JOINT WORKING GROUP MEETING

OF THE

NAMMCO SCIENTIFIC COMMITTEE WORKING GROUP ON THE POPULATION STATUS OF NARWHAL AND BELUGA IN THE NORTH ATLANTIC

AND THE

CANADA/GREENLAND JOINT COMMISSION ON CONSERVATION AND MANAGEMENT OF NARWHAL AND BELUGA SCIENTIFIC WORKING GROUP

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Report

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EXECUTIVE SUMMARY

The NAMMCO-JCNB Joint Working Group (JWG) on narwhal and beluga met during December 13th–17th, at the Canadian Museum for Human Rights located in Winnipeg, Manitoba, with mixed in-person and virtual attendants, under the leadership of Co-Chairs Cortney Watt (JCNB) and Roderick Hobbs (NAMMCO).

The **Terms of Reference** for this meeting were to: a) *review advice on beluga stocks in West Greenland, the North Water stock and West Greenland stock from the 2020 JWG meeting, including landings and seasonal closures for belugas;* b) *review information on availability bias correction factors, updated abundance estimates, and movement of narwhal*; c) *assess the impacts of climate change on narwhal and beluga movements, distribution, population dynamics, habitat and hunt methods, timing and location*; d) r*evise advice models to incorporate climate change impacts where information is available and identify additional information requirements*; e) *update and review the narwhal allocation model to assign harvested animals to individual summer stocks* and; f) *generate advice on management of narwhal stocks in West Greenland and eastern Canada, including: Smith Sound, Jones Sound, Inglefield Bredning, Melville Bay, Somerset Island, Admiralty Inlet, Eclipse Sound, East Baffin Island*.

Narwhal

Using results from the Quantitative Subworking Group (QSG), availability bias estimates for narwhal stock surveys were updated and final abundance estimates were included in the narwhal allocation model. The allocation model was updated using expert knowledge and recent tag data which showed limited movement of narwhal between stocks in the summer.

New **abundance estimates** from Golder Associates Ltd. for Eclipse Sound and Admiralty Inlet were reviewed and adjusted to include all replicate surveys and update the CV to reflect variation among survey replicates. **Availability bias** estimates from satellite tracking data and overlapping aerial images were reviewed in the QSG and presented to the WG. Preliminary results from overlapping aerial images showed potential for investigating availability bias in the future but would not be used within this assessment. The JWG agreed that a CV of 20% be used for availability bias corrections, to account for uncertainty in the depth to which narwhal can be seen. To correct existing survey results, where the availability bias correction was embedded in the calculation, a CV of 18% could be added to the CV of the availability component. All survey estimates were adjusted to reflect this new CV on the availability bias estimate. Although water clarity is likely to have an impact on narwhal detection, and was shown to impact time-in-view, satellite tags do not have high enough accuracy in detecting depth to incorporate 0–1 m depths into availability bias calculations at this time; thus only 0–2 m availability bias adjustments were used for abundance estimation. Abundance estimates used in the allocation model were:

Year	Smith Sound	Jones Sound	Inglefield Bredning	Melville Bay	Somerset Island	Admiralty Inlet	Eclipse Sound	East Baffin Island
1975	-	-	-	-	-	29,740 (0.47)	-	-
1981	-	-	-	-	32,520 (0.22)	-	-	-
1985	-	-	3,690 (0.32)	-	-	16,400 (0.43)	-	-
1986	-	-	9,560 (0.40)	-	-	-	-	-
1996	-	-	-	-	45,360 (0.35)	-	-	-
2001	-	-	3,010 (0.41)	-	-	-	-	-
2002	-	-	1,940 (0.33)	-	29,770 (0.58)	-	-	-
2003	-	-	-	-	-	5,700 (0.56)	-	10,710 (0.34)
2004	-	-	-	-	-	-	21,110 (0.41)	-
2007	-	-	4,110 (0.29)	1,830 (0.94)	-	-	-	-
2010	-	-	-	-	-	19,160 (0.31)	-	-
2012	-	-	-	920 (0.48)	-	-	-	-
2013	17,010 (0.68)	13,200 (0.38)	-	-	51,730 (0.28)	36,430 (0.47)	10,900 (0.31)	11,990 (0.40)
2014	-	-	-	1,770 (0.50)	-	-	-	-
2016	-	-	-	-	-	-	12,040 (0.30)	-
2019	-	-	2,870 (0.28)	4,760 (0.77)	-	25,260 (0.25)	8,460 (0.32)	-

Catch statistics for Canada for the period of 2017–2020, and an update on catch statistics in Greenland for the period of 2005–2020, were presented and accepted for use in the population models.

The **availability matrix** for the narwhal allocation model was updated to include known and unknown movement between narwhal stocks. In particular, the WG reviewed potential weights for stocks where no narwhal movement has been observed between stocks, but movement is possible. The potential for movement between these stocks, or soft zeros in the availability matrix, are represented by a value of 0/n. After discussion on the variance for different values of n, the WG agreed that *n*= 50 should be used, as it would reflect the maximum number of satellite tags deployed for any one stock within the availability matrix.

The **allocation model** that was used to determine recommendations for optimal catch was reviewed and revised. In previous assessments optimal catch levels were developed by trial and error. For this assessment an optimization routine was developed to determine the optimal distribution of landed catches. The WG agreed to an additional criterion for the optimization which set the lower 5% confidence limit in the probability of meeting the management objective of at least 0.5 as a precautionary method. This lower confidence limit was applied to all stocks with the exception of Melville Bay, where this was not possible. Considering this, the working group applied a 0.8 probability of meeting management objectives for Melville Bay at the point estimate. The global optimum in narwhal takes was determined by maximising the relative take (proportional to recent take levels) across all hunting areas. The global optimum in narwhal takes would close the hunt in Upernavik. To allow a small sustainable hunt allocated to Upernavik at the cost of a much larger reduction in the allowable takes in Uummannaq and Disko Bay, the WG agreed to present options for maximum yearly removals per hunting region based on average removals from Upernavik.

The WG reviewed available research on **climate change** effects on the narwhal stocks in West Greenland and the North Water which suggest that although narwhals may be able to adapt their migration patterns, there is an overall predicted loss of suitable habitat. The WG agreed that these impacts cannot be incorporated into the model at this time as the mechanisms that connect environmental change to narwhal stock dynamics are not known. However, the precautionary approach can be used to justify an increase in the probability of meeting the management objective in the allocation model above 0.7 or 0.8 to protect narwhal stocks. In order to monitor for climate change the WG recommends narwhal age class data be collected from aerial photos, and sightings of narwhals in new areas be reported to assess distribution changes.

The Eclipse Sound narwhal stock is undergoing habitat changes through the presence of shipping vessels and icebreakers travelling to and from the **Baffinland Mary River mine**. The WG agreed that the decline in abundance estimates for Eclipse Sound show that the increased anthropogenic activities appear to have already impacted the narwhal stock, which will likely result in narwhal abandonment of the area. Impacts may not be limited to the area, as vessels will pass through transboundary Baffin Bay waters that include habitat for the small narwhal stock in Melville Bay. In case of a declining narwhal population in Eclipse Sound the ongoing assessment will need to be updated more frequently to ensure that catches are maintained at sustainable levels.

Management Advice: *West Greenland and Eastern Canada*
To maintain a 70% probability for population increase in *West Greenland* and an 80% probability for population increase in *Eastern Canada* the assessment recommends an annual landed catch which is dependent on the division of catch between hunting regions. The WG recommends alternative optimal catch allotments (columns O1, O2, etc.) for each hunting region based on the size of the landed catches allowed for Upernavik:

Hunting Region (Season)	Hunted Stocks*	S&L	Alternative Landed Catch Allotments														
			O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	O13	O14	O15
Etah	SS,JS	0.05	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
Qaanaaq	IB	0.05	52	52	52	52	52	52	52	52	52	52	55	55	55	55	55
Grise Fjord (Sp)	JS,SS,IB,SI	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grise Fjord (Su)	JS	0.23	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Grise Fjord (Fa)	JS,SS,IB,SI	0.23	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Upernavik	**MB**	**0.15**	**0**	**2**	**3**	**5**	**7**	**9**	**10**	**12**	**14**	**16**	**17**	**19**	**21**	**23**	**24**
Uummannaq	MB,AI,ES,SI, SS,JS,IB,EB	0.3	123	108	100	100	85	85	69	54	38	46	31	31	15	15	0
Disko Bay	MB,AI,ES,SI, SS,JS,IB,EB	0.3	54	54	46	38	38	31	31	31	31	15	15	8	8	0	0
CCA (Sp)	SI,AI,ES	0.09	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
CCA (Su)	SI,AI,ES	0.09	130	133	133	133	133	133	133	133	133	133	133	133	133	133	133
CCA (Fa)	SI,AI,ES	0.09	69	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Arctic Bay Sp)	AI,ES	0.35	31	31	31	31	31	32	32	33	33	33	33	33	33	34	34
Arctic Bay (Su)	AI,ES	0.35	76	76	76	76	76	79	79	80	80	80	80	82	82	84	84
Arctic Bay (Fa)	AI,ES,SI	0.35	44	44	44	44	44	46	46	47	47	47	47	48	48	49	49
Pond Inlet (Sp)	ES,AI,SI,JS, IB,EB	0.15	29	29	30	30	30	31	31	31	31	33	33	34	34	34	34
Pond Inlet (Sp)	ES,AI	0.15	61	61	63	64	64	66	66	66	66	70	70	71	71	71	71
Pond Inlet (Fa)	ES,AI,SI,JS, IB,EB	0.15	58	58	60	62	62	63	63	63	63	67	67	69	69	69	69
BIC (Sp)	EB,SI,ES,AI, JS,IB	0.23	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
BIC (Su)	EB	0.23	47	48	48	48	48	48	48	48	50	50	50	50	50	50	50
BIC (Fa)	EB,SI,ES,AI, JS,IB	0.23	85	88	88	88	88	88	88	88	90	90	90	90	90	90	90
BIS (Sp)	EB,SI,ES,AI	0.23	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
BIS (Su)	EB	0.23	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
BIS (Fa)	EB,SI,ES,AI	0.23	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
BIS (Wi)	EB,SI,ES,AI	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*Most hunting regions take from a mix of stocks, the summering aggregation from which the greatest proportion of the harvest comes is listed first, stocks which are possible but not likely are in grey. Stock status and hunting regions that take from each stock are:

Stock	2022 Abundance from Model (CI)	Stock Trend in Model	Stock Status from model**	Hunting Regions
Smith Sound (SS)	16,300 (5,510-44,500)	Stable	Not Depleted	Etah, Grise Fiord, Uummannaq, Disko Bay
Jones Sound (JS)	12,700 (6,790-23,900)	Stable	Not Depleted	Etah, Grise Fiord, Uummannaq, Disko Bay, Pond Inlet (spring and fall), Baffin Island Central (spring and fall)
Inglefield Bredning (IB)	2,630 (1,640-3,940)	Declining	Depleted	Qaanaaq, Grise Fiord (spring and fall), Uummannaq, Disko Bay, Pond Inlet (spring and fall), Baffin Island Central (spring and fall)
Melville Bay (MB)	1,250 (412-2,730)	Declining	Depleted	Upernavik, Disko Bay, Uummannaq
Somerset Island (SI)	45,500 (32,100-67,500)	Increasing	Not Depleted	Central Canadian Arctic, Uummannaq, Disko Bay, Arctic Bay (spring and fall), Pond Inlet (spring and fall), Baffin Island Central (spring and fall), Baffin Island South (spring, fall, and winter), Grise Fiord (spring and fall)
Admiralty Inlet (AI)	19,400 (14,800-24,700)	Declining	Not Depleted	Arctic Bay, Pond Inlet, Baffin Island Central (spring and fall), Baffin Island South (spring, fall, and winter), Disko Bay, Uummannaq, Central Canadian Arctic (spring and fall)
Eclipse Sound (ES)	11,400 (8,530-15,100)	Stable	Not Depleted	Pond Inlet, Disko Bay, Arctic Bay, Central Canadian Arctic, Baffin Island Central (spring and fall), Baffin Island South (spring, fall, and winter), Uummannaq
East Baffin Island (EB)	10,600 (6,760-16,500)	Stable	Not Depleted	Baffin Island Central, Baffin Island South

** Depleted Status determined as the (median abundance in 2022)/(median equilibrium population size with no hunting) < 60%.

Additional Recommendations: Narwhal

New Recommendations for Conservation and Management

- Use of the allocation model by Canada for recommending sustainable narwhal catches using either model or PBR-based estimates. Use of the model-based estimates is recommended as this would ensure compatibility with catch recommendations for Greenland.
- Collect length information and samples (e.g., blubber, skin, reproductive organs, information on presence of foetus, whether there is milk in the mammary glands of females).

New Recommendations for Research

- Further research should be undertaken to investigate the stock structure and abundance in Smith Sound.
- A sensitivity analysis should be conducted to determine how soft zeros in the allocation matrix could impact small or isolated narwhal stocks.
- A new survey in Melville Bay and Inglefield Bredning should be conducted as soon as possible, due to the critical situation for these stocks.
- It should be resolved if there is sufficient genomic resolution for stock discrimination in Baffin Bay narwhals (as has been found for narwhals in East Greenland).

Beluga

There were no new recommendations on beluga catches as these were updated in the June 2020 JWG virtual meeting.

The WG reviewed available research on **climate change** effects on the beluga stocks in West Greenland and the North Water projecting loss of habitat in Cumberland Sound. Similar to narwhals, the mechanism connecting climate change and beluga population dynamics are unknown, and new beluga movement should be monitored for early detection of distribution changes.

Previous Recommendations for Conservation and Management of belugas that were reiterated:

- Implement the following seasonal closures:
  - Northern (Uummannaq, Upernavik, Savissivik): June through August
  - Central (Disko Bay): June through October
  - Southern (South of Kangaatsiaq): May through October
- In the area south of 65°N, no hunting of beluga be allowed at any time. The WG rejected the MCC request for further research on the effectiveness of this closure noting that beluga populations have shown sustained growth in areas with much greater vessel traffic than SW Greenland and that the habitat changes resulting from climate change are similar to a previous warming period in the 1920s when belugas were caught in large numbers. These observations provide sufficient support for this closure.

New Recommendations for Conservation and Management

- Collect length information and samples (e.g., blubber, skin, reproductive organs, information on presence of foetus, whether there is milk in the mammary glands of females, a tooth)

Previous Recommendations for Research on belugas that were reiterated:

- A summer survey of the High Arctic beluga population.
- Revise assessment model for beluga in relation to data available from Canada.
- If samples from the fall hunt in Qaanaaq become available, a genetic analysis should be performed for possible stock assignment.
- Determine summer grounds and seasonal movements and distribution of the proposed North Water stock.

New Recommendations for Research

- Genetic data and/or microchemistry data that could show new stocks or mixing of existing stocks should be obtained.
- Genomic analysis should be performed on samples from Igloolik and Taloyoak.

Additional Recommendations: Small stocks

The WG also had a discussion on developing a principle based approach for managing **small stocks**. It recommended that NAMMCO adopt the following principles on which to base the management of small cetacean and pinniped stocks:

1. Sustainable management actions should be to maintain or restore stocks at levels ideally above 60% of their equilibrium in the absence of anthropogenic removals, disturbance, and resource competition.
2. Stocks that are depleted below 60% should be managed to increase so that they can recover to the 60% level in a reasonable time period.
3. Stocks that are small (<1000 individuals or <400 reproductive age females) require greater protection due to threats inherent to small populations, such as loss of genetic diversity, greater vulnerability to demographic and environmental variation including catastrophic events, decreased potential for growth, and management uncertainties such as unknown levels of struck and loss and underreporting. Management of small stocks should take these factors into account to allow for recovery and avoid a significant risk of extirpation or extinction. Small stocks should be fully protected from exploitation unless a data-based assessment is able to recommend a sustainable hunt.
4. Management decisions should be based on the best available science, which may include hunter and user data and observations.
5. Where the best available science is insufficient the precautionary approach shall be widely applied, particularly for small stocks. Lack of scientific certainty shall not be used as a reason for postponing measures to prevent the further depletion or extirpation of a stock. With greater uncertainty more caution is required.
6. Noting that the long-term value of a healthy stock far exceeds the short-term economic value of further depletion or extirpation, economic concerns should not delay or prevent the recovery of a small or depleted stock.
7. Acknowledging that halting all hunting of a stock may not be sufficient to promote recovery of a depleted or small stock, additional management actions such as establishing protected areas of critical habitat, e.g., closing areas to hunting, fishing and vessel traffic, may be considered.

MAIN REPORT

1. CHAIRMAN WELCOME AND OPENING REMARKS

1.1 WELCOME AND LOGISTICS

The Co-Chairs of the meeting, Cortney Watt (appointed by the Canada-Greenland Joint Commission on Narwhal and Beluga, JCNB) and Roderick Hobbs (appointed by the North Atlantic Marine Mammal Commission, NAMMCO) welcomed the virtual and in-person participants (Appendix 2) to the 2021 meeting of the Joint Working Group. A round of introductions was made followed by some practical information provided by Watts on the logistics of this hybrid meeting.

1.2 APPOINTMENT OF RAPPORTEURS

The Department of Fisheries and Oceans Canada hired rapporteur, Emma Ausen, and the NAMMCO Interim Scientific Secretary, Heleen Middel, were appointed as rapporteurs for the meeting, with assistance from participants as necessary.

1.3 REVIEW OF TERMS OF REFERENCE

The Joint Commission on the Conservation and Management of Narwhal and Beluga (JCNB) was formed in 1989 via a Memorandum of Understanding between Fisheries & Oceans Canada and the Ministry of Fisheries and Industry of the Greenland Home Rule Government. The role of the JCNB is to make recommendations to the Parties with respect to research, conservation, and management of shared stocks of narwhal (*Monodon monoceros*) and beluga (*Delphinapterus leucas*). A Scientific Working Group was also established to provide scientific advice as requested by the Joint Commission and to coordinate the exchange of data and assessment of research results.

The Scientific Working Group of the JCNB jointly with the North Atlantic Marine Mammal Commission (NAMMCO) Scientific Committee Working Group on the Population Status of Narwhal and Beluga in the North Atlantic are known collectively as the Joint Working Group (JWG). The JWG met 13-17 December 2021, in Winnipeg, Manitoba, Canada. The meeting was held to review and revise procedures for the allocation of the animals taken in hunts to the summer stocks and to provide scientific advice on sustainable levels of removals of narwhals and belugas.

The specific Terms of Reference of the 2021 JWG meeting were:

- To review advice on beluga stocks in West Greenland, the North Water stock and West Greenland stock from the 2020 JWG meeting, including landings and seasonal closures for belugas;
- To review information on availability bias correction factors, updated abundance estimates, and movement of narwhal;
- To assess the impacts of climate change on narwhal and beluga movements, distribution, population dynamics, habitat and hunt methods, timing and location;
- To revise advice models to incorporate climate change impacts where information is available and identify additional information requirements;
- To update and review the narwhal allocation model to assign hunted animals to individual summer stocks and;
- To generate advice on management of narwhal stocks in West Greenland and eastern Canada, including: Smith Sound, Jones Sound, Inglefield Bredning, Melville Bay, Somerset Island, Admiralty Inlet, Eclipse Sound, East Baffin Island.

1.4 REVIEW OF AVAILABLE DOCUMENTS

Hobbs reviewed the list of available documents for the meeting (Appendix 3) and drew attention to documents that were made available shortly before the start of the meeting.

1.5 ADOPTION OF AGENDA

The draft agenda (Appendix 1) was adopted without changes.

2. BELUGA ALLOCATION

2.1 REVIEW OF RECOMMENDATIONS FROM THE 2020 JWG MEETING

At the 2020 meeting of the JWG the population assessment for belugas in West Greenland was updated and a new assessment model was developed for beluga in the North Water, from which the following management advice resulted (NAMMCO-JCNB JWG, 2020):

- To maintain a 70% probability for population increase, the assessment for West Greenland recommends an annual landed catch of no more than 265 individuals south of Cape York and north of 65°N.
- To maintain a 70% probability for population increase, the assessment for the North Water recommends an annual landed catch of no more than 37 individuals north of Cape York.

In addition to the recommendations of annual landed catches, the following recommendations were made for belugas:

<u>Recommendations for Conservation & Management</u>

- Emphasise the importance of reporting on kill dates and locations.
- Carry out new surveys of the Somerset Island beluga stock in the summer and in West Greenland in the winter.

Previous recommendations for conservation and management that were reiterated at the 2020 JWG meeting:

- Implement the following seasonal closures:
    - Northern (Uummannaq, Upernavik, Savissivik): June through August
    - Central (Disko Bay): June through October
    - Southern (South of Kangaatsiaq): May through October
- In the area south of 65°N, no hunting of beluga be allowed at any time.

<u>Recommendations for Research</u>

- Collate the Canadian catch statistics required to develop a joint model at a future meeting.
- Present the latest research on reproductive senescence at the next meeting and investigate how this information may be incorporated into the population model.
- Perform a genetic analysis on samples from fall catches in the Qaanaaq area to establish their stock.
- Determine summer grounds and seasonal movements and distribution of the proposed North Water stock.
- Develop a joint beluga allocation model for the High Arctic/Baffin Bay population, that will consider Greenland/Canada movement data from tagging, dates and locations of kills, and abundance data.

2.2 IMPLEMENTATION OF EARLIER RECOMMENDATIONS ON BELUGAS

2.2.1 Recommendations on allowable landings of belugas in West Greenland

The recommendations regarding the advised catch quota for beluga in West Greenland and the North Water were endorsed by the NAMMCO Management Committee for Cetaceans (MCC), and already implemented by Greenland for 2021 (NAMMCO, 2021a).

2.2.2 Recommendations on seasonal closures and no hunt of belugas south of 65 degrees in West Greenland

The recommendation by the JWG in 2020 (and in previous assessments) of seasonal closures and no hunt south of 65˚ was reiterated by the NAMMCO Scientific Committee (SC) (NAMMCO, 2021b), but was not endorsed by the MCC. The MCC was informed by the Government of Greenland that a quota system has been in place since 2004 and that for several years this allocated quota has not been caught. Additionally, potential impacts of shipping and other human activities as well as environmental changes in this area may make it difficult for beluga stocks to recover even if there was a hunting closure. The MCC suggested that "substantially more research would be required to assess whether it would actually be possible to restore stocks in this area using these measures" (NAMMCO, 2021a).

2.2.2.1 Response from JWG to MCC

It is well-known that both small vulnerable and large healthy beluga populations can exist in areas with heavy ship traffic and other marine activities (Hobbs et al., 2019). The obvious examples are St. Lawrence River in Canada, Cook Inlet and Bristol Bay in Alaska, and the White Sea and Anadyr Gulf in Russia. Bristol Bay is a particularly good example in that it has the largest salmon fishery anywhere in the world during the summer and there is substantially more vessel traffic throughout the year than occurs in most areas of Southwest Greenland, this population increased at a rate of 4.8% between 1993 and 2005 (Lowry et al., 2008). Evidently belugas have the ability to habituate to underwater noise pollution from marine activities.

Belugas have been present in large numbers in Southwest Greenland (south of 65°N) both during cold periods and during the warming in the 1920's. During the cold period 1874–1891 mean catches of belugas were 5 per year as far south as Qaqortoq, 9 per year in Paamiut and 203 per year in Nuuk (Heide-Jørgensen, 1994). During the warm period (1908–1922) the mean of annual catches in Nuuk was 304. There is ample evidence that belugas can thrive under different climatic conditions in Southwest Greenland and adapt to changes in the ecological conditions.

It is at present unknown if the belugas that used to inhabit Southwest Greenland constituted a separate population or if they primarily were migrants from northern areas and perhaps from Canada. New genetic studies suggest belugas from Cumberland Sound, on the southeast coast of Baffin Island, may be closely related to belugas from West Greenland (NAMMCO-JCNB JWG, 2020; Skovrind et al., 2021).

There is no guarantee that the belugas in Southwest Greenland will recover and re-inhabit the area south of 65°N in West Greenland in the absence of hunting activities. However, nothing suggests that belugas could not re-inhabit the area even though it may take some time before noticeable numbers of belugas will be present in the area. On the other hand, if hunting continues it can be guaranteed that the low number of belugas that occasionally are found in Southwest Greenland will not be able to establish a larger and more permanent presence in Southwest Greenland.

3. NARWHAL ALLOCATION

3.1 NARWHAL MOVEMENT AND ABUNDANCE

3.1.1 Quantitative Sub-Group meeting review

During the course of the virtual meeting of the JWG in October 2020, a Quantitative Subworking Group (QSG) was requested to review analysis methods for abundance estimation used by the JWG, and identify preferred and/or comparable methods that could be applied to current and past survey data. In addition, recent satellite telemetry data from Eclipse Sound brought into question some of the assumptions on which the hunt availability matrix was based. The QSG was requested to revise the matrix to accommodate the new movement and distribution data and update the soft zeros and hunts. The QSG reviewed methods and dive data used to analyse and correct aerial surveys to identify a set of preferred methods and corrections that could be applied to recent and past surveys where needed. They also reviewed recent information on abundance, including survey analyses conducted by Golder in 2019 in Eclipse Sound and Admiralty Inlet in 2019, and distribution, movements, and hunting locations of Baffin Bay narwhals to revise and update the availability matrix to assign hunted animals to individual summer stocks. The resulting analyses and working papers were presented and discussed at the JWG meeting in 2021 as outlined below.

3.1.1.1 Review methods and dive data used to analyse and correct aerial surveys

Estimating narwhal time at the surface from overlapping photos

Marcoux and Hobbs co-presented Working Paper 06 – *Estimating narwhal time at the surface from overlapping photos. (JWG/2021/06)*

<u>Summary</u>

Aerial surveys that estimate narwhal abundance are corrected for narwhals that are submerged during the over flight of the plane. Narwhal dive cycles and the fraction of time that they are available at the surface have been studied using depth recording tags. A method was developed using re-sights of narwhals from overlapping consecutive photos taken during aerial surveys. The probability of re-sighting a narwhal in two consecutive overlapping photos was used to estimate the average time narwhals were visible when surfacing. Average times at the surface for Eclipse Sound and Tremblay Sound were 58 s (CV=0.19) and 24 s (CV=0.23), respectively and were significantly different from each other (t-test p=0.01). These times are shorter than estimates derived from time-at-depth data from tags. This is a proof of concept study and the methods require further development. It was difficult to identify duplicate sightings with certainty from aerial photos taken at 600 m in this study. As a result, the observer was likely conservative in their estimate of duplicate sightings, which would result in a shorter estimate of the time narwhals spend at the surface. To remedy this, the matching could be repeated with a second and third analyst to estimate the uncertainty and the analysis then refined to account for this uncertainty.

One major advantage of this method is that the time narwhals spend at the surface during each survey can be calculated directly from data collected from that survey, and availability can be related to factors such as turbidity and sea state.

<u>Discussion</u>

The JWG expressed interest in this new method but noted that further development was necessary before it could be used to correct surveys.

This method to determine time at the surface resulted in a much shorter estimate than previous methods (approximately 30 s difference). A shorter time at the surface would yield larger abundance estimates. Uncertainty in the matching of individuals in overlapping photographs could cause this. Overlapping individuals in photos were verified, using location in the photograph, appearance, orientation and number of individuals. It was noted that there is potential for similar individuals to be matched if one whale dove and another took its place.

Coordinated group behaviour was discussed, as it may influence the time at the surface. Watt informed the WG about a current project using drone recordings taken of beluga groups in Churchill, which may provide more information relevant to this discussion. Some challenges from the drone recording include that it is difficult to determine group composition, and once the whales go below visibility it cannot be determined if the same whale reappears near the surface. These considerations can all impact time spent at the surface, something which could be improved if photograph or video quality allows photographic identification of whales.

The difference in time at the surface estimates between the fjord (Tremblay Sound) and Eclipse Sound may result from differences in the detection depth and in narwhal diving behaviours in these locations. Differences in the ratio of different age classes were also noted between locations as a higher proportion of calves were sampled in Tremblay Sound than Eclipse Sound. It was concluded that although results are preliminary, the ability to estimate surface time through overlapping captures of the same narwhals has high potential, but there are no recommendations to use surface time from this analysis at this point.

Updated surface and dive time for narwhals equipped with Acousonde tags in Eclipse Sound

Marcoux presented Working Paper 05 – Updated surface and dive time for narwhals equipped with Acousonde tags in Eclipse Sound. (JWG/2021/05)

Summary

High frequency time-depth data can be used to calculate the average time that narwhals spend at the surface (T_s) potentially visible to survey observers and the time they are at depth (T_d) where they are not visible to observers. A zero offset correction method was implemented to correct new Acousonde time-depth collected from four narwhals tagged in Eclipse Sound, Canada, in 2017 and 2018. The method uses a series of quantile filters to smooth the data and detect the surface of the water. From the corrected data, dive events were detected and the average time narwhals spent at the surface as well as underwater were computed. Dives and surfacing events that occurred before 8 a.m. and after 6 p.m. were excluded from the analysis. Surface ratios were calculated as the time at surface divided by the time at depth. For the 2 m dive threshold, the weighted average T_s was 114.1 s (weighted SD: 16.1) and weighted average T_d was 253.5 s (weighted SD 12.5) for a total average dive cycle of 367.6 s (weighted SD: 25.1). The surface ratio was 0.31.

Discussion

The time-at-depth profile of the Acousonde tags included near surface movements that were not detected to break the surface, and it was discussed that this variation in the 1 m depth is likely due to various surface behaviours. These near-surface patterns could also be explained by errors in the tag data. It was suggested that to correct for depth, the acoustic recordings could be reviewed to see if they capture the moment narwhals surface, which could be used to correct for depth errors. The ability to accurately determine narwhal depth was discussed, considering the accuracy of the depth is 0.5 m. Acousonde tags detected similar values as backpack tags for 0-1 m depths, although both have low confidence to accurately determine 0-1 m depth. Acousonde tags additionally provide higher temporal resolution because they include a complete record of depth measurements.

The WG agreed that the ratio of time above 2 m to the surface determined from the Acousonde tags should be used as a surface time, as results are similar to other locations.

Time in view for 0–1 m and 0–2 m depth bins

In response to questions that arose from the discussion on Working Paper 05, Doniol-Valcroze presented Working Paper 26 – *Time in view for 0–1 m and 0–2 m depth bins. (JWG/2021/26)*

Summary

Time-in-view data from the 2013 survey of the Canadian narwhal stocks was separated for areas where whales could be seen to 2 m depth, and in East Baffin Island fjords where whales could be seen to 1 m depth. Time-in-view was approximately 1 s less in the East Baffin Island fjords. This was not an artefact of time-in-view being shorter in fjords generally, as time-in-view estimates from other fjords in the survey were not significantly different from the time-in-view in the offshore strata.

Discussion

Water clarity has an impact on time-in-view, resulting in shorter time-in-view in murkier water.

Availability bias in narwhal abundance estimates

Heide-Jørgensen presented Working Paper 19 – *On the availability bias in narwhal abundance estimates. (JWG/2021/19)*

Summary

The most frequently used method for estimating the abundance of narwhals is visual aerial surveys. The basic estimation is based on detection of whales at the surface, and to obtain fully corrected abundance estimates it is required to correct the at-surface detections with the proportion of whales that are submerged. This is usually done by estimating the proportion of whales that at any given time is available to be detected at the surface i.e., the surfacing time. The 'availability correction factor' is then obtained from whales instrumented with dive recorders that either relay concatenated information on the proportion of time spent at different depth intervals to satellites, or from recovered instruments that collect entire dive profiles measured at high frequency from the whales. Concatenated data binned in depth histograms from Satellite-Linked-Time-Depth-Recorders (SLTDR) falls in two categories where those that correct the zero depth values with information from the saltwater switch provide larger and apparently more accurate surfacing times than those collected from instruments that do not correct the zero depth readings. The erroneous detection of the near-surface pressure values is likely due to slow response of depth transducers that are made from temperature sensitive materials. The mean estimate of surface time from the SLTDRs was 29%. The high frequency sampling from Acousonde recorders documents erroneous surface detections, and adjustments of the dive profiles need to be conducted to obtain realistic near-surface values. One SLTDR with a steel pressure transducer and zero-adjustments, that was retrieved from the whale provides a particularly long record (83 days) of reliable data. The surface time for this sample was 28% when calculated as the sum of all depth readings at or above 2 m. When a criterion of ignoring dives above 3 m was included, the surface time increased to 33%. Any reconstruction of dive profiles and near-surface values apparently involves some level of uncertain manipulations and it is recommended for development of availability correction factors for aerial surveys that data from zero-adjusted SLTDRs or TDR instruments are used. Even with high resolution instruments detection of 0–1 m depth bins appears less reliable than detection of deeper bins.

Discussion

This paper was thoroughly discussed at the QSG meetings (minutes are available as JWG/2021/04a). The JWG discussed how the use of one tagged whale to estimate time at surface and time at depth values could introduce error into analysis. It was noted, however, that the whale used in this analysis has consistent behaviour to other whales, and was assumed to be representative.

Review of available depth for narwhal and implications for availability corrections

Hobbs presented Working Paper 7 – *Review of availability depth for narwhal and implications for Availability Corrections. (JWG/2021/07)*

Summary

A depth of 2 m has been used for availability correction from dive data for narwhal based on experiments reported in Richard et al. (1994) and Heide-Jørgensen (2004). In both experiments, life size cut-outs of dorsal silhouettes of narwhal adults, juveniles and calves, painted to match the coloration of each age group, were anchored at different depths and photographed during aerial over flights. Review of these two experiments suggested a maximum sighting depth that fell between 1–5 m. Using daily time at depth data for twelve days typical of survey days, average and variation of correction factors for time above depths was estimated for maximum depths ranging between 1–5 m.

Average and variation for this range was determined by bootstrap using probabilities drawn from a beta distribution with parameters alpha = beta = 2. The resulting average was equivalent to current values used for correction surveys. The variation resulted in an estimated CV of 20% when both variation in maximum depth and variation in time at depth were considered and an estimated CV of 18% when only variation in maximum depth was considered.

Discussion

The daily estimates of confidence intervals were discussed to clarify why this scale was selected instead of an hourly scale. It was explained that daily confidence interval estimates were chosen to keep data consistent across studies as longer narwhal dives (up to 20 min) could bias hourly estimates. Although there is some uncertainty in dive data there is consistency across methods described. The 20% availability bias estimate also accounted for the variation in all previous estimates. The JWG agreed that a CV of 20% be used for availability bias corrections. To correct existing survey results, where the availability bias correction was embedded in the calculation, a CV of 18% could be added to the CV of the availability component.

3.1.1.2 Review updated availability matrix to assign hunted animals to individual summer stocks

Marcoux presented Working Paper 08 – *Update on the movement of narwhals from Eclipse Sound stock (2016-2018) and an updated availability matrix. (JWG/2021/08)*

Summary

Twenty-five narwhals were captured and instrumented with satellite tags in 2016–2018 in Eclipse Sound, Canada. Continuous-time state-space models were fitted to locations derived from satellite-linked tags to reconstruct tracks of the narwhals' movements. Tracks were overlaid on top of traditional hunt locations for narwhals with a 10 km buffer around the area and then used to determine the proportional availability of the tagged narwhals to the different hunt locations, for each season (spring: 1 April–23 July, summer: 24 July–24 August, fall: 25 August–30 November, winter: 1 December–31 March). The proportions were calculated as the number of narwhals that visited a traditional hunting location during the hunting season divided by the number of tagged narwhals that were transmitting at that time. Lastly, the availability matrix for the stock allocation model was updated based on these new data. We also used expert knowledge to update some of the cells.

Discussion

Previous narwhal assessments have assumed that there is no mixing between stocks during the summer, however, recent tagging data presented showed movement from the Eclipse Sound stock to the Admiralty Inlet stock. This movement would result in the availability of both stocks to hunters in Admiralty Inlet. It is uncertain whether this is a new phenomenon or if this movement has always occurred, since the tag data arises from tagging that occurred earlier in the year than previous tags that were deployed towards the end of the defined summer stock season. It was agreed that the decisions surrounding summer stock dates should be evaluated at a later date. Given the new movement data it should be investigated if this movement has always occurred and has not been previously observed, or if this is a new movement pattern. It was discussed if it is possible to investigate narwhal movement between stocks using 1999 tagging data, although this may not provide any additional information as this data was used to delineate summer season and narwhal migratory timing. Narwhal movements and migration may be driven by environmental changes.

The WG **accepted** the new availability matrix with decisions on changes to seasonal dates for the availability matrix to be discussed at a later date.

3.1.1.3 Review abundance estimate from Eclipse Sound and Admiralty Inlet conducted by Golder Associates Ltd.

The JWG in 2020 requested Canada to perform a review on the abundance estimates from Eclipse Sound and Admiralty Inlet conducted by Golder Associates Ltd. for the discussions of the QSG.

Watt presented Working Paper 09 – *Review of Golder's 2019 narwhal survey in Eclipse Sound and Admiralty Inlet. (JWG/2021/09)*

<u>Summary</u>

Golder (2020) conducted aerial surveys in Eclipse Sound and Admiralty Inlet in August 2019 as part of the Baffinland monitoring program. This was the first time both stocks have been surveyed together since 2013. The surveys followed protocols similar to those used by Fisheries and Oceans Canada for surveying, and covered the summering range for both stocks. However, two issues with the survey estimates as presented by Golder were identified. First, the coefficient of variation of the survey estimates did not consider between-group variation for the photographic sampling (i.e., variance was calculated within each encounter based on differences among photos, but not between photographic encounters). Golder (2020) also calculated an average between surveys 3 and 4 (flown August 21–27), excluding survey 5 (flown August 29–30) in Eclipse Sound because a large aggregation of narwhals may have been missed. Within any survey some animals are missed; it is an assumption that some animals are distributed between survey lines and therefore are not directly surveyed. Without more information on where this aggregation was (i.e., was it in an area not surveyed or between survey lines), it is impossible to know the impact of missing or including this aggregation on the abundance estimates, and it is not a valid reason to discard a survey replicate. As a result, an abundance estimate which included the three survey replicates for Eclipse Sound and Admiralty Inlet, with the variance calculated as the variation between replicate surveys was presented. Survey estimates were also adjusted based on time at surface and time at depth data for narwhals in Canada, with an updated variance that incorporates uncertainty in the depth to which whales can be seen. For the joint allocation model, abundance estimates of 8,464 (CV=0.32) for Eclipse Sound and 25,255 (CV=0.25) for Admiralty Inlet in 2019 are recommended for use in the narwhal allocation model.

<u>Discussion</u>

The Golder survey estimates were reviewed in light of the potential issues brought forward regarding the analysis. It was discussed that although Golder (2020) used an adaptive sampling scheme there was no defined rule for when they switched from a visual to a photographic survey. It was discussed that this is not a significant issue for the statistical analyses, it just may inflate the variance of one portion of the survey and reduce it in another if there is no *a priori* adaptive sampling protocol. It was also discussed that technically the survey dates for the replicate surveys 4 and 5 fall outside of the defined summering period dates that are used by the availability matrix (the summer period is from 24 July–24 August, and surveys 4 and 5 were flown on 25–27 August and 29–30 August, respectively). It was decided that although it would be ideal if the survey occurred within the defined summer aggregation period, it was desirable to have replicate surveys, particularly given the variation among the replicates. It was agreed that future surveys should be timed to fall in the defined summering aggregation period, acknowledging that this may change over time.

It was also discussed that a portion of the northern stratum in Admiralty Inlet was missed in survey 4 and that the density from the portion of the stratum that was surveyed was extrapolated into the unsampled area. There was discussion on whether, because of this, survey 4 should be excluded from the analysis. However, it was deemed that the estimate from survey 4 was similar to survey 3, and that the variation observed among the survey replicates more than accounted for this potential bias. Other possible ways to calculate variance were discussed but it was agreed that variance across the survey replicates was a supported and standard protocol and could be used for this analysis.

After careful review the WG **accepted** these abundance estimates for use in the assessment models.

3.1.1.4 Review abundance estimates for allocation model

Updated survey estimates for Canadian stocks from Baffin Bay population

Watt presented Working Paper 10 – *Updated survey estimates for Canadian narwhal stocks from the Baffin Bay population. (JWG/2021/10)*

Summary

There has been limited data on high frequency dive profiles for narwhals. This data is required to account for the interval of time that narwhals are at the surface available to be seen by the surveyors. Previous surveys have used data from three narwhals tagged in Eclipse Sound in 1999 and in Creswell Bay in 2000 to estimate the narwhal dive cycle (Richard et al., 2011). New high frequency time-at-depth data were presented for narwhals tagged in Eclipse Sound in 2017 and 2018, and were used to update abundance estimates in Canada. In addition, previously the McLaren method was used to adjust survey estimates for availability bias, but the Laake correction factor is deemed more appropriate and was used to adjust survey estimates for the Canadian survey abundance estimates, with an increased variance on the availability bias estimate that incorporates the uncertainty in the depth to which narwhal can be seen. It is recommended the survey estimates presented in Table 1 be used in the narwhal allocation model.

Table 1: Availability bias adjustment factors used for narwhal survey estimates using T_s and T_d values of 114.1 and 253.5 s respectively, and using the Laake et al. (1997) method.

Stock	Year	Surface Abundance with perception bias (CV)	Time in View (s)	Laake Adjustment Factor (CV)	Final Abundance (Laake) (CV)	CI
Smith Sound	2013	5,563 (0.65)	4.3	3.06 (0.20)	17,008 (0.68)	5,073 – 57,019
Jones Sound	2013	4,316 (0.32)	4.3	3.06 (0.20)	13,195 (0.38)	6,436 – 27,051
Admiralty Inlet	1975	9,683 (0.42)	3.92	3.07 (0.20)	29,739 (0.47)	12,464 – 70,956
	2003	1,857	3.92	3.07 (0.20)	5,703 (0.56)	2,055 – 15,828
	2010	7,799 (0.27) [a]	3.13	3.10 (0.20)	19,156 [b] (0.31)	10,601 – 34,615
		4,704 (0.40)	3.13	3.10 (0.20)	n/a	n/a
	2013	11,915 (0.42)	4.3	3.06 (0.20)	36,427 (0.47)	15,267 – 86,915
Eclipse Sound	2004	6,677 (0.36)	1.52	3.16 (0.20)	21,114 (0.41)	9,696 – 45,979
	2013	3,566 (0.24)	4.3	3.06 (0.20)	10,902 (0.31)	5,974 – 19,895
East Baffin Island	2003	3,487 (0.27)	3.92	3.07 (0.20)	10,709 (0.34)	5,623 – 30,395
	2013	3,921 (0.34)	4.3	3.06 (0.20)	11,988 [c] (0.40)	5,673 – 25,326
Somerset Island	2002	9,836 (0.54)	5.15	3.03 (0.20)	29,770 (0.58)	10,412 – 85,114
	2013	16,921 (0.20)	4.3	3.04 (0.20)	51,732 (0.28)	29,921 – 89,444

[a] Survey 1 included a photographic survey which had a surface estimate of 522 whales. This estimate was multiplied by 3.18 and added to survey 1, to calculate final abundance estimates, weighted by effort. [b] This final abundance is an average weighted by effort, for survey 1 (visual and photographic together) and survey 2. [c] This estimate is based on applying a 0–2 m adjustment factor for both the offshore and fjords strata, whereas Doniol-Valcroze et al. (2020) used a 0–2 m and 0–1 m adjustment factor for the offshore and fjords strata, respectively.

Discussion

It was agreed that the updated time at surface and time at depth data were more appropriate for correcting the aerial survey abundance estimates and they resulted in a similar instantaneous availability bias correction factor that had been calculated based on data from the backpack satellite tags presented in Watt et al. (2015), which gave more confidence to the adjustment factor. It was also agreed that the increased CV on the availability bias adjustment factor better reflected the uncertainty in the estimate and was appropriate to incorporate. A discussion was held on the use of the 0–1 m adjustment factor for the East Baffin Island fjord stratum, which was considered to have murky water. Although we are not confident in the tag data within the upper 1 m of the water column, there are conditions in which whales cannot be seen to 2 m and to ignore this will negatively bias the survey estimate. It was suggested that the uncertainty at which depth whales can be seen in murky water could be calculated much like it was for the 0–2 m bin. In the case of the East Baffin Island survey it was agreed that because the allocation model is evaluating a series of abundance estimates to evaluate a trend in the stock abundance, and the 2003 survey did not consider two separate strata with different adjustment factors, for consistency, an adjustment factor for the 0–2 m bin would be employed for both strata.

The use of time in view was also discussed as there has been inconsistency in collection of time in view during visual surveys of narwhals, and the accuracy of time in view recorded is not known. It was proposed an increased variance could account for errors associated with both time in view and time-at-surface and time-at-depth. Although using time in view data did not result in large changes to survey results, it was determined that inclusion is a better practice as it allows for more conservative abundance estimates. It was also agreed that there should be consistency across surveys.

Trends in abundance and distribution in Inglefield Bredning and Melville Bay from 2007–2019

Hansen presented Working Paper 11 – *Trends in abundance and distribution of narwhals on the summering grounds in Inglefield Bredning and Melville Bay, Greenland from 2007–2019. (JWG/2021/11)*

Summary

Narwhal abundances were estimated from aerial surveys during summer in Melville Bay (MB) in 2007, 2012, 2014 and 2019 and in Inglefield Bredning (IB) in 2007 and 2019. Analyses were completed using Hidden Markov Line Transect (HMLT) techniques that take account of stochastic animal availability by using independent estimates of the availability process together with forward sighting distances, as well as perpendicular sighting distances of sightings from a double platform design that includes perception bias. The HMLT techniques do not assume certain detection at perpendicular distance zero, but only certain detection of animals that are available (i.e., not too deep to be seen) at radial distance zero. The estimation requires detailed information on the availability process, and this was obtained from a narwhal tagged with a time-depth-recorder from East Greenland with 1 Hz sampling of depth during a sub-sample of 12 days.

Separate models were fitted to each survey. HMLT models were fitted to the MB 2012, 2014 and 2019 surveys but because no forward distances were available in 2007, a conventional distance sampling model was fitted to this survey, and the resulting abundance estimate “corrected” for g(0)<1 using the g(0) estimator of Laake et al. (1997) with a somewhat subjectively chosen forward distance, in a way that made it consistent with g(0) estimates from the fitted HMLT models.

Fully corrected abundance was estimated at 4,109 (CV=0.21, 95% CI: 2,738–6,168) and 2,874 (CV=0.21, 95% CI: 1,938–4,354) in Inglefield Bredning in 2007 and 2019, respectively. In Melville Bay the abundance was 1,834 (CV=0.92, 95% CI: 396–8,500) in 2007, 915 (CV=0.44, 95% CI: 431–2,141) in 2012, 1,768 (CV=0.39, 95% CI: 864–3,709) in 2014 and 4,755 (CV=0.65, 95% CI: 1,158–20,066) in 2019. The abundance estimates were used to estimate a trend in abundance between 2007 and 2019 and while there is a suggestion of an increase in abundance in Melville Bay since 2012, this is largely due to the highly uncertain 2019 estimate, and the trend is not significantly different from zero. The trend in Melville Bay is highly susceptible to the estimate from 2019 where sightings on one transect line contributes about half of the abundance estimate. The two estimates from Inglefield Bredning suggest a decrease in abundance, but this is also not significantly different from zero.

The distribution of sightings of narwhals in Inglefield Bredning was similar between years. The sightings in Melville Bay were concentrated in the central stratum in 2019, which is remarkably different from 2007 where narwhals were detected in all four surveyed strata. In 2012, narwhals were detected in three out of four strata and in 2014 in only two strata. The area on a stratum level where narwhals have been sighted has gone from ~16,400 km^2 in 2007 to 2,610 km^2 in 2019; a decrease in area usage of 84%. The average group size has not changed throughout the years but the distance between groups has dropped significantly after 2007. The large groups that are still available, however in a smaller area, leave the impression to the hunters that the population is still large, but the monotonic decline in area usage in the coastal part of Melville Bay observed between 2007 and 2019 may be an indication of a decline in the population.

Discussion

This Working Paper was reviewed thoroughly by the QSG (see JWG/2021/04b). There was concern that the use of HMLTMs may not be comparable to the survey abundance estimates from mark-recapture-distance-sampling methods that are employed for all the other surveys used in the narwhal assessment model. In addition, there was discussion on how the HMLTM may be swayed since it only incorporates the dive behaviour of a single whale from East Greenland. However, a thorough assessment of narwhal behaviour from tag data from Canada and Greenland showed variability among whales but generally similar behaviour (see Section 3.1.1.1). In addition, a comparative analysis of a selected survey using both MRDS/Laake correction and HMLTM methods gave similar results. Thus, the WG agreed that either method could be employed to analyse survey results.

Updated survey estimates for West Greenland stocks from the Baffin Bay population

Heide-Jorgensen presented Working Paper 27 – *Updated survey estimates for West Greenland narwhal stocks from the Baffin Bay population with additional variance on the availability bias. (JWG/2021/27)*

Summary

Following the approach for the abundance estimates from Canada it was decided that the same procedure should be applied to the abundance estimates from West Greenland. An extra variance (CV=0.18) was added to the availability part of abundance estimates of narwhals for HMLTM estimates and a slightly higher estimate of CV=0.20 for the photographic surveys. For the single platform visual surveys in 1985 and 1986 the mean g(0) value (0.37, CV=0.07) from four later surveys was estimated (JWG/2020/14). Surface time for the two photographic narwhal surveys from 2001 and 2002 was assumed to be 0.29 (CV=0.09, see JWG/2020/18). For the double platform survey in Melville Bay 2007 a mean g(0) from the four later surveys was estimated to be 0.37 with CV=0.07 (see JWG/2021/11).

Table 2: Updated Greenland abundance estimates updated with the greater variance on the CV of the availability bias estimate.

Stock	Year	Abundance	Original g(0) (CV)	Original CV of Abundance Estimate	Recalculated CV of Abundance Estimate
Inglefield Bredning	1985	3,689	0.37	0.25	0.32
	1986	9,558	0.37 (0.07) $	0.35	0.40
	2001	3,010	0.29 (0.09) §	0.36	0.41
	2002	1,938	0.39 (0.09) §	0.26	0.33
	2007	4,109	0.37 (0.07) $	0.21	0.29
	2019	2,874	0.35 (0.21) #	0.21	0.28
Melville Bay	2007	1,834	0.37 (0.07) $	0.92	0.94
	2012	915	0.35 (0.31) #	0.44	0.48
	2014	1,768	0.37 (0.31) #	0.39	0.50
	2019	4,755	0.41 (0.41) #	0.65	0.77

$Average of g(0) values from four surveys. §Only availability bias. #Approximate calculation: var(g(0))=var(N)-(var(n/L)+var(E)).

Discussion

Additional variance was added to the survey abundance estimates to reflect the uncertainty we have in the depth to which narwhals can be seen in the water column which mirrors what was done with the Canadian survey estimates. There was discussion on how this added variance has a smaller impact on surveys which already have large variance estimates, but does increase the survey variance estimates in all cases. The WG **accepted** the newly revised abundance estimates for use in the narwhal assessment model.

Final discussion on abundance estimation

As mixing between stocks was found through narwhal movement data collected from tags, the WG was concerned that this should also impact how abundance estimates are determined. Through discussion it was determined that treating stocks separately would be the conservative approach, given the degree of mixing is unknown, and currently only a small amount of movement is seen. How abundance estimates are impacted by the movement of narwhal between stocks during or between surveys should be investigated further, as there is inconsistency between surveys (which do not account for mixing) and the availability matrix (which accounts for mixing). Abundance estimates incorporated in the population model were reviewed. In particular the two surveys estimating the summer stock of Smith Sound. It was determined that this summer stock should be further reviewed, as some evidence indicates this stock may be inaccurately classifying multiple stocks as one. Evidence for this includes a tagged narwhal near Etah in June 2013 which moved north towards Cape Louis Napoleon (79°45'N) in western Kane Basin. This is far north of Mackinson Inlet where most of the abundance estimates from Smith Sound comes from. As there is not enough evidence to classify new stocks, this will be further evaluated at a later date, which will also allow for a western Smith Sound survey planned for this summer (2022). It was decided that to account for the uncertainty in the meantime, Smith Sound will be represented in the availability matrix using 1/1, representing the movement shown by the Etah narwhal tag. Additionally, it was decided that the abundance estimate derived from the spring 2009 survey will be removed from the model as it was conducted outside of summer stock dates as defined by this committee.

The WG **recommended** that further research be undertaken to investigate the stock structure in Smith Sound, and a survey in Smith Sound. Due to the critical situation in Melville Bay and Inglefield Bredning the WG **recommended** surveys of these stocks, as soon as possible.

3.2 NARWHAL CATCH STATISTICS

3.2.1 Update by management area

Canada

Watt presented Working Paper 14 – *Catch Statistics for Narwhal in Canada from 1970-2020. (JWG/2021/14)*

<u>Summary</u>

Catch statistics from 1970–2020 for 13 Canadian communities that hunt narwhals from the Baffin Bay population were reviewed. The date of kill was reported for some hunts but often not all catches had an associated catch date. As a result, to determine the seasonal distribution of catches, the proportion of whales taken across the different seasons based on those reported were attributed to the total take for each year. Information on seasonal hunt dates were not available for 2020 at the time of the meeting and therefore the proportion of the catches in each season was assumed to be the same as it was in 2019. Updated information is anticipated for the next meeting. Seasonal catches were attributed to six different hunting regions in Canada, including Grise Fiord, Central Canadian Arctic, Arctic Bay, Pond Inlet, Baffin Island Central, and Baffin Island South and assigned different struck and loss corrections by period (1979–1989, 1990–2004, and 2005–2020), and when possible, by type of hunt (open water, ice edge/crack), and community.

<u>Discussion</u>

Information on how Canada receives the catch data was discussed, and it was highlighted that the data comes from Fisheries and Oceans Fisheries Management Department. Hunters are required to report their hunt to obtain a marine mammal tag, which is needed in order to export their tusk for sale; thus, it is expected that all narwhal catches are reported. However, hunters are not required to provide other biological information such as a tissue sample or the length of the whale. Ongoing discussions about the desire for this biological information are underway with Canadian co-management partners. It was highlighted that marine mammal sampling programs would be more successful with increased communication back to the hunters that provided the samples. Sharing of information can promote the program and engage hunters in research questions.

The WG **accepted** the Canadian catch statistics for use in the narwhal assessment model.

Greenland

Heide-Jørgensen presented For Information Paper 19 – *Update on catch statistics for narwhal in Greenland, 2005 to 2019 (JWG/2021/FI19)*

<u>Summary</u>

This paper was a reiteration of the catch statistics presented in October 2020. The report updated the catch statistics from the Special Reports (2020) for the period from 2005–2019. A database with revised and quality assured catch statistics from the Special Reports for the years 2005–2019 was provided by the Government of Greenland in February 2020 and this is now considered to represent the official catch statistics for narwhals from 2005–2019. The revision of catches has, however, resulted in altered catch numbers especially for the early years (2005–2009). As a consequence, there are some differences between catch numbers presented in Garde et al. (2019) and the catch numbers presented in the present paper. Discrepancies in catch numbers are highest for the early years and are probably a result of the transition from the previous catch reporting system (Piniarneq) to the current system from 2005 (the Special Reports). For assessments, catches published in Garde et al. (2019) should be used through to 2015. From 2016 to 2019, catches in the present paper should be used. From 1993 to 2010, catches in Siorapaluk were subtracted from the catches in Inglefield Bredning as they were assumed to be from the Smith Sound stock; in 2011 this practice was, however, changed to allocate any catches with location data north of Siorapaluk to the Smith Sound stock (Garde et al. 2019). In the present paper, catches from Siorapaluk are included in the Inglefield Bredning stock from 2005–2019, as has been the practice since 2011, Siorapaluk has been included in the Smith Sound stock (Etah and Siorapaluk) and thus subtracted from catches from Inglefield Bredning (i.e., Qaanaaq, Qeqertat and Moriusaq). It was roughly assessed, based on information on hunting location from the Special Reports (2020), that about 1/3 of catches from hunters from Siorapaluk are taken at Etah and 2/3 are taken in Inglefield Bredning.

Discussion

It was discussed that the special reports are a reliable source of information for the catch statistics, especially in more recent years. The WG **accepted** the catch statistics presented for use in the population models.

3.2.2 Review of struck-but-lost and under-reporting corrections

Narwhal catches are corrected for animals that are struck-but-lost prior to being input in the assessment model. Canada and Greenland use different struck-but-lost corrections depending on the community and type of hunt. The most recent struck-but-lost information from Canada comes from a community-based monitoring program, and the data provided by the hunters in communities that participated in the program forms the basis for the current values used. It was discussed that independent unbiased collection of this data is important but logistically challenging. The question of how to collect this data was discussed and it was deemed that although useful, it may not warrant the dedicated investment that would be required to obtain an estimate, and in some cases may be impossible.

3.3 REVIEW OF MANAGEMENT MODEL STRUCTURE FOR NARWHAL

3.3.1 Review of allocation model

Pregnancy rates for narwhal in Canada

Watt presented Working Paper 25 – *Pregnancy rates for narwhal in Canada. (JWG/2021/25rev)*

Summary

Reproductive tracts from 11 sexually mature narwhals hunted in Canada from the communities of Pond Inlet and Kugaaruk (which hunt whales from the Baffin Bay population), and Naujaat (which hunt whales from the northern Hudson Bay population) were assessed to determine a pregnancy rate. Four narwhals had foetuses, measuring 315 mm, 294 mm, 210 mm and 17.5 mm in length. Six narwhals had a corpus luteum which indicated they were pregnant when hunted. Using the presence of a foetus and/or a *corpora luteum* to indicate pregnancy, our pregnancy rate for narwhal from Baffin Bay was higher than that found by Garde (NAMMCO SC/28/NEGWG/08) 0.35 for 54 mature females from West Greenland). Adding Garde's pregnancy estimate for whales hunted near Pond Inlet (six mature whales of which three were pregnant) to the pregnancy estimate for whales from Pond Inlet and Kugaaruk assessed here, we get a pregnancy estimate of 9/13 or 0.69. These are preliminary results and should be interpreted with caution because in many cases only one ovary was collected. Further analyses of reproductive tracts and organs are still underway.

Discussion

It was noted that this new information from Canada suggests a higher pregnancy rate to what is found for narwhals in West Greenland. As the pregnancy rate was so high, some potential alternative interpretations were discussed including that there could be a bias towards hunting pregnant females which are slower, or due to the incentive of getting double compensation for the whale and the foetus; there could also be a high pregnancy loss rate.

It was suggested that the pregnancy rate within the current assessment is possibly too low (0.33). It was agreed this is a minor change and does not need to be updated within the current assessment, but in the future an evaluation of the pregnancy rates, either stock specific or a global point estimate, could be determined by pooling all whales from Greenland and Canada that have been assessed.

Witting presented Working Paper 16 – *Meta-population model for narwhals in East Canada and West Greenland – 2021. (JWG/2021/16)*

<u>Summary</u>

In this paper the meta-population model for narwhal was updated. The 2019 abundance estimates from Inglefield Bredning, Melville Bay, Admiralty Inlet, and Eclipse Sound were added, and the other abundance estimates were updated with the corrections and adjustments described above. The availability matrix was updated based on new tracking from Eclipse and Smith Sound, and a recalculation of the connection between Uummannaq and Somerset Island. Compared with the earlier assessments, the soft zeroes and ones in the availability matrix were also activated to allow for a wider mixing of narwhals from different stocks across hunting areas. A sensitivity analysis to determine the impact of selecting different *n* values for the soft zeroes and ones was considered.

Five of the eight narwhal aggregations were estimated to have a rather stable abundance (Figure 1). The three exceptions are Somerset Island where the abundance was estimated to increase from 24,500 (90% CI: 15,400–38,900) to 45,500 (90% CI: 32,100–67,500) over the simulation period from 1970 to 2021, Inglefield Bredning where the abundance was estimated to decline from 4,540 (90% CI: 3,440–6,540) to 2,630 (90% CI: 1,640–3,940), and Melville Bay where the abundance was estimated to decline from 2,910 (90% CI: 1,710–4,890) to no more than 1,250 (90% CI: 420–2,730) narwhals. The two aggregations of narwhals in West Greenland are much smaller than the aggregations in Canada, with the current abundance of the largest Greenlandic aggregation (Inglefield Bredning) being 25% of the current abundance of the smallest Canadian aggregation (Eclipse Sound).

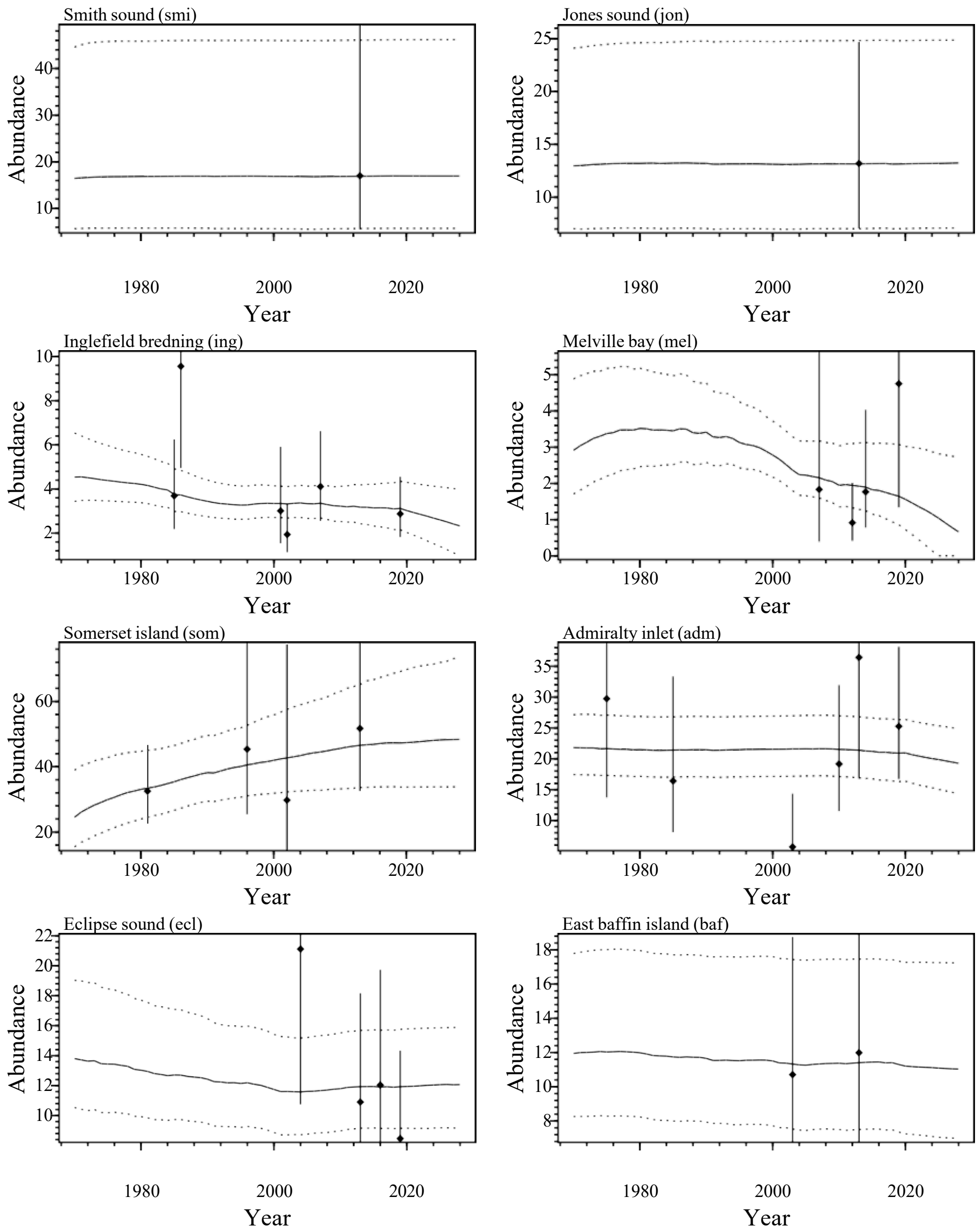

Figure 1: The abundance estimates (points with 90% CI bars) and model trajectories (curves with dashed curves being the 90% CI) of the eight narwhal aggregations.

Discussion

See discussion below for 3.3.2 as 3.3.1 and 3.3.2 were discussed together.

3.3.2 Review of population model to generate recommendations for narwhal removals

Witting presented Working Paper 24 – *Optimal meta population removals for narwhals in East Canada and West Greenland – 2021. (JWG/2021/24)*

Summary

As defined by the agreed 0.7 and 0.8 probabilities of meeting management objectives for the aggregations in Greenland and Canada, respectively, the current removals were found to be unsustainable for Melville Bay, Inglefield Bredning, Eclipse Sound, and Baffin Island. JWG/24 extended the assessment model to identify optimal sustainable removals across all hunting grounds. It used the allocation matrix and total allowable take recommendations for each summer aggregation to assess the sustainability of more than two billion unique hunting patterns. Applying a global search across these options, it identified the sustainable takes that allow for the largest increase in the absolute and relative removals across all hunts.

It is especially the takes from the small aggregation in Melville Bay that are critical. This aggregation is currently exploited not only by the hunt from Upernavik in Melville Bay, but also by the fall hunt in Uummannaq, and the winter hunt in Disko Bay. The optimal sustainable removals were shown to depend strongly on the summer hunt in Upernavik (Figure 2). Both the global absolute, and the global relative, optimum catch closes the hunt in Upernavik to achieve a much higher yield in the fall hunt in Uummannaq and the winter hunt in Disko Bay. Narwhals from Melville Bay are also taken in these areas but are mixed with animals from much larger summer aggregations during fall and winter; therefore, the risk that a hunted narwhal is from the depleted aggregation in Melville Bay is reduced.

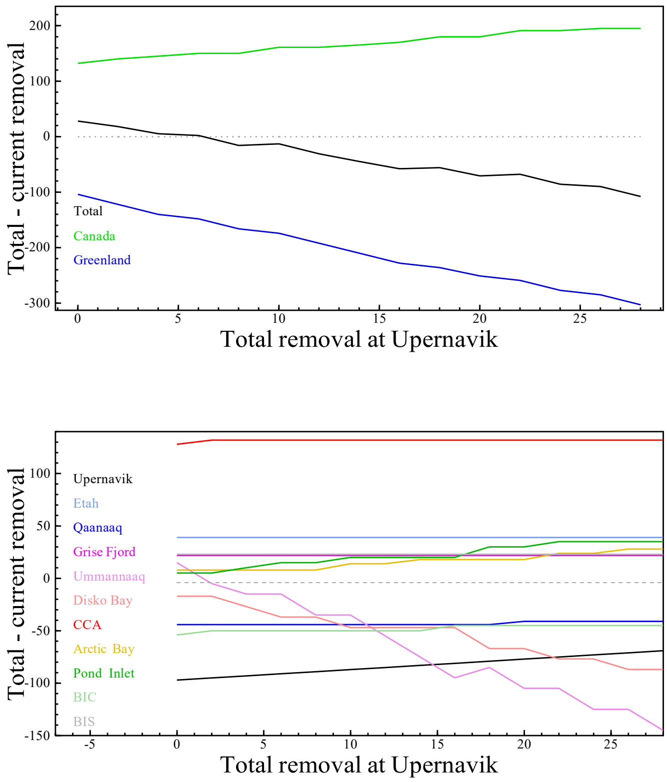

Figure 2: Optimal removals across regions and areas. The optimal total removals minus current removals (average from 2015 to 2019) per hunting region (top plot: Canada, Greenland, both countries) and hunting area (bottom plot) as a function of the total removals in Upernavik, given hunts that are optimised for relative removals across all the hunting areas.

Discussion

Relating to the prior of the meta population model, it was noted that age of sexual maturity is now represented by a distribution rather than by a point estimate. The reproductive rate in the model could be re-evaluated for a future assessment based on data collected in Greenland and Canada. The WG agreed on the model priors.

The model for the Admiralty Inlet aggregations was discussed as the model trajectory did not follow an observed decline and increase in the point estimates of abundance over time. As the apparent change in abundance occurs faster than expected for a narwhal population, the fluctuating abundance estimates may reflect between-year variation in the number of narwhals in the survey area, with potential movements of narwhal between summering areas.

The availability matrix describes the availability of narwhal stocks for the hunts in different areas. Where there is uncertainty of movement between stocks, values representing this uncertainty were included as either soft zeros or probable hunts. Probable hunts were represented using tag information, in particular the number of tagged narwhals that moved between stocks compared to the number of tags for that stock. The inputs for soft zeros were discussed, which are stocks where although unlikely there is still a chance of movement between stocks, represented by 0/*n*. Doniol-Valcroze informed the WG of the variance in the model depending on the value of *n* (Figure 3).

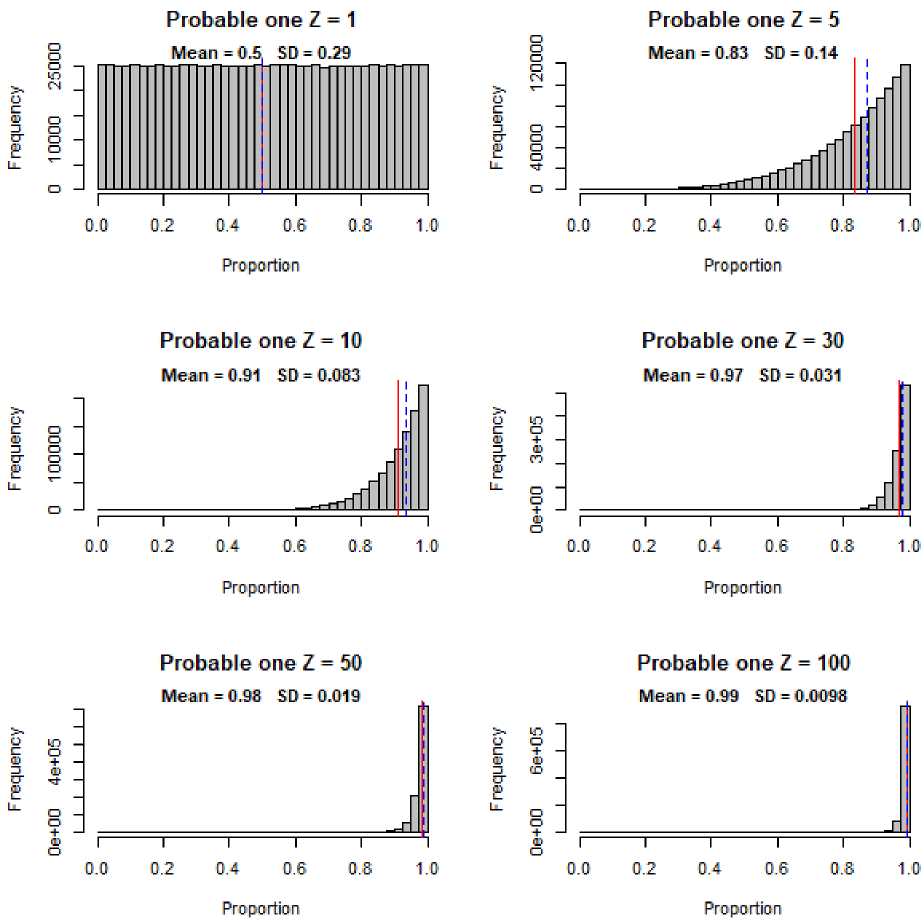

Figure 3: Evaluation of the variance incorporated in the model depending on the value of n (indicated by Z in the figure) chosen.

There was a large decrease in the variance observed between values of *n* from 1, 5, 10, and 30, while there was limited change beyond a *n* of 50. It was decided that a *n* of 50 should be used as it would reflect the maximum number of satellite tags deployed for any one stock within the availability matrix. The catch histories from Canada and Greenland were extended to 2020 and 2019 respectively.

3.4 REVIEW OF FINAL ANALYSIS FOR NARWHAL MANAGEMENT RECOMMENDATIONS

The WG agreed that the optimisation of relative removal across all hunts was more equitable than the optimisation of absolute removals. An optimisation on absolute numbers fails to recognise that the catch of a single individual is unlikely to be equally important on the different hunting grounds. In a community where they are allowed to take 10 whales, the allocation of an extra whale to a total take of 11, is much more important to the community, than the allocation of an extra whale to a community where they are allowed to take 100 whales. The relative optimisation gives equal weight to 1 extra whale allocated to a current hunt of 10, and 10 extra whales allocated to a current hunt of 100.

In evaluating the sustainability of the different hunting options, it is insufficient to ensure that the point estimates of sustainability agree with the accepted 0.7 and 0.8 probabilities of meeting management objectives. The WG agreed that the lower confidence levels of the probabilities in Table 3 should preferably be above 0.5 to ensure that management objectives are more likely to be fulfilled, than rejected. The hunt optimisation model, however, deals so far only with the point estimates of sustainability, with the result that the initial catch optimum had a lower confidence estimate of no more than a 3% chance of meeting the agreed management objective for Melville Bay. To increase this limit, the WG agreed to apply a 0.8, instead of 0.7, probability of meeting the management objective for Melville Bay at the point estimate. The lower bounds for all other summer aggregations were above the agreed limit of 0.5.

Based on these considerations, the WG identified the associated probabilities of sustainability across the eight summer aggregations listed in Table 3 to the sustainable hunting regions listed in Table 4. The option that closes the hunt in Upernavik is the global optimum that maximises the relative take across all hunting areas, yet a small sustainable hunt might be allocated to Upernavik at the cost of a much larger reduction in the allowable takes in Uummannaq and Disko Bay. Owing to the strong impact that any catch in Upernavik has on the small aggregation in Melville Bay, it is advised that any continued hunting in Upernavik is associated with additional management measures that ensure that all takes and losses in the area are reported.

Table 3: Examples of future annual removals (not including struck-but-lost) (C#) per summer aggregation, with associated probabilities (P#) of fulfilling management objectives. The 90% confidence intervals of the estimates are given by the sub- and superscripts.

	Smith Sound	**Jones Sound**	**Inglefield Bredning**	**Melville Bay**	**Somerset Island**	**Admiralty Inlet**	**Eclipse Sound**	**Baffin Bay**
C0 P0	11_{2}^{45} $1.00_{0.98}^{1.00}$	29_{22}^{51} $0.99_{0.97}^{0.99}$	101_{100}^{106} $0.26_{0.2}^{0.28}$	126_{104}^{197} $0.03_{0.00}^{0.1}$	315_{199}^{371} $0.98_{0.97}^{0.99}$	245_{200}^{309} $0.81_{0.66}^{0.89}$	166_{123}^{222} $0.78_{0.52}^{0.92}$	152_{122}^{198} $0.72_{0.52}^{0.85}$
C1 P1	49_{38}^{84} $0.97_{0.91}^{0.98}$	51_{44}^{75} $0.97_{0.94}^{0.98}$	57_{56}^{62} $0.72_{0.66}^{0.73}$	28_{6}^{100} $0.79_{0.12}^{0.98}$	447_{325}^{501} $0.95_{0.92}^{0.98}$	248_{204}^{311} $0.8_{0.65}^{0.88}$	160_{121}^{212} $0.8_{0.57}^{0.92}$	133_{107}^{176} $0.81_{0.62}^{0.9}$
C2 P2	45_{38}^{68} $0.98_{0.94}^{0.98}$	49_{43}^{66} $0.98_{0.95}^{0.98}$	57_{55}^{60} $0.72_{0.68}^{0.74}$	28_{14}^{76} $0.79_{0.26}^{0.93}$	414_{320}^{461} $0.96_{0.94}^{0.98}$	247_{207}^{303} $0.8_{0.67}^{0.88}$	160_{124}^{207} $0.8_{0.6}^{0.91}$	133_{108}^{172} $0.81_{0.63}^{0.9}$
C3 P3	42_{36}^{51} $0.98_{0.97}^{0.99}$	46_{42}^{56} $0.98_{0.97}^{0.98}$	59_{58}^{61} $0.7_{0.68}^{0.7}$	27_{22}^{46} $0.79_{0.57}^{0.86}$	364_{301}^{406} $0.97_{0.96}^{0.99}$	244_{206}^{292} $0.81_{0.7}^{0.88}$	159_{125}^{203} $0.81_{0.62}^{0.91}$	134_{109}^{169} $0.8_{0.65}^{0.89}$
C4 P4	39_{35}^{40} $0.98_{0.98}^{0.99}$	44_{41}^{51} $0.98_{0.97}^{0.98}$	59_{58}^{59} $0.7_{0.69}^{0.71}$	28_{28}^{28} $0.79_{0.79}^{0.79}$	334_{283}^{377} $0.98_{0.97}^{0.99}$	247_{209}^{291} $0.8_{0.7}^{0.87}$	156_{123}^{197} $0.82_{0.64}^{0.92}$	132_{108}^{165} $0.81_{0.66}^{0.9}$

Table 4: Examples (C#) of maximum yearly removals per hunting region. C0 is the average of removals from 2015 to 2019, and C1 to C4 are options presented in Table 3 divided by hunting region. Season is only indicated when the hunt is allocated by season.

Hunt	Season	C0	C1	C2	C3	C4
Etah		1	40	40	40	40
Qaanaaq		99	55	55	58	58
Grise Fjord	Spring	0	0	0	0	0
Grise Fjord	Summer	18	38	38	38	38
Grise Fjord	Fall	1	3	3	3	3
Upernavik		97	0	10	20	28
Uummannaq		145	160	110	40	0
Disko Bay		87	70	40	20	0
CCA	Spring	4	9	9	9	9
CCA	Summer	62	142	145	145	145
CCA	Fall	32	75	76	76	76
Arctic Bay	Spring	40	42	43	44	46
Arctic Bay	Summer	99	103	106	108	113
Arctic Bay	Fall	58	60	62	63	66
Pond Inlet	Spring	32	33	36	38	39
Pond Inlet	Summer	68	70	76	80	82
Pond Inlet	Fall	65	67	73	77	79
BIC	Spring	3	3	3	3	3
BIC	Summer	77	58	59	61	61
BIC	Fall	140	105	108	111	111
BIS	Spring	7	16	16	16	16
BIS	Summer	4	10	10	10	10
BIS	Fall	7	15	15	15	15
BIS	Winter	0	0	0	0	0
Sum		1146	1174	1133	1075	1038

4. IMPACTS OF CLIMATE CHANGE ON NARWHAL AND BELUGA MANAGEMENT

4.1 NARWHAL

4.1.1 Baffinland, Mary River Mine and other developments

Marcoux presented on the Baffinland Phase 2 Proposal and DFO science perspective.

Summary

The Baffinland Mary River Project is an operating open pit iron ore mine located on North Baffin Island in Nunavut. Ore is transported to Europe via the Northern Shipping Route through Milne Inlet, Eclipse Sound, Pond Inlet, and Baffin Bay. In December 2018, the Phase 2 Addendum was submitted, which describes the activities associated with the second phase of the Project.

The Phase 2 includes an upgrade to port facilities in Milne Inlet (including a second ore dock to accommodate larger cape size vessels), increased shipping activities through Milne Inlet to accommodate the planned production increase up to 12 Mtpa (Million tonnes per annum) and icebreaking in the spring and fall to extend the existing shipping season. An estimated 176 ore carrier round trips (upper end of range) would occur per season, as well additional sailings for resupply vessels. Shipping would occur seasonally within a window of approximately 135 days between July 1 and November 15. Ice breakers would also be operating, when conditions require, along the Northern

Shipping Route and ice management vessels (tugs) would operate as required in the Milne Port/Inlet area. The proposed extended shipping season through the Northern Shipping Route associated with the Mary River Project is unprecedented in scale for the Canadian Arctic.

Based on the material presented in the environmental impact assessment from the Proponent, DFO Science disagrees with the Proponent's overall conclusion that the proposed project operations will inflict no significant impacts on the marine ecosystem within Eclipse Sound. The overall conclusion of no significant impact on any marine mammal, and no long-term impacts, is difficult to accept. DFO Science is concerned that BIM's statements and conclusions are not always supported by robust evidence (e.g., small sample sizes and lack of appropriate data analyses), justification, or rationale (e.g., that restriction of ship vessel speed removes any significant risk of ship strike).

DFO Science is particularly concerned with icebreaking activities at the beginning and end of the shipping season, and the associated impact on marine mammals. For example, icebreaking activities during the fall may impede the formation of ice across the inlets (e.g., ice type, lack of formation, rubble) and result in narwhal ice entrapments during the fall migration.

The cumulative noise soundscape is a necessary component of the impact assessment. Noise will have a negative impact on marine mammals. For example, the large number of vessels transiting from the Milne Port and those awaiting entry may deter narwhals from entering Eclipse Sound. DFO Science is concerned that narwhals will be exposed to continuous noise >120 dB. The proponent's assessment should include all vessel traffic (e.g., cruise ships, community resupply) and vessels at anchor (e.g., Ragged Island), as well as outside the Eclipse Sound area.

DFO Science would like to see several Early Warning Indicators for marine mammals (e.g., physiological impacts and behaviour, abundance, and distribution) to be developed and implemented with thresholds as soon as possible.

Discussion

As a mitigation measure for noise from "ice management", the mining company proposed to have limited transits of the icebreaker; in 6/10 ice concentration this would be 1 transit/day, and 2 transits/day in 4/10-6/10 ice concentration. The WG discussed an alternative measure of having 1 transit/day of the icebreaker and that the transport ships come in by convoys. This would reduce the number of noise events and provide 'silent breaks' for the whales. Additionally, it could be investigated whether it would be better to have the ships move faster, which would increase the noise but reduce the time of disturbance. The WG noted that there are no studies that can inform the value of different shipping strategies.

The cumulative impact assessment performed by the mining company was discussed. The WG agreed that this assessment should have included impacts that were not related to the company (e.g., climate change, increase of killer whales, other construction activities in the inlet). The classification of the magnitude of impacts (level I: an effect that results in a change that is not distinguishable from natural variation; level II: an effect that results in a change that is measurable but allows recovery within one to two generations; level III: an effect predicted to result in a reduced population size or other long-lasting effect on the subject of the assessment) was deemed inadequate and somewhat arbitrary. There was a large difference between levels I and II, and level III was never reached in the assessment. The WG agreed that the cumulative impact assessment did not include supportive quantitative tests and did not include the latest information on behavioural response of narwhals to anthropogenic activities (Heide-Jørgensen et al., 2021; Tervo et al., 2021; Williams et al., in review).

The WG discussed monitoring methods and the use of early-warning indicators. The mining company proposed the use of the proportion of immature narwhals as an early-warning indicator. If a certain threshold of this proportion would be reached, mitigation measures would be implemented on an annual basis. The WG had several concerns with this approach:

- the mine only identified one 'indicator',
- proportion of immature would not be an early warning indicator given the late age of maturity and low pregnancy rates in narwhals,
- proportion of immature whales is unlikely to be representative of the entire population as the field observations are constrained to one shore-based location,
- the definition and reliability of the detection of immature whales from visual observations is somewhat uncertain.

The WG agreed that a combination of three or more indicators should be developed. Additional indicators were discussed, e.g., changes in body condition and stress levels as well as the changes in distribution, abundance, and fraction of calves from the aerial surveys. Watt informed the WG on a study that sampled narwhal blubber for cortisol levels which showed a significant increase from pre and post shipping periods (JWG/2021/FI15). There is also an ongoing study sampling narwhal tusks for hormones to evaluate stress and reproduction over a narwhal's lifetime (JWG/2021/FI16). None of these suggested indicators would, however, adequately address the possible effects of the shipping activity.

Eclipse Sound is home to one of the largest narwhal summer stocks. The main concern is that narwhals may abandon this critical habitat due to the unprecedented level of shipping and icebreaking activities. This would have a severe impact on hunting communities in both Canada and Greenland. The WG **requested** more information on changes in abundance, and dispersion of whales to other hunting grounds. Several methods were suggested to monitor for abundance changes, including passive acoustic monitoring in Milne Inlet, more frequent aerial surveys, tagging from a helicopter and detection of whales on satellite imagery. A comparative study of Admiralty Inlet could be used to separate other influences (climate change and killer whale presence) from mining activity effects on narwhal abundance and distribution. A comparison of the abundance estimates from 2004 and onwards suggests there may already have been substantial distributional shifts in narwhal abundance from Eclipse Sound to Admiralty Inlet. The WG also highlighted that an apparent decline of narwhals in Eclipse Sound has been observed since the start of shipping activities.

Considering the increased anthropogenic activities in Eclipse Sound, the WG **recommended** annual aerial surveys to inform the ongoing assessment of narwhals in the allocation model. In case of a declining narwhal population in Eclipse Sound the ongoing assessment will need to be updated more frequently to ensure that catches are maintained at sustainable levels. Considering the relatively large variance of fully corrected abundance estimates, relative estimates from annual aerial surveys are required to monitor trends in narwhal presence in the Eclipse Sound complex.

Icebreaking and its accompanying increased anthropogenic noise in transboundary Baffin Bay waters as shipping vessels travel to and from the mine may have consequences on narwhal and other species who rely on the unique habitat. This will also include risks to the small narwhal stock in Melville Bay.

4.1.2 Changes in habitat, movements, and distribution

Three Working Papers and one For Information paper related to changes in habitat, movements, and distribution due to climate change were presented. These were discussed together.

Migration phenology shifts

Marcoux presented a study by Shuert et al. – *"Keeping pace with Climate: Migration phenology shifts over the last three decades in a long-lived Arctic icon".*

<u>Summary</u>

We investigate the timing of narwhal migration over a period of 27 years. We used data from 63 narwhals equipped with satellite transmitters from 1997 to 2018 in Eclipse Sound and Admiralty Inlet.

The timing of migration varied annually and between sexes. Male narwhals were found to lead the migration out of the summering areas, while females and often dependent young departed later. Narwhals are remaining longer in their summer areas at a rate of 6–10 days per decade, a rate of change similar to that observed for climate-driven sea-ice loss across the region. The consequences of remaining in the summering areas for longer have yet to be evaluated but will likely leave individuals at a greater risk of exposure to the increasing natural and anthropogenic activities in the region.

Habitat suitability

Chambault presented Working Paper 18 – *Short-term expansion but long-term habitat loss: how far narwhals should go to avoid warmer waters? (JWG/2021/18)*

Summary

Satellite tracking data extending over 28 years and covering the different narwhals' populations located in the Atlantic sector of the Arctic were used in both summer (n=118 individuals) and winter (n=64 individuals) to (i) model the current and (ii) project the future distribution of narwhals to assess responses to climate change over the coming decades. A series of eight machine learning algorithms were used to relate the whale's occurrences to three environmental variables including sea surface temperature, distance to shore and bathymetry. With respect to the short-term predictions (between now and 2060), climate change appears beneficial, providing new accessible habitats in West Greenland for narwhals in summer, indicating a progressive northern shift towards North of Baffin Island, while in the East, no major change is projected. The situation differs in winter, with a complete loss of habitat expected by 2100 in the East. Long-term predictions (by 2100) project a significant contraction of the narwhal's geographic range. Narwhals are projected to move northwards (up to 370 km west in summer) to cope with rising sea temperatures, leaving their current summer (maximum loss: 20%) and winter hotspots (maximum loss: 100%). Over the short-term (by 2060), climate change appears beneficial to the species, making current ice-covered areas progressively accessible in West Greenland. Remaining habitat in the West is predicted to exist only in small areas north of Baffin Island, which have been predicted to be the last Arctic summer ice refugia. Narwhal distributions north of the current range might be feasible, given that narwhals are deep divers that might be able to feed on mesopelagic prey in the depths of the Arctic Ocean. However, given the existing hunting pressure already present in the East, together with the strong site fidelity of the species, the ability of the narwhal to cope with such environmental changes is currently uncertain.

Regime shift in Southeast Greenland

Heide-Jørgensen presented Working Paper 20 – *A regime shift in Southeast Greenland. (JWG/2021/20)*

Summary

Two major oceanographic changes have recently propagated through several trophic levels 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 warm Irminger Current that advects the warm, saline Atlantic Water northward through the Denmark Strait to the East Greenland shelf has changed its temperature regime from 5.5–6.5˚C to 6.5–7.5˚C after 1997. This has, together with the absence of sea ice, been a major driver for increasing sea temperatures in the SEG shelf area. The lack of pack ice in summer together with a warming ocean has had cascading effects on the marine ecosystem in SEG that is manifested in a changed fish fauna with an influx of capelin in coastal areas and mackerel, herring, and tuna in offshore areas. At higher trophic levels there has been an increase in the abundance of several boreal cetaceans such as, humpback whales, fin whales, killer whales, pilot whales and white-beaked dolphins, that are either new to this area of the Arctic or occur in surprisingly large numbers. It is estimated that the new cetacean species in SEG are responsible for an annual predation level of 700,000 tons of fish. In addition, predation on krill species is estimated at >1,500,000 tons that are mainly consumed by the large number of fin whales. There has at the same time been a reduction in the abundance and catches of narwhals and walrus in SEG and it is speculated that these species, that are endemic to the Arctic and depend on cold polar water, have been reduced in numbers due to habitat changes from increasing sea temperatures and perhaps increasing competition with sub-Arctic species.

Final discussion

The presented studies suggest that although narwhals may be able to adapt their migration patterns, there is an overall predicted loss of suitable habitat. It was noted that new habitats may become available due to a loss of sea ice, but the expected rise of sea temperatures might force narwhals from some stocks to abandon their current habitats. Some model limitations were that future habitat variables that are likely related to narwhal distribution are not available to date, including prey availability. Climatic projections of higher resolution environmental data would increase the predictive robustness of these models, but such projections are not available at this stage. Due to their deep-diving hunting behaviour, information on diving activities of narwhals at depth together with the potential modifications of sea temperature at depth are also needed to investigate how narwhals will react to climate change across the entire water column. The ability of narwhals to react to thermal stress from temperature rise also needs to be investigated to complement such correlative distribution models. There are observations of narwhals outside their traditional distribution, which suggests distributional shifts. It will be challenging to investigate these changes as many of these areas are uninhabited and not frequently visited. The use of satellite imagery may be used to observe narwhal in these locations. Furthermore, the WG noted that although there are indications that some stocks can move to different locations, this is not necessarily the case for all stocks.

4.1.3 Changes in hunting behaviour, location, and seasons

The WG welcomed more information on changes in hunting behaviour, hunting locations, and seasons from communities and management to inform future discussions.

4.1.4 Impacts on population dynamics

Impacts of rising sea temperatures on narwhal demography

Chambault presented For Information Paper 21 – *The impact of rising sea temperatures on an Arctic top predator, the narwhal. (JWG/2021/FI21)*

<u>Summary</u>

Using a large dataset of 144 satellite tracked narwhals, sea surface temperature (SST) data spanning 25 years (1993–2018) and narwhal abundance estimates from 17 localities, we (1) assessed the thermal exposure of this species, (2) investigated the SST trends at the summer foraging grounds, and (3) assessed the relationship between SST and abundance of narwhals. We showed a sharp SST increase in Northwest, Mideast, and Southeast Greenland, whereas no change could be detected in the Canadian Arctic Archipelago (CAA) and in the Greenland Sea. The rising sea temperatures were correlated with the smallest narwhal abundance observed in the Mideast and Southeast Greenland (< 2,000 individuals), where the mean summer sea temperatures were the highest (6.3 °C) compared to the cold waters of the CAA (0.7 °C) that were associated with the largest narwhal populations (> 40,000 individuals). These results support the hypothesis that warming ocean waters will restrict the habitat range of the narwhal, further suggesting that narwhals from Mideast and Southeast Greenland may be under pressure to abandon their traditional habitats due to ocean warming, and consequently either migrate further North or locally go extinct.

<u>Discussion</u>

The content of this document contributed to the discussion on the impact of climate change on narwhal habitat, see the *Final Discussion* under Section 4.1.2. No further discussion was held on changes in population dynamics.

4.2 BELUGA

4.2.1 Changes in habitat, movements, and distribution

Chambault presented the section on belugas from Working Paper 18 – *Short-term expansion but long-term habitat loss. (JWG/2021/18)*

<u>Summary</u>

The current and future habitat suitability of belugas were projected for West Greenland in summer using Species Distribution Models applied to satellite tracking data (n=29 individuals tracked from 1995 to 2001). Belugas currently have a broad north-south range, but they are divided into small local populations that exhibit high site-fidelity, which makes them vulnerable to environmental changes. The models projected a geographic range expansion North of Baffin Island in 2060 but the disappearance of most of the current habitats used by belugas by 2100. Most beluga populations are currently small, including the one at southeast Baffin Island tracked in this study. The average northern shift expected for beluga in summer was 363 ± 10.4 km and the projected habitat loss 12.5 ± 2.08%.

<u>Discussion</u>

The sensitivity of beluga to loss of habitat was discussed, and the models projected a habitat loss in Cumberland Sound. It was discussed that additional information, in particular beluga tag data, would inform discussions on climate change impacts on beluga habitat, movements, and distribution. Tagging data from the Bering Sea beluga stocks revealed an earlier departure date by beluga from winter habitat to summer habitat to the Chukchi Sea as well as a later return date, reflecting longer summer habitat occupation. There are some current projects investigating beluga movements through tagging in Cumberland Sound and the Beaufort Sea that would be of interest to this discussion upon completion. Other indicators were suggested to investigate changing climate impacts, such as the prevalence of disease, and while there have been observations of whales with poor body condition in the Chukchi Sea, there is no clear connection to climate change impacts.

4.2.2 Changes in hunting behaviour, location, and seasons

The WG had no new information on changes in hunting behaviour, location, or seasons for belugas and would welcome more information from communities and management on changes in these parameters to inform future discussions.

4.2.3 Impacts on population dynamics

No new information was presented, and no discussion was held on the impacts of climate change on population dynamics.

4.3 REVIEW OF OPTIONS FOR MODIFYING EXISTING ASSESSMENT METHODS

Watt presented For Information document 11 – *Environmental covariates into stock production model (JWG/2021/FI11)*

<u>Summary</u>

Population dynamics of the Cumberland Sound beluga whale population have been modelled in the past, but the effect of environmental covariates on these models has not previously been considered. An existing Bayesian population model fitted to CS beluga whale aerial survey data from 1990–2017 and catch data from 1960–2017 was modified to include the environmental covariates sea ice concentration (ICE) and sea surface temperature (SST). ICE and SST were extracted for all years from the Cumberland Sound study area in March and August, respectively, and because the mechanistic relationship between these covariates and beluga reproduction are unknown, they were incorporated into the state process component of the state space model. Compared to the previous model without environmental covariates, which followed a relatively linear trajectory, our model had more noticeable peaks and troughs in the population trend and much wider confidence intervals

Discussion

The WG discussed options for including climate change indicators into the narwhal population models. Some potential adjustment factors included increasing the variance and adding an error term incorporating environmental cues. After thorough discussion it was decided that these possibilities would not serve to accurately improve the model as the mechanisms that would connect climate changes and population dynamics are unquantified. The WG **recommended** that the proportion of calves, juveniles and adults be collected from aerial photographic and/or visual surveys. Information on the age structure should be collected through hunt sampling programmes, as this could inform reproduction rates in modelling and be an indicator of changes in reproduction. The WG also **recommended** that sightings of narwhals and belugas in new areas be recorded and used to inform investigations into distribution changes.

4.4 DATA REQUIREMENTS FOR MODIFICATIONS

The WG agreed that adding information on climate variables with no mechanistic understanding of the interactive impacts would not improve model assessments. However, the WG **recommended** that life history data including information on annual reproductive rates could inform the models. Continued evaluation of abundance data would provide information on whether animals have moved from one location to another, and getting anecdotal sightings information, especially in extralimital areas, would provide information on distributional changes. The WG also **recommended** that information on age structure data from surveys and catches would be useful in the models. The WG also **recommended** that more tagging data would highlight if movement patterns have changed substantially. For belugas, the WG **recommended** genetic data that could show new stocks or mixing of existing stocks. For narwhals in West Greenland and Canada there is currently limited genetic resolution among stocks, but with increased genomic resolution it may be possible to differentiate stocks (as is suggested for stocks in East Greenland).

4.5 SENSITIVITY TO UNCERTAINTY IN THE POPULATION RESPONSE TO CLIMATE CHANGES

As the mechanism for climate change impacts on belugas and narwhals are unknown, the addition of climate data to models would only add noise. However, the WG agreed there is no value in adding additional uncertainty to the model unless there is understanding of the mechanism. Another possibility to incorporate climate change uncertainty into hunting allocation would be to increase the probability of achieving management objectives.

4.6 PROPOSED IMPROVEMENTS TO BE IMPLEMENTED IN NEXT ASSESSMENT

The WG agreed that improved understanding on life history and age structure of stocks would serve to inform best management decisions. Future work could also include monitoring for stock movement and include these movements within the model predictions. This could potentially be incorporated by creating a summer aggregation availability matrix that could be added to abundance estimates, creating survey abundance distributions that are negatively correlated, adding a transient stock to the availability matrix that represents the proportion of animals that move between stocks, or combining stocks to represent the movement between them.

5. RECOMMENDATIONS FOR RESEARCH & MANAGEMENT

5.1 RECOMMENDATIONS FOR CONSERVATION AND MANAGEMENT

Narwhal

New narwhal catch advice for all hunting areas is presented in Table 5. There have been no changes in stock discrimination (Figure 4) or hunting areas and seasons (Figure 5).

Table 5: The optimal sustainable landings per hunt, given as a function of the landed catches in Upernavik (bold). Each column represents an optional catch (O1, O2, etc.) distribution across hunting regions. Annual landed catches are recommended from 2022 until the next narwhal assessment which is expected to be delivered no later than 2025. All catch recommendations have at least a 70% probability of increasing the stock over a 5-year period (at the point estimate, see Table 1). Season is indicated when the hunt is allocated by season. Sp = spring, Su = summer, Fa = fall, Wi = winter, S&L = struck and lost rate.

Hunting region	Season	S&L	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	O13	O14	O15
Etah		0.05	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
Qaanaaq		0.05	52	52	52	52	52	52	52	52	52	52	55	55	55	55	55
Grise Fjord	Sp	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grise Fjord	Su	0.23	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Grise Fjord	Fa	0.23	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Upernavik		**0.15**	**0**	**2**	**3**	**5**	**7**	**9**	**10**	**12**	**14**	**16**	**17**	**19**	**21**	**23**	**24**
Uummannaq		0.3	123	108	100	100	85	85	69	54	38	46	31	31	15	15	0
Disko Bay		0.3	54	54	46	38	38	31	31	31	31	15	15	8	8	0	0
CCA	Sp	0.09	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
CCA	Su	0.09	130	133	133	133	133	133	133	133	133	133	133	133	133	133	133
CCA	Fa	0.09	69	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Arctic Bay	Sp	0.35	31	31	31	31	31	32	32	33	33	33	33	33	33	34	34
Arctic Bay	Su	0.35	76	76	76	76	76	79	79	80	80	80	80	82	82	84	84
Arctic Bay	Fa	0.35	44	44	44	44	44	46	46	47	47	47	47	48	48	49	49
Pond Inlet	Sp	0.15	29	29	30	30	30	31	31	31	31	33	33	34	34	34	34
Pond Inlet	Su	0.15	61	61	63	64	64	66	66	66	66	70	70	71	71	71	71
Pond Inlet	Fa	0.15	58	58	60	62	62	63	63	63	63	67	67	69	69	69	69
BIC	Sp	0.23	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
BIC	Su	0.23	47	48	48	48	48	48	48	48	50	50	50	50	50	50	50
BIC	Fa	0.23	85	88	88	88	88	88	88	88	90	90	90	90	90	90	90
BIS	Sp	0.23	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
BIS	Su	0.23	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
BIS	Fa	0.23	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
BIS	Wi	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

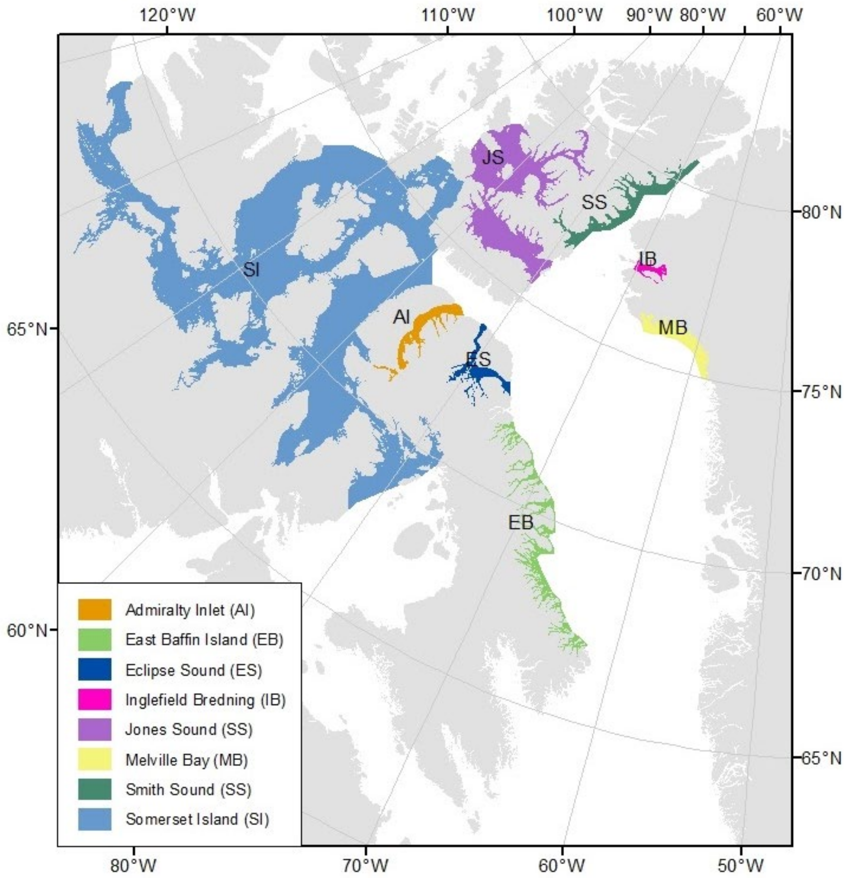

Figure 4: Summer distribution of narwhal stocks in the Canadian high Arctic and West Greenland.

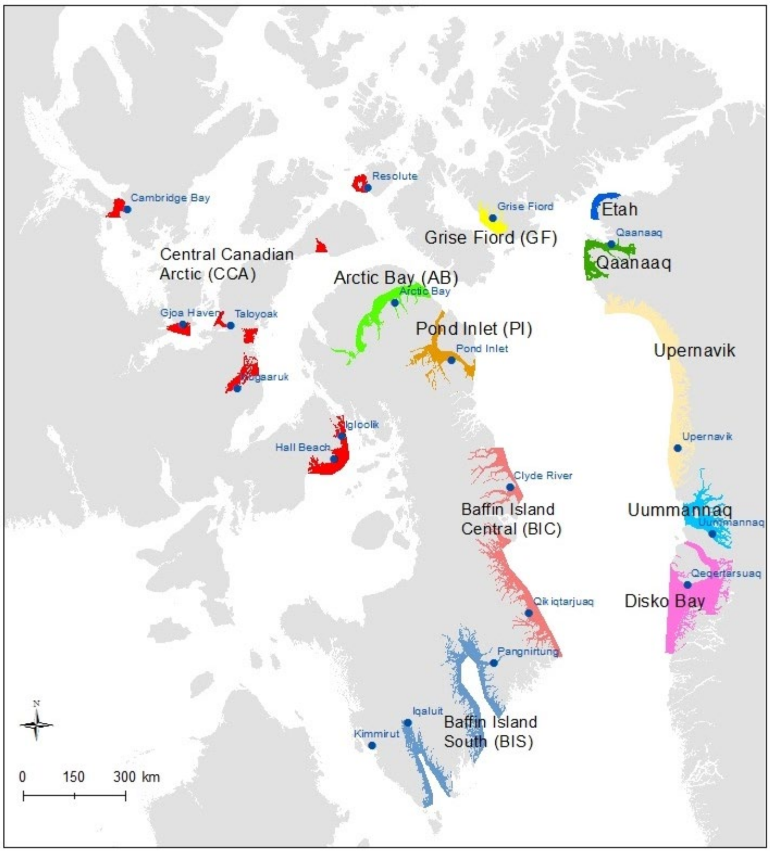

Figure 5: Hunting regions for narwhal in the Canadian high Arctic and West Greenland.

Additional recommendations for the conservation and management of narwhal:

- Use of the allocation model by Canada for recommending sustainable narwhal catches using either model or PBR-based estimates. Use of the model based estimates is recommended as this would ensure compatibility with catch recommendations for Greenland.
- Collect length information and samples (blubber, skin, reproductive organs, information on presence of foetus, whether there is milk in the mammary glands of females).

Beluga

- Collect length information and samples (e.g., blubber, skin, reproductive organs, information on presence of foetus, whether there is milk in the mammary glands of females, a tooth)

Previous recommendations for conservation and management that were reiterated at this meeting:

- Implement the following seasonal closures:
    - o Northern (Uummannaq, Upernavik, Savissivik): June through August
    - o Central (Disko Bay): June through October
    - o Southern (South of Kangaatsiaq): May through October
- In the area south of 65°N, no hunting of beluga be allowed at any time.

5.2 RECOMMENDATIONS FOR RESEARCH

General

- More work should be done on reproduction rates, including collecting the ratio of juveniles to adults from aerial surveys, and age distribution data from hunted whales.
- More tagging data should be obtained to highlight if movement patterns have changed substantially.
- Life history data, including information on annual reproductive rates, should inform the assessment models.
- The WG implements demographic stochasticity (discussed in Section 6.2) in the assessment model when appropriate (i.e., abundance estimates less than 500).

Narwhal

- Further research should be undertaken to investigate the stock structure and abundance in Smith Sound.
- A sensitivity analysis should be conducted to determine how soft zeros in the allocation matrix could impact small or isolated narwhal stocks.
- A new survey in Melville Bay and Inglefield Bredning should be conducted as soon as possible, due to the critical situation for these stocks.
- It should be resolved if there is sufficient genomic resolution for stock discrimination in Baffin Bay narwhals (as has been found for narwhals in East Greenland).

Beluga

- Genetic data and/or microchemistry data that could show new stocks or mixing of existing stocks should be obtained.
- Genomic analysis should be performed on samples from Igloolik and Taloyoak.

The following recommendations for research on belugas were reiterated from previous meetings:

- A summer survey of the High Arctic beluga population.
- Revise assessment model for beluga in relation to data available from Canada.
- If samples from the fall hunt in Qaanaaq become available, a genetic analysis should be performed for possible stock assignment.
- Determine summer grounds and seasonal movements and distribution of the proposed North Water stock.

6. OTHER BUSINESS

6.1 DEVELOPMENT OF A PRINCIPLE BASED APPROACH FOR MANAGEMENT OF SMALL STOCKS

The NAMMCO SC is requested to "explain how and at what level the precautionary approach is, or can be, integrated into advice provided by the SC for use in conservation and management, with a particular focus on depleted stocks". In response to this request, Hobbs, in collaboration with Heide-Jørgensen and Hansen, drafted a principle-based approach to setting management objectives for removals of small cetaceans and pinnipeds. The document (JWG/2021/17-revII) includes a proposed set of principles and an example of their application within NAMMCO's existing assessment procedures. The WG discussed the document at this meeting and agreed on the following proposed principles:

1. Sustainable management actions should be to maintain or restore stocks at levels ideally above 60% of their equilibrium in the absence of anthropogenic removals, disturbance, and resource competition.
2. Stocks that are depleted below 60% should be managed to increase so that they can recover to the 60% level in a reasonable time period.
3. Stocks that are small (<1000 individuals or <400 reproductive age females) require greater protection due to threats inherent to small populations, such as loss of genetic diversity, greater vulnerability to demographic and environmental variation including catastrophic events, decreased potential for growth, and management uncertainties such as unknown levels of struck and loss and underreporting. Management of small stocks should take these factors into account to allow for recovery and avoid a significant risk of extirpation or extinction. Small stocks should be fully protected from exploitation unless a data-based assessment is able to recommend a sustainable hunt.
4. Management decisions should be based on the best available science, which may include hunter and user data and observations.
5. Where the best available science is insufficient the precautionary approach shall be widely applied, particularly for small stocks. Lack of scientific certainty shall not be used as a reason for postponing measures to prevent the further depletion or extirpation of a stock. With greater uncertainty more caution is required.
6. Noting that the long-term value of a healthy stock far exceeds the short-term economic value of further depletion or extirpation, economic concerns should not delay or prevent the recovery of a small or depleted stock.
7. Acknowledging that halting all hunting of a stock may not be sufficient to promote recovery of a depleted or small stock, additional management actions such as establishing protected areas of critical habitat, e.g., closing areas to hunting, fishing and vessel traffic, may be considered.

6.2 DEMOGRAPHIC VARIATION IN NARWHAL POPULATION DYNAMICS

Witting presented Working Paper 21, 22, & 23 – *Demographic variation in narwhal population assessment. (JWG/2021/21, JWG/2021/22, JWG/2021,23)*

<u>Summary</u>

JWG/2021/21 estimates the negative impact that demographic variation has on the population dynamics growth of narwhal. It is shown that realised growth might be negative for a deterministic growth rate of 0.01 in a population of 100 individuals, and for a deterministic growth rate of 0.03 in a population of 20 individuals. With 500 individuals, there is a five percent risk that the realised growth rate is less than half of the deterministic growth rate, should the latter be 0.01 and annual survival no larger than 0.95.

JWG/2021/22 and JWG/202123 examine the inclusion of demographic variation in the assessment of small narwhal stocks, based on the models for narwhal in the Tasiilaq and Ittoqqortoormiit areas in

East Greenland. With current abundance estimates below 100, and around 150, demographic variation will generate a small decline in the long-term growth rate of both stocks. This agrees with the results of the assessments, where the models with and without demographic variation tend to converge on the same long-term growth rate over the simulation period. This creates slightly higher estimates of the deterministic growth rate in the models with demographic variation. In other words, by including demographic variation, the statistics of fitting models to data compensate for the decline in the growth rate by demographic variation, with the end-result being that there are no big differences in the stock status conclusions that are made from models with and without demographic variation.

Discussion

The WG **recommended** that Witting implements this demographic stochasticity in the assessment model when appropriate (i.e., abundance estimates less than 500).

6.3 OTHER

The JWG received the request to hold a workshop to exchange information on effective tagging practises for belugas. It was agreed that such a workshop is desirable, but that a larger range of experts should be invited. Additionally, the WG recommended that this workshop should not be limited to tagging on beluga, but also include other species (e.g., narwhal, walrus, small cetaceans), and be convened by the NAMMCO SC.

The JWG recommended at its 2020 meeting that the latest research on reproductive senescence would be presented at the 2021 meeting, and that it would investigate how this information may be incorporated into the population model. The WG did not consider this as there was no information available.

7. MEETING CLOSE

The Co-Chairs thanked all the participants for their active contribution to the meeting and the excellent research done to inform the discussions. The WG thanked the Co-Chairs for efficient guidance through the agenda to arrive at recommendations for both research and management, and the extremely extensive efforts throughout the QSG meetings. The WG also thanked the JCNB Co-chair for the excellent hospitality and logistics in Winnipeg. The rapporteurs were thanked for their comprehensive record of the discussions. The WG appreciated and enjoyed having a physical meeting.

The meeting was closed at 17:00 CST on December 17th 2021.

The draft report with recommendations was accepted before the close of the meeting on December 17th 2021. Following minor editing and formatting work, the report was finalised on January 7th 2021.

REFERENCES

Chambault, P., Tervo, O. M., Garde, E., Hansen, R. G., Blackwell, S. B., Williams, T. M., ... & Heide-Jørgensen, M. P. (2020). The impact of rising sea temperatures on an Arctic top predator, the narwhal. Scientific reports, 10(1), 1-10.

Doniol-Valcroze, T., Gosselin, J. F., Pike, D., Lawson, J., Asselin, N., Hedges, K., & Ferguson, S. (2020). Narwhal abundance in the eastern Canadian high Artic in 2013. NAMMCO Scientific Publications, 11. Doi:10.7557/3.5100.

Heide-Jørgensen, M. P. (1994). Distribution, exploitation and population status of white whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) in West Greenland. Meddr Grønland, Bioscience, 39: 135-149.

Heide-Jørgensen, M. P. (2004). Aerial digital photographic surveys of narwhals, *Monodon monoceros*, in northwest Greenland. Mar. Mamm. Sci, 20(2):246-261

Heide-Jørgensen, M. P., Blackwell, S. B., Tervo, O. M., Samson, A. L., Garde, E., Hansen, R. G., ... & Ditlevsen, S. (2021). Behavioral response study on seismic airgun and vessel exposures in narwhals. Frontiers in Marine Science, 665.

Hobbs, R. C., Reeves, R. R., Prewitt, J. S., Desportes, G., Breton-Honeyman, K., Christensen, T., Citta, J. J., Ferguson, S. H., Frost, K. J., Garde, E., Gavrilo, M., Ghazal, M., Glazov, D. M., Gosselin, J. -F., Hammill, M., Hansen, R. G., Harwood, L., Heide-Jorgensen, M. P., Inglangasuk, G., ...Watt, C. A. (2019). Global Review of the Conservation Status of Monodontid Stocks. Marine Fisheries Review, 81(3-4), 1+.

Laake, J. L., Calambokidis, J., Osmek, S. D., & Rugh, D. J. (1997). Probability of detecting harbor porpoise from aerial surveys: estimating g(0). J. Wildl. Manage, 61(1):63-75.

NAMMCO-JCNB Joint Working Group (JWG) (2020). Report of the Joint Working Group Meeting of the NAMMCO Scientific Committee Working Group on the Population Status of Narwhal and Beluga in the North Atlantic and the Canada/Greenland Joint Commission on Conservation and Management of Narwhal and Beluga Scientific Working Group. October, 2020. Tromsø: Norway.

NAMMCO-North Atlantic Marine Mammal Commission (2021a). Report from the Management Committee for Cetaceans. March, 2021. Tromsø, Norway: NAMMCO.

NAMMCO-North Atlantic Marine Mammal Commission (2021b). Report of the 27th meeting of the NAMMCO Scientific Committee. Tromsø, Norway: NAMMCO.

Richard, P., Weaver, P., Dueck, L., & Barber, D. (1994). Distribution and numbers of Canadian High Arctic narwhals (*Monodon monoceros*) in August 1984 – Meddr Grønland, Biosci. 29: 41-50. Copenhagen 1994-04-22.

Skovrind, M., Louis, M., Westbury, M. V., Garilao, C., Kaschner, K., Castruita, J. A. S., ... & Lorenzen, E. D. (2021). Circumpolar phylogeography and demographic history of beluga whales reflect past climatic fluctuations. Molecular Ecology.

Tervo, O.M., Blackwell, S.B., Ditlevsen, S., Conrad, A.S., Samson, A.L., Garde, E., Hansen, R.G. and Heide-Jørgensen, M.P. (2021). Narwhals react to ship noise and airgun pulses embedded in background noise. Biology Letters 17: 20210220. https://doi.org/10.1098/rsbl.2021.0220

Lowry, L. F., Frost, K .J., Zerbini, A., Demaster, D., Reeves, R. R. (2008). Trend in aerial counts of beluga or white whales (*Delphinapterus leucas*) in Bristol Bay, Alaska, 1993-2005. J. Cetacean Res. Manage, 10(3), 201-207.

Williams, T.M., M.P. Heide-Jørgensen, A.M. Pagano, C.M. Bryce. 2020. Hunters versus Hunted: New perspectives on the energetic costs of survival at the top of the food chain. Functional Ecology 34: 2015-2019. doi:10.1111/1365-2435.13649

Williams, T.M., S. Blackwell, O. Tervo, E. Garde, M.-H. S. Sinding, B. Richter, and M.P. Heide-Jørgensen. (In review). Physiological responses of narwhals to anthropogenic noise: A case study with seismic airguns and vessel traffic. Functional Ecology

Watt, C. A., Marcoux, M. M., Asselin, N. C., Orr, J. R., & Ferguson, S. H. (2015). Instantaneous availability bias correction for calculating aerial survey abundance estimate for narwhal (*Monodon monoceros*) in the Canadian High Arctic. DFO Can. Sci. Advis. Sec. Res. Doc, 2015/044. v + 13 p.

APPENDIX 1: AGENDA

Monday (8:30-17:30 CST):

1. CHAIRS 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. BELUGA ALLOCATION

2.1. Review of recommendations from 2020 JWG Meeting
2.2. Implementation of earlier recommendations on belugas

2.2.1. Recommendations on allowable landings of belugas in West Greenland
2.2.2. Recommendations on seasonal closures and no hunt south of 65 degrees of belugas in WG.
2.2.2.1. NAMMCO-MCC requests evidence that the closures would be sufficient to allow these beluga populations to recover given the increases in ship traffic and habitat decline resulting from climate change.

3. NARWHAL ALLOCATION

3.1. Narwhal movement and abundance
3.1.1. Quantitative SubGroup Meeting Review
3.1.1.1. Review methods and dive data used to analyse and correct aerial surveys
3.1.1.2. Review updated availability matrix to assign harvested animals to individual summer stocks
3.1.1.3. Review abundance estimate from Eclipse Sound and Admiralty Inlet conducted by Golder Associates Ltd.
3.1.1.4. Review updated abundance estimates for allocation model

Tuesday (8:30-17:30 CST):

3.2. Narwhal catch statistics
3.2.1. Update by management units – Canada takes – Watt
– Greenland takes – Garde, Heide-Jørgensen
3.2.2. Review of struck-but-lost and under-reporting corrections – Canada takes – Watt
– Greenland takes – Garde, Heide-Jørgensen
3.3. Review of management model structure for narwhal
3.3.1. Review of allocation model
3.3.2. Review of population model to generate recommendations for narwhal removals
3.3.3. Review of preliminary narwhal management recommendations

Wednesday (8:30-17:30 CST):

3.4. Review of final analysis for narwhal management recommendations
3.5. Implementation of earlier recommendations for narwhal
3.6. Report preparation for narwhal and beluga assessments

Thursday (8:30-17:30 CST):

4. Impacts of Climate Change on narwhal and beluga management

4.1. Narwhal
4.1.1. Baffinland, Mary River Mine and other developments – Marcoux
4.1.1.1. Development of monitoring guidelines

- 4.1.2. Changes in habitat, movements, and distribution
- 4.1.3. Changes in hunting behaviour, location, and seasons
- 4.1.4. Impacts on population dynamics

4.2. Beluga

- 4.2.1. Changes in movement and distribution
- 4.2.2. Changes in hunting behaviour, location, and seasons
- 4.2.3. Impacts on population dynamics

4.3. Review of options for modifying existing assessment methods.
4.4. Identify data requirements for modifications.
4.5. Sensitivity to uncertainty in the population response to climate changes
4.6. Proposed improvements to be implemented in the next assessment.

Friday (8:30-17:30 CST):

5. Other business

5.1. Development of a principle based approach for management of small stocks

6. Workshop outputs

6.1. Report preparation

7. ADJOURN

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APPENDIX 3: LIST OF DOCUMENTS

Working Papers

Doc. No.	Title	Agenda item
JWG/2021/00	Terms of Reference	1.3
JWG/2021/01	Draft Agenda	1.5
JWG/2021/02	Draft List of Participants	1
JWG/2021/03	Draft List of Documents	1.4
JWG/2021/04	Hobbs, R. and Watt, C. (2021). Quantitative Subgroup Meeting Review	3.1.1
JWG/2021/04b	Hobbs, R. and Watt, C. (2021). Quantitative Subgroup Meeting Review – Appendix A	3.1.1
JWG/2021/05	Marcoux, M. (2021). Updated surface and dive time for narwhals equipped with Acousonde tags in Eclipse Sound.	3.1.1.1
JWG/2021/06	Marcoux, M., and Hobbs, R. (2021) Estimating narwhal time at the surface from overlapping photos.	3.1.1.1
JWG/2021/07	Hobbs, R. (2021). Review of availability depth for narwhal and implications for availability corrections.	3.1.1.1
JWG/2021/08	Marcoux, M. and Shuert, C. (2021). Update on the movement of narwhals from Eclipse Sound stock (2016-2018) and an updated availability matrix.	3.1.1.2
JWG/2021/09	Watt, C. et al. (2021). Review of Golder's 2019 narwhal survey in Eclipse Sound and Admiralty Inlet.	3.1.1.3
JWG/2021/10	Watt, C. (2021). Updated survey estimates for Canadian narwhal stocks from the Baffin Bay population.	3.1.1.4
JWG/2021/11	Hansen, R.G., Borchers D.L., and Heide-Jørgensen M.P. (2020). Trends in abundance and distribution of narwhals (*Monodon monoceros*) on the summering grounds in Inglefield Bredning and Melville Bay, Greenland from 2007–2019.	3.1.1.4
~~JWG/2021/12~~	*Moved to For Information*	
~~JWG/2021/13~~	*Moved to For Information*	
JWG/2021/14	Watt, C. and Young, J. (2021). Catch statistics for narwhal in Canada from 1970-2020.	3.2
~~JWG/2021/15~~	*Moved to For Information*	
JWG/2021/16	Witting, L. (2021). Meta-population model for narwhals in East Canada and West Greenland – 2021.	3.3
JWG/2021/17	Hobbs, R., Heide-Jørgensen, M.P., Hansen, R.G. (2021). A principle based approach to setting management objectives for removals of small cetaceans and pinnipeds.	5.1

JWG/2021/18	Chambault, P. (2021). Short-term expansion but long-term habitat loss: how far narwhals should go to avoid warmer waters?	4.1.2
JWG/2021/19	Heide-Jørgensen, M.P., Lage, J. (2021). On the availability bias in narwhal abundance estimates.	3.1.1.1
JWG/2021/20	Heide-Jørgensen, M. P., Chambault, P., Rosing-Asvid, A., Macrander, A., MacKenzie, B., Andresen, C. S. (2021). A regime shift in Southeast Greenland.	4.1.2
JWG/2021/21	Witting, L. (2021). Demographic variation in narwhal population growth.	5.1
JWG/2021/22	Witting, L. (2021). Demographic variation in the assessment of narwhals at Tasiilaq, East Greenland.	5.1
JWG/2021/23	Witting, L. (2021). Demographic variation in the assessment of narwhals at Ittoqqortoormiit, East Greenland.	5.1
JWG/2021/24	Witting, L. (2021). Optimal meta population removals for narwhals in East Canada and West Greenland – 2021.	3.3
JWG/2021/25	Watt, C. and Hudson, J. (2021). Pregnancy rates for narwhal in Canada.	3.3
JWG/2021/25rev	Watt, C. and Hudson, J. (2021). Pregnancy rates for narwhal in Canada. - revised	3.3
JWG/2021/26	Doniol-Valcroze, T. (2021). Distribution of time-in-view data during HACS 2013	3.3
JWG/2021/27	Heide-Jørgensen, M.P. (2021). Updated survey estimates for West Greenland narwhal stocks from the Baffin Bay population with additional variance on the availability bias.	3.1.1.4

For Information Documents

Doc. No.	Title	Agenda item
JWG/2021/FI01	2020 JWG Meeting Report	2.1
JWG/2021/FI02	Garde, E., and Heide-Jørgensen, M.P. (2020). Update on catch statistics for belugas, *Delphinapterus leucas*, in Greenland, 1993–2019.	2
JWG/2021/FI03	Watt, C.A. (2021). Catch statistics for beluga (*Delphinapterus leucas*) harvested from the Eastern High Arctic – Baffin Bay and Cumberland Sound populations from 1977-2020.	2
JWG/2021/FI04	Marcoux, M. Montsion, L.M. Dunn, J.B., Ferguson, S.H., and Matthews, C.J.D. (2020). Estimate of the abundance of the Eclipse Sound narwhal (*Monodon monoceros*) summer stock from the 2016 photographic aerial survey.	2.2
JWG/2021/FI05	Heide-Jørgensen, M.P. (2020) Abundance of narwhals in Inglefield Bredning in 1985 and 1986. *NAMMCO-JCNB JWG/2020/14*	2.2

JWG/2021/FI06	Heide-Jørgensen, M.P. and Hansen, R.G. (2020). Abundance of narwhals and belugas in the eastern part of the North Water in April 2018.	2.2
JWG/2021/FI07	Garde, E. (2020). Female narwhal age at sexual maturity.	3.3
JWG/2021/FI08	Heide-Jørgensen, M.P. & Garde, E. (2017). Catch statistics for belugas in Greenland 1862-2016. Working Paper NAMMCO JCNB/SWG/2017-JWG/06rev	3.2
JWG/2021/FI09	Witting, L. (2020). An assessment model for beluga in the North Water – 2020.	2.1
JWG/2021/FI10	Witting, L. (2020). Assessment of beluga wintering off West Greenland – 2020.	2.2
JWG/2021/FI11	Biddlecombe, B.A. & Watt, C.A. (2021). Incorporating environmental covariates into a Bayesian stock production model to project future abundance for the endangered Cumberland Sound beluga population.	4.3
JWG/2021/FI12	Witting, L. (2021). On selection-regulated population dynamics in birds and mammals.	4.1.4, 4.2.3, 5.1
JWG/2021/FI13	Witting, L. (2002). Evolutionary dynamics of exploited populations selected by density dependent competitive interactions.	4.1.4, 4.2.3, 5.1
JWG/2021/FI14	Heide-Jørgensen, M.P. (2020). Abundance of narwhals in Inglefield Bredning in 2001 and 2002. *NAMMCO-JCNB JWG/2020/18*	3.1.1.4
JWG/2021/FI15	Watt., C., Simonee, J., L'Herault, V., Zhou, R., Ferguson, S., Marcoux, M., Black, S. (2020). Cortisol levels in narwhal (Monodon monoceros) blubber from 2000 to 2019.	4.1
JWG/2021/FI16	Hudson, J., Matthews, C., Watt, C. (2021). Detection of steroid and thyroid hormones in mammalian teeth.	4.1, 4.2
JWG/2021/FI17	NAMMCO (2021). Report of the Ad hoc Working Group on Narwhal in East Greenland.	5.1
JWG/2021/FI18	Tervo, O.M., Hansen, R.G., Borchers, D. and Heide-Jørgensen, M.P. (2020). Preliminary results on estimation of abundance of narwhals (*Monodon monoceros*) using density surface modelling.	3.1.1.4
JWG/2021/FI19	Garde, E. and Heide-Jørgensen, M.P. (2021). Update on catch statistics for narwhal, *Monodon monoceros,* in Greenland, 2005 to 2019.	3.2
JWG/2021/FI20	Garde, E. (2021). New pregnancy rate(s) for narwhals in West Greenland. *NAMMCO SC/28/NEGWG/08*	3.3
JWG/2021/FI21	Chambault, P., Tervo, O. M., Garde, E., Hansen, R. G., Blackwell, S. B., Williams, T. M., ... & Heide-Jørgensen, M. P. (2020). The impact of rising sea temperatures on an Arctic top predator, the narwhal.	4.1.2, 4.2.1