information from one animal from Kangerlussuaq indicating an alternative movement pattern. It was noted that information contradicting site fidelity was limited but that complete fidelity is also not necessary for the allocation of management areas.

6.1.3 Management Based Stock Structure

The recommendations from the WG regarding management units are based on the known high degree of site fidelity, the observed distribution of animals during the summer, and the desire to facilitate a precautionary approach to management.

The WG acknowledges uncertainty on the stock structure in management area 1 (Ittoqqortoormiit and Scoresby Sound), as it is unclear whether the area is inhabited by two separate aggregations at different times of the year (e.g. as indicated by the bimodal distribution of catches and tagging data).

Although current data suggests that there may be an inflow of animals from another area in the spring, there is as yet no concrete evidence linking the animals caught in Scoresby Sound in the spring to populations of narwhals in the north. This means that although there may be a second stock supplying the spring hunt in Scoresby Sound (and it is therefore theoretically possible to manage the spring and fall hunts differently), there is currently not enough information to differentiate the area into separate management units or to make recommendations regarding a sustainable catch for the spring hunt.

The WG therefore agreed that a precautionary approach is to continue treating Scoresby Sound as a single management area until more information on the stock structure is available.

Despite these questions regarding stock structure, the WG sees no reason to believe that the aerial surveys performed in the area in summer were incomplete.

6.2 STOCK ASSESSMENT MODEL

6.2.1 Draft Assessment Model

For the assessments, an age structured, density dependent population model was used that included parameters such as survival rates, birth rates, abundance estimates, catch statistics etc to estimate how the population will grow and change over time. Estimates are normally provided for the next 5 years, with information given on the probabilities that the population will meet management objectives given different harvest levels.

The WG noted that the current management objective for narwhals in East Greenland is to have an increasing stock, with NAMMCO recommending the use of a 70% probability that the population will increase when providing recommendations for conservation and management.

Draft runs of the population model were conducted to examine the status of narwhals in the three management areas referred to as Ittoqqortoormiit (including Scoresby Sound and Bosseville Coast), Kangerlussuaq (from 67˚N00' to 68˚N30') and Tasiilaq (south of 67˚N00'). These assessments were presented in working paper 16. In all three cases, the model indicated that with an annual growth rate estimate below 1%, it was highly unlikely that the aggregations could sustain any removals at this time.

The parameters and data used in the draft model were then discussed by the WG and new runs decided for sensitivity testing the results.

6.2.2 Review of Draft Population Model

The draft model runs that were conducted had a standard reproductive rate of 0.33 (reflecting a three-year birth interval) and some members found that adult survival could be too low in the model. The information presented during the meeting seemed to contradict the results of the draft assessment, indicating instead that adult survival was fine but there seemed to be a problem with reproduction. Furthermore, it seemed that climate change may be impacting the population, with the most likely route for this being through impacts on reproduction and juvenile survival, and/or through emigration.

One proposal for a revision to the model that may allow it to better match the data presented was to fix adult survival rather than birth rates, and allow birth rates to be estimated instead since this seemed to be what was fluctuating in the population in practice. There was some disagreement on the appropriateness of fixing adult survival though as there is currently no data available to inform the value to be set.

An alternative approach proposed was to investigate the impact of narrowing the priors on adult survival and changing the value of the birth rate to see the impact of this. The priors used in the model were agreed following significant discussion during the previous NAMMCO-JCNB joint working group meeting and the appropriateness of changing them now was therefore challenged. The WG agreed that since this meeting had reviewed new information that all pointed to a declining birth rate for narwhals in East Greenland, amendments to the model and the priors were required. A question was asked as to whether it was possible to use different priors for the different areas given the variation in data and situations. It was also proposed that different catch series could be included in areas where underreporting may be an issue.

The accuracy of the age structure information and the appropriateness of its use was also a topic of discussion, and particularly whether the age structure determined from Scoresby Sound should be applied to all three management areas. The draft model runs assumed that the lack of young animals in the hunt stemmed from hunter selectivity, but it is not clear this is true or whether it actually reflects an absence of young animals in the population due to other factors. It was noted that underrepresentation of young animals has been seen in other hunts of beluga, walrus and narwhals, but that the reasons for this may differ between hunts. While age structure data from catches are not used in assessments in Canada (due to bias in this type of data), they have been used in previous NAMMCO assessments, where the assessment models correct for the underrepresentation of younger animals in the catch.

Whether it was appropriate to use the model in cases where there is only one abundance estimate was also discussed. An argument was presented that it may not be considered problematic if there is confidence in the priors used. There is only one abundance estimate used in Tasiilaq because although there have been two surveys, the zero observation from the recent survey is not used in the model. The WG discussed using a 'dummy' small number (e.g. 50 animals) for the purposes of investigating the impact of including a second abundance estimate. Another alternative proposed was to use PBR instead of the current model, or to adopt a principle-based approach – such as no hunt permitted for populations with less than a set number (e.g. 1000) animals. The WG agreed that the sufficiency of the model to inform management advice will be revisited and further discussed after new runs based on the feedback already received had been made.

Based on the discussion, the WG requested that the following new model runs be performed for sensitivity testing: A run with and without the age structure data; a run with a narrower prior on adult survival (adjusted to start at 0.97) and a wider prior on juvenile survival (if this was necessary); a run using lower birth rates (0.2 and 0.1 in Scoresby Sound and 0.2 in all other areas); a run using a dummy abundance estimate of 50 animals (with a CV of 100%).

6.2.3 Longer Term Model Revisions

The WG also discussed potential model revisions from a longer-term perspective. This was particularly in terms of how to adjust the model to be able to account for environmental variability. It was noted that certain aspects may already be incorporated in the model, in the sense that a parameter like reproductive rate may already be capturing impacts from stress generated by environmental conditions. Incorporating a range of changing factors was also suggested as not necessary if the projections are only for short time periods. That is, if the timeframe for the projection is only 5 years ahead, then rather than adjusting the model to include additional parameters it may be sufficient to have good data on the current situation. In this sense it was argued that it may not necessarily be helpful to try and integrate all factors into a model and that an alternative approach would be to just state certain things directly. However, since scenario testing using the model is already done to try and understand what is going on in the system, the WG agreed that assessing the explanatory power of environmental factors was a valid extension of this work.

The WG noted that the model currently assumes that if hunting stops, recovery will happen and discussed the potential relevance of considering longer timeframes to be able to indicate the potential that trends of decline may continue due to environmental changes. Adding environmental factors to the model can give more flexibility in this regard and better capture the situation in which climactic changes can also have a significant impact on the population. One way to incorporate environmental factors may be to begin by including the most relevant aspects for each species. For narwhals, this may, for example, involve linking temperature change to natality. The WG acknowledged that this data would be hard to obtain and especially if the hunt is closed. It also noted that there seems to be a good correlation between sea surface temperature and available habitat so some function of sea surface temperature could also be used. With the data already available, it seemed possible to plot narwhal abundance against suitable habitat (based on temperature) over time. This was considered useful to do and it was suggested that this could be requested for the NAMMCO-JCNB joint working group meeting in 2020. It was proposed that it may also be useful to include birth rates as part of the likelihood in the model as is currently the case for age structure.

6.2.4 Revised Stock Assessment Models

Summary of Revised Model Runs

The model was run again for all three management areas with the revisions requested and described above. New working documents providing the results of these revised runs were presented and discussed.

Discussion

The most significant impact in the revised model runs seemed to come from the inclusion or exclusion of the age structure data. Since this data comes from one area but is being applied in the model to all three stocks, the relevance of this approach was discussed. It was noted that if environmental factors are affecting the age structure, it may be appropriate to apply the same data across all three areas as it could be reasonable to assume there would be similar patterns. However, since hunters' reports show twice as many young animals in Tasiilaq as in Ittoqqortoormitt, it was not clear that the current approach was best. The WG therefore agreed to use model runs for Tasiilaq and Kangerlussuaq without information on age structure, while it would be used in the case of Ittoqqortoormitt since this is where the data had been gathered.

An additional revision was discussed regarding the most appropriate way to distribute the historical catches between Tasiilaq and Kangerlussaq. One proposal was to not have the model period extend all the way back to 1955 but rather include only catch history from 1993 when it is possible to know where catches were taken (due to the introduction of the new reporting scheme in 1993 linking each hunt to the hunter's home town). One argument presented against this was that having a longer time period in the model allows the percentage of decline in the population to be more clearly observed. Using a linear progression for Kangerlussaq from 1955 (when catch was first reported) was discussed as another possible approach. However, this was dismissed since there were periods in which no hunters were living in the area and therefore a linear increase was not accurate. On the basis of the discussion, the WG agreed that a revised catch history for Tasiilaq and Kangerlussuaq would be created for the period prior to 1993 based on a more realistic distribution of catches between the two areas.

The catch history working paper was updated including catches for Kangerlussuaq from Dietz et al. (1994), where sporadic catches during the period from 1955 to 1987 had been recorded.

The proportion of catches taken in Kangerlussuaq and the Tasiilaq area was then recalculated for 1955-1990, based on the catches from Dietz et al. (1994), and used for estimating total removals for that period.

An additional change was made as the proportion of catches taken using speedboats (open water hunt) was set to 0 for 1955-1990 as none or very few had speedboats at that time. All hunts for that period were done from kayaks and total removals was therefore estimated using only the lower correction factor for kayak hunting (1.05) compared to hunting from speedboats (1.44). This resulted in lower total removals for Tasiilaq and Kangerlussuaq for 1955-1990 than shown in Table 1 of the original version of working paper 07 on catch statistics.

Final Model Runs

Ittoqqortoormiit

The WG agreed on the dIw model for narwhals in the Ittoqqortoormiit area (i.e. the model using a birth rate fixed at the observed average of 0.31). The model estimates a small and depleted aggregation. With a historical population estimate of 2,290 (90% CI:1,750–2,840), and a current depletion to only 18% (90% CI:6%–40%) of this, the model estimates a 2019 abundance of 410 (90% CI:120–990) animals. With an annual growth rate estimate close to zero, it is unlikely that the aggregation can sustain any current removals. The estimated probability of increase is only 57% should a single individual be removed annually.

Kangerlussuaq

The WG agreed on the dKa model for narwhals around Kangerlussuaq in East Greenland (i.e. the model using no age structured data and a birth rate fixed at 0.33 for a three year birth interval). The model estimates a small depleted aggregation. With a historical population estimate of 1,050 (90% CI:720–1,540), and a current depletion to 27% (90% CI:12%–59%) of this, the model estimates a 2019 abundance of 290 (90% CI:140–560) animals. This aggregation is so small that it is unlikely that it can sustain any current removals. The estimated probability of increase is 72% should 4 individuals be removed annually. This estimate, is however, considered to be too optimistic because demographic variation, allee effects (i.e. the positive correlation between population density and individual fitness, or how aggregation can improve survival rates for individuals), and other factors— which negatively affect small populations—were not included in the model but should be taken into account when considering the sustainability of the harvest.

Tasiilaq

The WG agreed on the dIa model for narwhals in the Tasiilaq area (i.e. the model using no age structured data and a birth rate fixed at 0.33 for a three year birth interval). The model estimates a small depleted aggregation. With a historical population estimate of 820 (90% CI:580– 1,210), and a current depletion to 25% (90% CI:4%–74%) of this, the model estimates a 2019 abundance of 210 (90% CI:30–670) animals. This aggregation is so small that it is unlikely that it can sustain any current removals. The estimated probability of increase is 76% should two individuals be removed annually. This estimate, is however, considered to be too optimistic, partly because of a statistical bias (the model abundance being slightly larger than the survey estimate), and partly because demographic variation, allee effects, and other factors—which negatively affect small populations—were not included in the model but should be taken into account when considering the sustainability of the harvest.

Table 1: **Abundance** estimates with cv in parenthesis (given in %). I_a is relative estimates covering only Scoresby Sound. N_b is an absolute estimate for Scoresby Sound and the Bosseville Coast. N_c is absolute estimates for Kangerlussuaq. N_d is absolute estimate for Tasiilaq. Data from Hansen and Heide-Jørgensen (2017), Hansen et al. (2019), Hansen and Heide-Jørgensen (2019), and Heide-Jørgensen (2019).

Year	I_a	N_b	N_c	N_d
1983	1180 (34)	–	–	–
1984	401 (58)	–	–	–
2008	–	1940 (57)	613 (71)	206 (55)
2016	–	433 (49)	269 (37)	–
2017	246 (43)	–	–	–

Table 2: **Prior distributions** for the different models (M). The list of parameters: N^* is the population dynamic equilibrium abundance, p the yearly survival, p_0 the first year survival, b the birth rate, a_m the age of the first reproductive event, θ the female fraction at birth, γ the density regulation, β_i the abundance estimate bias (i: data reference), s_i the age-structured selectivity (i: data reference), and $a_{s,i}$ the maximum age with age-structured selectivity (i: data reference). Abundance is given in thousands. The prior probability distribution is given by superscripts; p: fixed value, u: uniform (min,max), U: log uniform (min,max), d: discrete uniform (min,max), and b: beta ($^{a,b}{}_{i,x}$) with i=min and x=max.

M	N^*	p	p_0	b	a_m	ϑ	γ	β_a	s_e	$a_{s,e}$
dIw	$1.2,3.6^U$	${}^{2,2}_{.95,1}{}^{b}$	$.2,1^u$	.31	${}^{2,2}_{7,15}{}^{b}$	.5	$2,4^u$	$.1,1^U$	$-0.8,1^u$	$2,15^d$
dKa	$.55,2.5^U$	${}^{2,2}_{.95,1}{}^{b}$	$.2,1^u$	.33	${}^{2,2}_{7,15}{}^{b}$	.5	$2,4^u$	-	-	-
dTa	$.4,2^U$	${}^{2,2}_{.95,1}{}^{b}$	$.2,1^u$	.33	${}^{2,2}_{7,15}{}^{b}$	.5	$2,4^u$	-	-	-

Table 3: **Sampling statistics** for the different models (M). The number of parameter sets in the sample (n_S) and the resample (n_R), the number of unique parameter sets in the resample, and the maximum number of occurrences of a unique parameter set in the resample. n_S and n_R are given in thousands.

M	n_S	n_R	unique	max
dIw	300	5	2094	35
dKa	300	5	4700	3
dTa	300	5	4813	3

Table 4: **Parameter estimates** for the different models (*M*). Estimates are given by the median ($x_{.5}$) and the 90% credibility interval ($x_{.05}$ - $x_{.95}$) of the posterior distributions. N_t and d_t are estimates for 2019. Abundance is given in thousands.

M		N^*	r	msyr	p	p_0	a_m	γ	msyl	N_t
	$x_{.5}$	2.29	.009	.007	.96	.555	11.5	2.91	.637	.41
	$x_{.05}$	1.75	.001	0	.954	.414	8.25	2.11	.594	.12
dIw	$x_{.95}$	2.84	.026	.020	.969	.8	14	3.88	.677	.992
	$x_{.5}$	1.05	.027	.021	.973	.625	11	2.98	.657	.288
	$x_{.05}$	.723	.003	.002	.957	.267	8.06	2.09	.606	.136
dKa	$x_{.95}$	1.54	.055	.042	.988	.966	14	3.9	.699	.557
	$x_{.5}$	.824	.030	.023	.974	.661	11	3.03	.661	.206
	$x_{.05}$	.578	.005	.003	.958	.267	8.1	2.11	.609	.030
dTa	$x_{.95}$	1.21	.056	.044	.989	.968	13.9	3.9	.703	.669

M	d_t	$\dot{r}_t$	$\tilde{n}_{0,t}$	$\tilde{n}_{1,t}$	β_a	s_e	$a_{s,e}$
	.184	.001	.069	.045	.413	.151	7
	.058	-0.00996	.048	.038	.236	-0.25	5
dIw	.405	.019	.087	.054	.677	.907	14
	.27	.025	.083	.049	-	-	-
	.118	.003	.065	.028	-	-	-
dKa	.582	.049	.107	.065	-	-	-
	.248	.026	.081	.052	-	-	-
	.038	.004	.059	.029	-	-	-
dTa	.741	.049	.106	.075	-	-	-

Table 5: **Catch objective trade-off.** The probabilities of population increase for the different models (*M*), given annual total removals between 1 and 10 individuals in the period 2020 to 2025. θ gives the assumed female fraction in the removals.

M	dIw	dKa	dTa
ϑ	0.5	0.5	0.5
1	0.57	0.94	0.88
2	0.48	0.86	0.76
3	0.4	0.79	0.66
4	0.32	0.72	0.58
5	0.28	0.65	0.52
6	0.22	0.57	0.46
7	0.18	0.5	0.41
8	0.15	0.44	0.36
9	0.13	0.37	0.33
10	0.11	0.32	0.29

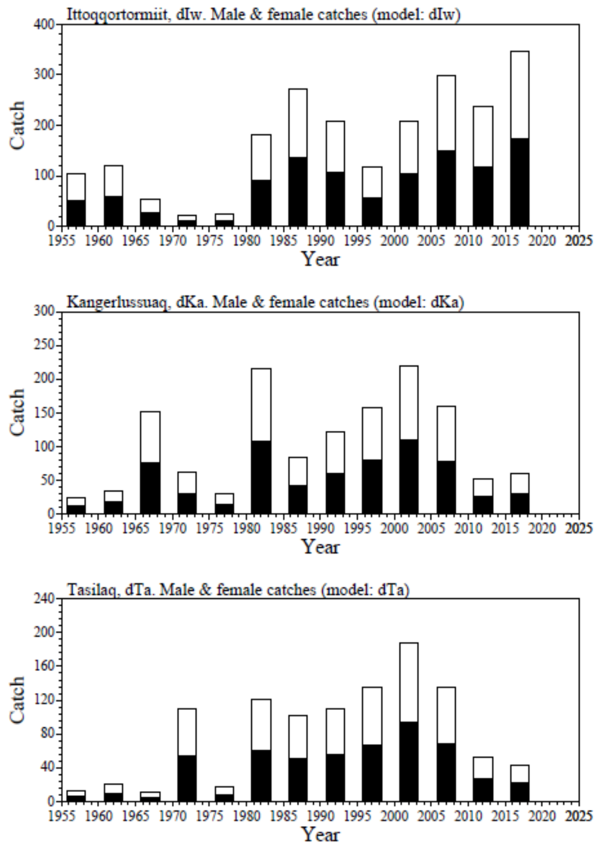

Figure 2: The total removals estimates for males (solid bars) and females (open bars). Data from Garde et al., 2019.

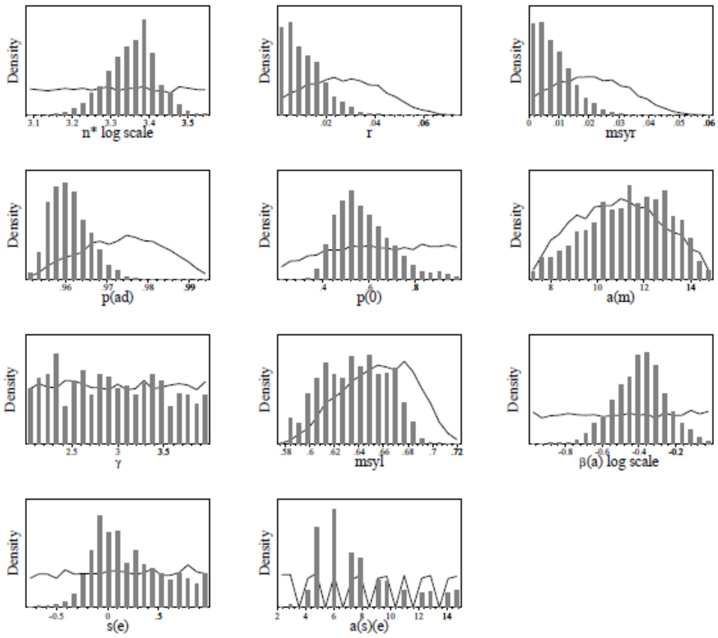

Figure 3: Realised prior (curve) and posterior (bars) distributions for model dIw.

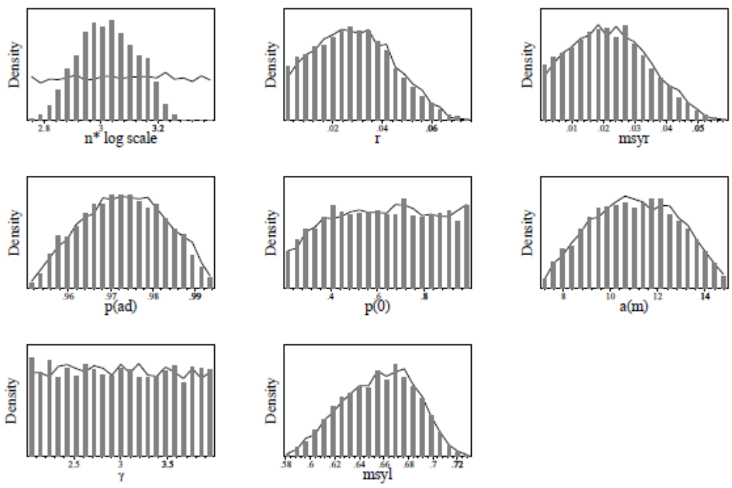

Figure 4: Realised prior (curve) and posterior (bars) distributions for model dKa.

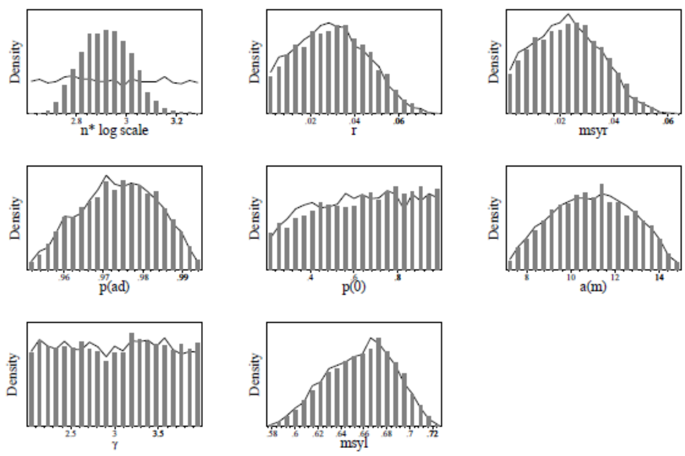

Figure 5: Realised prior (curve) and posterior (bars) distributions for model dTa.

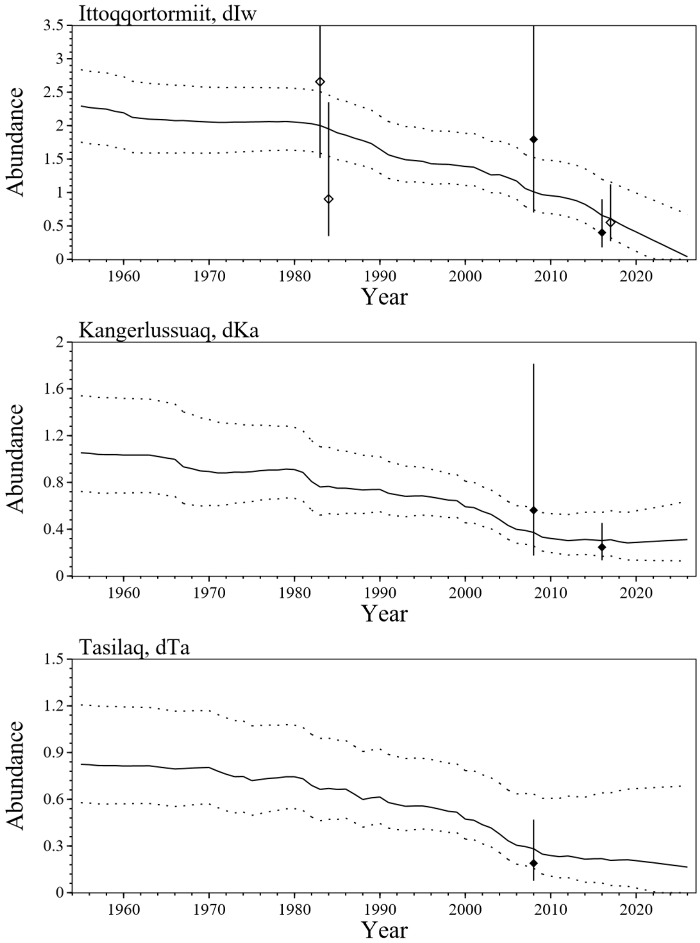

Figure 6: The projected median and 90% credibility interval of the different models.

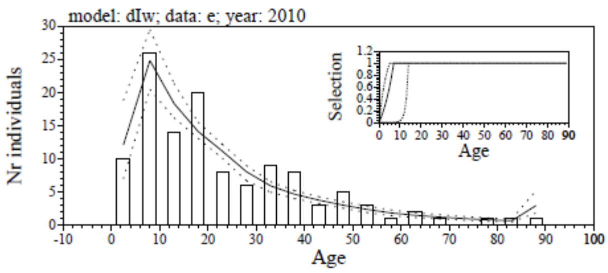

Figure 7: Fits to the age-structure of caught animals. Data are given by bars, and models by the median estimate (solid curve) and the 90% credibility interval (dashed curves). Inserts show the estimated median and credibility intervals of the age-structured harvest selection.

The WG expressed significant concern over the fact that removals continue to take place in small populations observed to be in decline. It believes that step-wise reductions in quotas would increase the already high level of risk facing these populations and therefore such an approach is not recommended. It considers the urgency of the situation to now require immediate action.

7. IMPLEMENTATION OF EARLIER ADVICE ON EAST GREENLAND NARWHALS

Responses to the recommendations from the 2017 meeting of the Joint NAMMCO-JCNB Working Group on Narwhal and Beluga are outlined below.

- *Three management areas be recognised for East Greenland*

The NAMMCO Management Committee for Cetaceans (MCC) requested further clarification of the justification for this recommendation. This was provided by the NAMMCO Scientific Committee in 2018 and accepted by the MCC in 2019. It is assumed that the implementation of this will be considered in 2020 and acknowledged that this may require a new executive order to be carried out.

- *Catch quota be reduced to less than 10 narwhals in both Kangerlussuaq and Ittoqqortormiit management areas, and there be no catches south of 68˚N in the Tasiilaq management area*

This recommendation has not yet been implemented

- *More information be gathered on stock structure, as well as on distribution and movement (i.e. due to environmental changes);*

The latest information available on these issues was presented at this meeting.

- *The Larsen et al. 1994 survey be re-evaluated*

This has now been done.

- *An aerial survey be performed in Scoresby Sound in 2017*

This was carried out.

- *The stock identity of the winter hunt in Scoresby Sound be clarified*

This requires ongoing investigation as no firm conclusion has been reached on the issue and hence, this meeting recommends further work to clarify stock identity in the ITT management area (although the WG notes that information from the spring hunt will be most valuable for providing this clarification).

The WG also notes that the last meeting of the joint NAMMCO-JCNB working group proposed organising a workshop (in connection with its next meeting) to assemble and analyse the latest data on the impacts of climate change. Information presented at this WG meeting has further demonstrated the importance of this issue and shown that relevant data is available. The WG therefore supports the value of collating and reviewing the available information on impacts of climate change on Arctic cetaceans (i.e. narwhal, beluga and bowhead whales), as well as further discussions on how best to incorporate this data into future assessments.

8. RECOMMENDATIONS FOR RESEARCH & MANAGEMENT

8.1 RECOMMENDATIONS FOR CONSERVATION AND MANAGEMENT

- *The NAMMCO SC seek an immediate response from managers to the information that current removal levels are unsustainable*
- *The NAMMCO SC develop guidance on a standard or principle-based approach for how to manage small stocks and harvest advice*
- *Data on struck and lost be obtained to inform assessments of sustainability if any harvest continues*
- *Reports of any landed animals include the length of the animal in addition to the age category and presence of a foetus*
- *Hunters receive payment for assisting scientific research to clarify stock structure and abundance (e.g. through tagging animals)*
- *Ways to improve the reporting of user observations (e.g. on struck and lost, pregnancies, stomach contents, and seasonal presence) be investigated to inform future assessments*
- *The negative impact of climate change on narwhals be recognised and included in management decision-making on all stocks*

8.2 RECOMMENDATIONS FOR RESEARCH

- *Perform further analysis of the study on the effects of noise disturbance on narwhals in Scoresby Sound*
- *Conduct further research on the impact of increasing sea temperatures and the thermal regulation of narwhals*

- *Carry out further research to clarify stock structure, especially in the Ittoqqortoormiit management area (Scoresby Sound), e.g. through tagging animals in the spring, a spring survey and ongoing genetic analysis.*
- *Estimate a plausible maximum population size in Tasiilaq from the 2016 survey*
- *Investigate the possibility of calculating the detection function for the most recent survey and assess whether applying it to previous surveys has a significant impact*
- *Include the collection of data on calves in future surveys*
- *Develop predictive models of narwhal habitat and project changes over time*
- *Further evaluate the feasibility of using mark-recapture data for estimating abundance*
- *Expand the knowledge available regarding narwhal diets and trophic roles*

9. OTHER BUSINESS

ICES Working Group on Integrated Ecosystem Assessment in the Greenland Sea

A presentation was given on the work within ICES to establish Working Groups on Integrated Ecosystem Assessment within different regions. The aim of these groups is to develop a holistic perspective on marine ecosystems and the changes occurring there. There is now an initiative to establish such a Working Group for the Greenland Sea. The terms of reference are:

- Assemble relevant data for describing spatial and temporal changes in the Greenland Sea
- Review and consider methodological approaches and analytical tools for conducting integrated ecosystem assessment for the Greenland Sea
- Prepare an Ecosystem Overview for the Greenland Sea

There is a workplan for year 1 that includes: assemble relevant data that can be used to describe spatiotemporal changes in the Greenland Sea; create a merged database containing physical, chemical and biological oceanographic data; develop an ecosystem overview; start discussions on methodological approaches and analytical tools for conducting integrated ecosystem assessment; identify additional scientists/partners and invite them to join the group.

The priority for this work is considered high and the group is likely to have a lifespan of at least 3 years, with annual meetings. The first meeting of the group is planned for early 2020. The Chairs of the group are Jesper Boje and Colin Stedmon (jbo@aqua.dtu.dk; cost@aqua.dtu.dk), with participants from Greenland, Iceland, Norway and Denmark. If anyone is interested in participating in this work they can take contact with the Chairs.

The WG recommends that the NAMMCO Scientific Committee consider collating the data available on marine mammals in the Greenland Sea and contribute to the ICES Working Group.

10. MEETING CLOSE

The Chair thanked all of the participants for their active contribution to the meeting and the excellent research done to inform the discussions. The WG thanked the Chair for efficient guidance through the agenda to arrive at recommendations for both research and management. The WG also thanked the rapporteur for her comprehensive record of the discussions.

The meeting was closed at 13:15 on September 27th 2019.

The draft report with recommendations was accepted before the close of the meeting on September 27th 2019. Following minor editing and formatting work, the final report was accepted October 7th 2019.

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NAMMCO SCIENTIFIC COMMITTEE

AD HOC WORKING GROUP ON NARWHAL IN EAST GREENLAND

24-27 September 2019, Greenland Representation Copenhagen, Denmark

AGENDA

Tuesday 24 September 09:00-17:00

1. CHAIRMAN WELCOME AND OPENING REMARKS

1.1. Welcome & Logistics
1.2. Appointment of Rapporteurs
1.3. Review of Terms of Reference
1.4. Review of Available Documents
1.5. Adoption of Agenda

2. DISTRIBUTION AND ABUNDANCE OF EG NARWHAL

2.1. Review of Movements and Dive Behaviour Data
2.1.1. Satellite tracking studies
2.1.2. Time-depth recorder studies
2.1.3. Local knowledge observations
2.2. Review of aerial surveys in East Greenland
Hansen et al.: Abundance of narwhals in Scoresby Sound and southeast Greenland
Hansen et al.: Abundance of narwhals in Dove Bay and adjacent areas
Heide-Jørgensen: Abundance of narwhals in Scoresby Sound in 1983-84 and 2019.
Heide-Jørgensen: Timing and direction of the spring migration of narwhals entering Scoresby Sound
Heide-Jørgensen: Statistics from the live capturing operations in Hjørnedal 2010-2019

3. ANTHROPOGENTIC IMPACTS

3.1. Hunt Removals
Garde: Catch statistics for East Greenland narwhals
3.2. Other Removals
3.2.1. Fisheries by-catch or entanglement data
3.2.2. Vessel strikes
3.3. Non-lethal Impacts
Tervo et al.: The short-term effects of seismic exploration on narwhals
For information papers on fisheries competition

Wednesday 25 September 09:00-17:00

4. BIOLOGY

4.1. Life History
Garde: Life history of narwhals from East Greenland
Hansen: Calf production of narwhals
4.2. Genetics and Physiology

5. HABITAT EAST GREENLAND NARWHALS

5.1. Habitat Changes
Heide-Jørgensen et al:. A regime shift in South-east Greenland
For Information papers on physical and biological changes

5.2. Narwhal Response to Changes
Heide-Jørgensen et al.: Temperature dependent habitat selection of narwhals
Chambault et al. The impact of rising sea temperatures on an Arctic top predator.

Hansen et al.: Trophic interactions between narwhals and their prey in Dove Bay
For Information papers on responses of other narwhal populations and other odontocetes
For Information papers on limits to adaptation to habitat change of narwhals and belugas

5.3. Synthesis of Population Response
5.3.1. Changes in seasonal distribution
5.3.2. Changes in life history parameters
5.3.3. Changes in habitat carrying capacity

Thursday 26 September 09:00-17:00

6. STOCK ASSESSMENTS AND MANAGEMENT ADVICE

6.1. Stock Structure
6.1.1. Genetics
6.1.2. Seasonal distribution
6.1.3. Management based stock structure
6.2. Stock Assessment Model
6.2.1. Draft assessment model
Witting: Assessment runs for East Greenland narwhals
6.2.2. Review of model structure: multiple stocks or seasons
6.2.3. Review of population model: time or habitat dependent parameters
6.2.4. Review of model priors
6.2.5. Revise stock assessment model (if necessary)
6.3. Develop Management Advice
6.3.1. Advice on management of hunting
6.3.2. Advice on management of interacting fisheries
6.3.3. Advice on management of other anthropogenic impacts

7. IMPLEMENTATION OF EARLIER ADVICE ON EAST GREENLAND NARWHALS

8. OTHER BUSINESS

Friday 27 September 09:00-13:00

PREPARE REPORT

ADJOURN

This Working Group is convened in response to a recommendation from the NAMMCO Scientific Committee (SC25) in 2018 to assess the status of narwhals in east Greenland and report results back to the committee at its 26th meeting (SC26). This recommendation was endorsed by the Joint Management Committee at the NAMMCO Council meeting held in 2019 (NAMMCO 26).

The Terms of Reference for the Meeting are:

1. Review the latest information on surveys in East Greenland including options for updating the surveys from the 1980s.
2. Review information of satellite tracking of narwhals in East Greenland
3. Present the latest information on genetic discrimination of stocks in East Greenland
4. Assess the importance of climate change on the distribution of narwhals in East Greenland
5. Compile hunting statistics and information from hunters on availability of narwhals
6. Assess the future sustainability of catches

NAMMCO SCIENTIFIC COMMITTEE

AD HOC WORKING GROUP ON NARWHAL IN EAST GREENLAND

24-27 September 2019, Greenland Representation Copenhagen, Denmark

LIST OF PARTICIPANTS

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NAMMCO SCIENTIFIC COMMITTEE

AD HOC WORKING GROUP ON NARWHAL IN EAST GREENLAND

24-27 September 2019, Greenland Representation Copenhagen, Denmark

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SC/26/NEGWG/FI02	Nielsen, M. R., & Meilby, H. (2013). Quotas on narwhal (Monodon monoceros) hunting in East Greenland: trends in narwhal killed per hunter and potential impacts of regulations on Inuit communities. *Human ecology*, *41*(2), 187-203.	3.1
SC/26/NEGWG/FI03	Heide-Jørgensen, M.P. et al. (2015). The predictable narwhal: satellite tracking shows behavioural similarities between isolated subpopulations. *Journal of Zoology 297*, 54-65.	2.1
SC/26/NEGWG/FI04	Ngô, M.C. et al. (2019). Understanding narwhal diving behaviour using Hidden Markov Models with dependent state distributions and long range dependence. *PLoS Computational Biology 15(3)*: e1006425	2.1
SC/26/NEGWG/FI05	Blackwell, S.B. et al. (2018). Spatial and temporal patterns of sound production in East Greenland narwhals. *PLoS ONE 13(6):* e0198295	3.3, 4.1
SC/26/NEGWG/FI06	Williams, T.M. et al. (2017). Paradoxical escape responses by narwhals (*Monodon Monoceros*). *Science 358:* 1328-1331	
SC/26/NEGWG/FI07	Vacquié-Garcia, J. et al. (2017). Late summer distribution and abundance of ice-associated whales in the Norwegian high Arctic. *Endangered species research 32*: 59-70.	2
SC/26/NEGWG/FI08	Hansen, R.G. et al. (2018). Summer surveys of marine mammals in the Greenland Sea and the Northeast Water and winter survey of marine mammals in the Northeast Water. *Internal report prepared for MLSA & EAMRA as part of the Joint Northeast Greenland Strategic Environmental Study Program.*	2
SC/26/NEGWG/FI09	Garde, E and Heide-Jørgense, M.P. (2017). Update on life history parameters of narwhals (*monodon Monoceros)* from East and West Greenland. *Working Paper for NAMMCO/JCNB Joint Working Group on Narwhal and Beluga*.	4.1

SC/26/NEGWG/FI10	Garde, E. et al. (2015). Life history parameters of narwhals (*Monodon monoceros*) from Greenland. *Journal of Mammology 96(4):* 866-879.	4.1
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SC/26/NEGWG/FI12	Doniol-Valcroze, T. and Hammill, M. O. (2012). Information on abundance and harvest of Ungava Bay beluga. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/126. iv + 12 p.	2