Global Review of the Conservation Status of Monodontid Stocks

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Introduction

The family Monodontidae is comprised of the narwhal, *Monodon monoceros*, and the beluga or white whale, *Delphinapterus leucas* (Rice, 1998). These two species are found in much of the Arctic and in a number of subarctic areas, generally inhabiting more coastal areas during the summer and deeper ice-covered areas in the winter. Both species are sought by indigenous subsistence hunters in several Arctic nations in their summer habitat as well as along migration routes and, in some cases, in wintering areas.

Some populations of the two species were reduced by commercial hunting for oil, meat, and skins and in the case of narwhals, the valuable tusk (Mitchell and Reeves, 1981; Reeves and Heide-Jørgensen, 1994; Heide-Jørgensen, 1994). Belugas in some areas were culled to reduce perceived competition with fisheries (Reeves and Mitchell 1984). More recently, some populations have been reduced (or further reduced) by uncontrolled subsistence hunting (Reeves and Mitchell,

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ABSTRACT—The monodontids—narwhals, Monodon monoceros*, and belugas,* Delphinapterus leucas*—are found in much of the Arctic and in some subarctic areas. They are hunted by indigenous subsistence users. In the past, some populations were substantially reduced by commercial hunting and culling; more recently, some populations have declined due to uncontrolled subsistence hunting and environmental degradation. Monodontids are impacted increasingly by human activities in the Arctic including ship and boat traffic, industrial development, icebreaking, seismic surveys, competition with fisheries, and alteration of habitat due to climate change. Since comprehensive reviews in the 1990's, substantial new information has become available on both species and on changes to their habitat as a result of human activities and climate change. Thus NAMMCO and partners undertook an updated review in 2017. The review recognized 21 extant beluga stocks, 1 extirpated beluga stock, and 12 stocks of narwhals. The available information on each stock regarding population size, depletion level, current and past removals, and trends in abundance was reviewed to determine status. Concern was expressed where the lack of information prevented reliable assessment, removals were thought to be unsustainable, or the population was deemed at risk of declining even without direct removals by hunting. Beluga stocks of greatest concern are the small stocks in Ungava Bay (possibly extirpated), Cook Inlet (ca 300), St. Lawrence Estuary (ca 900), and Cumberland Sound (ca 1,100), and the stocks with uncertainty in Eastern Hudson Bay and the Barents-Kara-Laptev Seas. Narwhal stocks of greatest concern are those in Melville Bay and East Greenland.*

1989; Hammill et al., 2004; Hobbs et al., 2015a) or hit hard by the live-capture industry (primarily for live display in zoos and oceanariums; Shpak et al., 2019). Other sources of impacts on monodontids include the noise from ship and boat traffic, industrial activities of various kinds, icebreaking, seismic surveys, competition with fisheries, and the rapid alteration of habitat as a result of climate change (Finley et al., 1990, Gordon et al., 2004; Laidre et al., 2008, 2015; Reeves et al., 2014; Norman et al., 2015).

The stocks of belugas and narwhals were reviewed by the Scientific Committee of the International Whaling Commission (IWC) in 1992 (IWC, 1993) and more thoroughly (for belugas) in 1999 (IWC, 2000). The North Atlantic Marine Mammal Commission (NAMMCO) Scientific Committee's Working Group on the Population Status of Beluga and Narwhal in the North Atlantic carried out an extensive review of beluga and narwhal stocks in the Atlantic and adjacent waters in 1999 (NAMMCO[1]).

Since 1999, much new information has become available on both species—regarding stock identity, distribution, movements, abundance, anthropogenic removals, and threats to populations. Additionally, new and newly recognized stressors have emerged, and significant changes in climate and habitat have occurred either directly or indirectly owing to increasing human activity in the Arctic as well as global climate change. Thus NAMMCO and various partner organizations and individual scientists unaffiliated with NAMMCO undertook an updated review in 2017 with the following three phases:

1) A steering committee was established with at least one member from each nation with beluga or narwhal stocks. The committee identified subject experts for each stock and requested a written review for each stock or known aggregation. These reviews included the following topics: a) stock identity—description and distribution with supporting genetic studies, telemetry data, catch locations and times, traditional knowledge, etc.; b) abundance—sighting surveys, mark-recapture data, etc.; c) anthropogenic removals by hunting (catch statistics, including struck-but-lost and under-reporting), bycatch or entanglement in fisheries, and other causes; d) population trend—historical and recent rates of decline or increase, current and maximum net reproduction rates; e) management measures to limit removals—e.g., PBR (potential biological removal)—and other methods of determining reference levels to ensure recovery and sustainability; f) habitat and other concerns; and g) national legal status of the stock.
2) The Global Review of Monodontids (GROM) workshop was held 13–16 March 2017 in Hillerød, Denmark, with monodontid experts as well as experts on genetics, environmental issues, stock assessment, and traditional knowledge. The workshop heard presentations on how stocks were defined and designated in previous monodontid reviews and on genetic methods used for stock delineation. The workshop devised an approach to assessment and determined a level of concern that accounted for the quality of information on each stock as well as its conservation status. More than 20 stocks of belugas and 12 stocks of narwhals were identified, reviewed in detail, and assessed.

   Consensus was sought on stock definitions, key points of assessment, and levels of concern. In most cases, the consensus became evident during the discussion and exchange of views among workshop participants. Where revisions or additions to a stock review were requested, the consensus was made contingent on those changes being made by the author(s). In a few cases where concerns remained or objections were made to the information provided or conclusions drawn, the majority opinion of the workshop was followed and a statement describing the concerns or objections was recorded in the discussion section of the workshop report.

   Following the stock by stock assessments, the workshop discussed global and regional issues related to the conservation of belugas and narwhals that had been raised either in the individual stock reviews or during the meeting, identified existing and emerging threats and knowledge gaps, and developed recommendations for research and cooperation.
3) Following the workshop, some of the stock reviews prepared as background information were revised in response to advice from the workshop. In some instances, this included information that was known but did not become available until after the workshop. The final workshop report, along with the revised stock reviews, was made public on the NAMMCO website in 2018 (https://nammco.no/wp-content/uploads/2018/05/report-global-review-of-monodontids-nammco-2018_after-erratum-060518_with-appendices_2.pdf).

In this paper, we summarize the current status of all beluga and narwhal stocks and the major findings and recommendations from the GROM. In a few cases, we incorporate new information that became available after the workshop. It should be noted that while a serious effort was made to provide peer-reviewed citations in support of statements made and conclusions reached, a review such as this one necessarily includes reference to gray literature (footnoted) and occasionally the opinions of subject experts. The

[1]NAMMCO. 1999. Report of the working group on the population status of beluga and narwhal in the North Atlantic. Oslo, 1-3 Mar. 1999. (avail. at http://nammco.wpengine.com/wp-content/uploads/2016/09/SC_7_4-WG-Report-1999.pdf).

Table 1.—Evidence supporting stock discrimination of belugas, *Delphinapterus leucas,* and narwhals, *Monodon monoceros*. Y = available data support stock discrimination; + = available data provide some support for stock discrimination; N = available data do not support stock discrimination or are inconclusive; – = no data are available.

Stocks	Summer distribution	Winter distribution	Movement, behavior, or life history traits	Genetics (mtDNA)
Beluga				
1. Sakhalin-Amur	Y	+	+	Y
2. Ulbansky	Y	–	+	Y
3. Tugursky	Y	–	+	N
4. Udskaya	Y	–	+	Y
5. Shelikhov	Y	+	+	Y
6. Anadyr	Y	Y	Y	Y
7. Cook Inlet	Y	Y	Y	Y
8. Bristol Bay	Y	+	Y	Y
9. Eastern Bering Sea	Y	+	Y	Y
10. Eastern Chukchi Sea	Y	+	Y	Y
11. Eastern Beaufort Sea	Y	+	Y	Y
12. High Arctic – Baffin Bay	Y	+	+	+
13. Western Hudson Bay	Y	+	Y	+
14. James Bay	Y	Y	+	+
15. Eastern Hudson Bay	Y	+	Y	+
16. Ungava Bay	Y	+	+	+
17. Cumberland Sound	Y	Y	Y	+
18. St. Lawrence Estuary	Y	Y	+	Y
19. Southwest Greenland	–	Y	Y	–
20. Svalbard	Y	Y	Y	Y
21. Barents-Kara-Laptev Seas	+	+	–	–
22. White Sea	Y	Y	Y	+
Narwhal				
1. Somerset Island	Y	+	Y	N
2. Jones Sound	Y	+	+	Y
3. Smith Sound	Y	+	+	N
4. Admiralty Inlet	Y	+	+	N
5. Eclipse Sound	Y	+	+	N
6. Inglefield Bredning	Y	+	–	N
7. Melville Bay	Y	+	Y	N
8. Eastern Baffin Island	Y	+	+	N
9. Northern Hudson Bay	Y	Y	Y	Y
10. East Greenland	Y	Y	Y	N
11. Northeast Greenland	Y	–	–	–
12. Svalbard-NW Russian Arctic	–	–	–	–

quality as well as the content of information available to the workshop was considered in seeking to reach a consensus of the expert opinion represented at the GROM workshop.

Identification of Stocks

Various criteria were used to define stocks generally, with emphasis on how beluga and narwhal stocks have been defined in previous reviews and by current management. In general, a stock is a population unit suitable for management and stocks should be designated in such a way that with good management, the species will persist throughout its historical range (IWC, 2000). Largely, stocks are breeding populations that occupy the same regions annually. For monodontids, recurrent aggregations were considered as candidate stocks, with the practical consideration that most hunting operations target these aggregations, and in many cases the migration routes had not been determined (IWC, 2000).

In its 1999 review, the IWC Scientific Committee (IWC-SC) used an essentially ad hoc approach to determine which aggregations should be considered stocks (IWC, 2000). The IWC-SC used a variety of criteria including genetic relationships, distribution and movements, patterns of exploitation, contaminant profiles, expert opinion, and traditional knowledge. A total of 29 putative beluga stocks were identified in that review. It is unclear how the participants balanced or weighted the different types and strengths of evidence, but in many cases the available data were deemed inadequate to delineate stocks with high confidence.

The approach used by the NAMMCO Scientific Committee (NAMMCO-SC) in its review of belugas and narwhals in the North Atlantic and adjacent waters was similarly ad hoc, identifying 25 major "aggregations" of belugas and 17 of narwhals. It was acknowledged that these aggregations (summering, wintering, or migrating areas) could be "discrete, or a mixture of stocks." As a guiding principle, the NAMMCO-SC review group concluded in 1999 that it was "prudent to base putative management units on local aggregations and/or harvesting areas until more information on stock structure is available."

Research on beluga mitochondrial genetics (mtDNA) since the early 1990's has demonstrated matrilineal fidelity to summering areas (Table 1; O'Corry-Crowe et al., 1997, 2002, 2010; De March et al., 2002, 2004; De March and Postma, 2003; Meschersky et al., 2008, 2013). Aerial surveys and satellite tracking studies have made it possible to map the distribution and estimate the abundance of many of these summer aggregations (Table 2). Narwhal summer aggregations have not been distinguished using mtDNA, and there has been only limited success using other methods (Palsbøll et al., 1997; de March and Stern[2]; de March et al.[3]; Petersen et al.[4]; Watt et al.[5]), which may be due to differences in the mating systems of the two species (Kelley et al., 2015). However, in satellite tracking studies of several narwhal stocks, the tracks that continued through the fall and spring migra-

[2]de March, B. G. E., and G. Stern. 2003. Stock separation of narwhal (*Monodon monoceros*) in Canada based on organochlorine contaminants. CSAS Res. Doc. 2003/79 (avail. at http://waves-vagues.dfo-mpo.gc.ca/Library/279332.pdf).

[3]de March, B. G. E., D. A. Tenkula, and L. D. Postma. 2003. Molecular genetics of narwhal (*Monodon monoceros*) from Canada and West Greenland (1982–2001). DFO Can. Sci. Advis. Sec. Res. Doc. 2003/080, 1–19 (avail. at http://waves-vagues.dfo-mpo.gc.ca/Library/279333.pdf).

[4]Petersen, S. D., D. Tenkula, and S. H. Ferguson. 2011. Population genetic structure of narwhal (*Monodon monoceros*). DFO Can. Sci. Advis. Sec. Res. Doc. 2011/021. vi + 20 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/Library/343698.pdf).

[5]Watt, C. A., S. H. Ferguson, A. Fisk, and M. P. Heide-Jørgensen. 2012. Using stable isotope analysis as a tool for narwhal (*Mondon monoceros*) stock delineation. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/057. iv + 29 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/Library/279333.pdf).

Table 2.—Summary of information provided for the status review.

	Stock/Summer Aggregation	Movements (e.g. winter, summer migrations, to/from location)	Abundance (Year) a: availability bias; p: perception bias	Trend	Removals	Threats and/or concerns	National legal status
Belugas							
1	Sakhalin-Amur	Summer in Sakhalinsky Bay and Amur estuary, winter in northern and central Okhotsk Sea (offshore)	3,954 (CV = 0.24) (average for 2009, 2010a, 2010b); corrected for a; Shpak and Glazov (2013)	Unknown	Recently above PBR, current allowable take set close to PBR	Pollution/infectious agents from Amur River, competition with fisheries, ship traffic, noise	None
2	Ulbansky	Summer in Ulbansky Bay and river estuaries, winter movements unknown but presumably similar to Sakhalin-Amur	2,334 (from direct count, corrected for a) (2010);Shpak and Glazov (2013)	Unknown	No direct removals	Fishery interactions, potential pollution risk from mining activities	None
3	Tugursky	Summer in Tugursky Bay, winter movements unknown but presumably, similar to Sakhalin-Amur	1,506 (from direct count, corrected for a) (2010); Shpak and Glazov (2013)	Unknown	No direct removals	Fisheries, mining activities/pollution, discharge of human and livestock waste	None
4	Udskaya	Summer in Udskaya Bay and river estuaries, found along south coast at ice formation, winter in areas unknown but presumably similar to Sakhalin-Amur	2,464 (from direct count, corrected for a) (2010); Shpak and Glazov (2013)	Unknown	No direct removals	Fisheries, mining activities/pollution, discharge of human and livestock waste, ship traffic/noise, leaks during diesel fuel transit	None
5	Shelikhov	Summer in Gizhiginskaya and Penzhinskaya bays of Shelikhov Bay in river estuaries and along west coast of Kamchatka Peninsula, presumably winter along ice edge in Shelikhov Bay and along Kamchatka	2,666 (from direct count, corrected for a) (2010); Shpak and Glazov (2013)	Unknown	No direct removals	Decreasing sea ice, future development in the area	None
6	Anadyr	Summer and autumn in Anadyr estuary, winter in western Bering Sea	Unknown but expert opinion indicates ca. 3,000 (Litovka, 2002)	Unknown but expert opinion that it is stable	Small numbers harvested	Competition from fisheries, ship traffic, reduced sea ice	None
7	Cook Inlet	Summer in river mouths in upper inlet, likely remain in upper inlet year-round (range reduction from historical)	279 (CV = 0.06) (2018); corrected for a and p; Shelden and Wade (text fn 22)	Declining	Reduced to 1-2/yr in 2000, prohibited since 2005	Very small numbers, decreasing trend, cumulative impacts (of competition from fisheries, industrial development, ship traffic, climate change, sewage discharge, etc.)	U.S. ESA “Endangered” (2008)
8	Bristol Bay	Summer in Nushagak and Kvichak bays and tributaries, winter in northern and eastern Bristol Bay	Aerial survey: 2,040 (CV=0.22, 95% CI: 1,541-2,702) (2016); corrected for a; genetic mark-recapture: 1,928 (95% CI: 1,611–2,337); Citta et al. (2019)	Stable	~ 20-25/yr, stable in recent years, below PBR	Climate warming, loss of sea ice, competition from large fishery for salmon, development plans (gold, Pebble Mine)	None
9	Eastern Bering Sea	Summer in Norton Sound and in or near the Yukon River delta; winter south in eastern Bering Sea to Bristol Bay	9,242 (CV = 0.12) (2017); corrected for a; Lowry et al. (2019)	Unknown	Average 190/yr landed w/ struck-but-lost , 215/yr, above PBR of 201 and under-reporting is not estimated.	Fisheries (competition, not bycatch), declining populations of salmon	None
10	Eastern Chukchi Sea	Summer in Beaufort Sea and Arctic Ocean to as far north as lat. 81° N, particularly along the shelf break; fall/winter move south to Bering Sea; winter between St. Lawrence Island, U.S., and Chukotka Peninsula, Russia	20,675 (CV = 0.66) (2012); corrected for a and p; Lowry et al. (2017a)	Unknown	Ca. 50/yr, below PBR	Ship traffic, oil and gas development, sea ice changes	None
11	Eastern Beaufort Sea	Summer in Beaufort Sea, winter in Bering Sea	39,258 (1992); corrected for a; Duval 1993	Unknown	Ca. 166/yr, below PBR	Summer tourism, ship traffic, ecosystem changes (climate change)	Canada: “Not at Risk” (COSEWIC, 2015)
12	High Arctic-Baffin Bay	Summer in estuaries, inlets, and small bays along and around Somerset Island in Canadian Arctic Archipelago; late summer/fall and spring migration through Lancaster Sound; some overwinter in North Water polynya, some off West Greenland	21,213 (95% CI 10,985–32,619) (1996); corrected for a,p; Innes et al. (2002)	Likely stable (but old abundance estimate); relative abundance in West Greenland is increasing	Ca. 400/yr (Canada + Greenland), considered sustainable	Loss of sea ice, ship traffic and icebreaking	Canada: “Special Concern” (COSEWIC, 2004)

Table Continued

Table 2.—*Continued.*

	Stock/Summer Aggregation	Movements (e.g. winter, summer migrations, to/from location)	Abundance (Year) a: availability bias; p: perception bias	Trend	Removals	Threats and/or concerns	National legal status
13	Western Hudson Bay	Summer concentrations in Seal, Churchill, and Nelson River estuaries, found along entire WHB coast; winter in Hudson Strait (overlap with Eastern Hudson Bay stock)	54,473 (CV = 0.098; CI: 44,988–65,957) (2015); corrected for a; Matthews et al. (2017)	Stable	Average 503/yr, below PBR	Icebreaking in Hudson Strait	None
14	James Bay	Remain in James Bay year-round	10,615 (CV = 0.25) (2015); corrected for a; Gosselin et al. (text fn 34)	Unknown; possibly increasing, uncertainty regarding abundance estimates	Limited (ca. 10/yr)	Hydroelectric development	None
15	Eastern Hudson Bay	Summer in eastern Hudson Bay, winter in Hudson Strait and Labrador Sea (overlap with Western Hudson Bay stock)	Aerial survey: 3,819 (CV=0.43) (2015) corrected for a; Gosselin et al. (text fn 34). Modeling: 3,443 (95% CI: 2014-5471) (2016); Hammill et al. (2017)	Stable	Ca. 63/yr	Uncertainties around abundance estimates, stock structure (and stock identity of removals), habitat issues (ship traffic, icebreaking, hydroelectric development)	Assessed as “Endangered” (COSEWIC, 2004) but not legally listed
16	Ungava Bay	Previous summer aggregation in S. Ungava Bay, winter unknown	Modeling: 32 (95% CI: 0-94) (2008); Doniol-Valcroze and Hammill (text fn 39)	Unknown; possibly extirpated	Previous removals	Possibly extirpated	Assessed as “Endangered” (COSEWIC, 2004) but not legally listed
17	Cumberland Sound	Remain within Cumberland Sound, concentrate in Clearwater Fiord in summer	1,151 (CV = 0.214, 95% CI: 761–1744) (2014); corrected for a; Marcoux et al. (text fn 42)	Declining	Removals higher than PBR	Hunting removals, ecosystem changes (diet shift), stress (possibly due to anthropogenic noise, cumulative impacts)	“Threatened” (COSEWIC, 2004; SARA, 2017)
18	St. Lawrence Estuary	Limited to northwestern Gulf of St. Lawrence and estuary (reduced from historical range)	Modeling: 889 (95% CI: 672–1167) (2012); Mosnier et al. (2015)	Declining (-1%/yr)	No direct removals since 1979	Vessel traffic, disturbance (whale-watching), contaminants, environmental changes	“Endangered” (COSEWIC, 2014; SARA, 2016)
19	Southwest Greenland	N/A	Extinct	N/A	Likely driven to extinction by overharvest	Extinct	None
20	Svalbard	Coastal around Svalbard in summer, further offshore in winter	Unknown	Unknown	No direct removals	Changes in sea ice, pollution, development	Protected since 1960s
21	Barents-Kara-Laptev Seas	Summer in waters of archipelagos (Franz Josef Land), in estuaries of large rivers, along mainland coast; movements unknown; very few observations in winter, mostly in Kara Sea	Unknown (widespread in low density), probably depleted by commercial whaling	Unknown	None since ca. 1990	Uncertainty around stock structure (likely several stocks), may have been greatly overexploited in the past, considerable new development and ship traffic, military activity	None
22	White Sea	Summer aggregations mostly in 3 large bays, late summer distribution more scattered in and near White Sea; winter in White Sea, mostly in central part (limited data)	5,593 (CV = 0.135) (2011); not corrected for a; (Solovyev et al., 2015)	Likely stable	Total allowable take 50, removals limited to live-captures (several whales, not every year)	Uncertainty around stock structure (could be several stocks), habitat issues (major shipping route through White Sea, pollution from oil storage and tankers, river discharge from northern Dvina River)	None
Narwhals							
1	Somerset Island	Summer around Somerset Island, distributed more widely in late summer (follow ice as it breaks up), fall migration into central Baffin Bay for overwintering	49,768 (CV = 0.20) (2013); corrected for a and p; Doniol-Valcroze et al. (text fn 65)	Possibly increasing	Considerable numbers (Canada and Greenland) but considered sustainable	Loss of sea ice, icebreaking, and development in some areas	“Special Concern” (COSEWIC, 2004) but not legally listed
2	Jones Sound	Summer in Jones Sound, wintering area unknown	12,694 (CV = 0.33) (2013); corrected for a and p; Doniol-Valcroze et al. (text fn 65)	Unknown	Low numbers, considered sustainable	Icebreaking, loss of sea ice, potential development	“Special Concern” (COSEWIC, 2004) but not legally listed
3	Smith Sound	Summer in Smith Sound, wintering area unknown	16,360 (CV = 0.65) (2013); corrected for a and p; Doniol-Valcroze et al. (text fn 65)	Unknown	Few (if any)	Icebreaking, loss of sea ice, potential development	“Special Concern” (COSEWIC, 2004) but not legally listed

Table Continued

Table 2.—*Continued*.

	Stock/Summer Aggregation	Movements (e.g. winter, summer migrations, to/from location)	Abundance (Year) a: availability bias; p: perception bias	Trend	Removals	Threats and/or concerns	National legal status
4	Admiralty Inlet	Summer in Admiralty Inlet, winter in Baffin Bay	35,043 (CV = 0.42) (2013); corrected for a and p; Doniol-Valcroze et al. (text fn 65)	Stable	Considerable numbers (Canada and Greenland) but considered sustainable	Ship traffic, icebreaking	"Special Concern" (COSEWIC, 2004) but not legally listed
5	Eclipse Sound	Summer in Eclipse Sound, winter in central Baffin Bay	10,489 (CV = 0.24) (2013) corrected for a and p; Doniol-Valcroze et al. (text fn 65)	Unknown	Considerable numbers in Pond Inlet (Canada) and other areas along migration route	Uncertainty about abundance estimates and stock identify (vs Admiralty Inlet stock); ship traffic, particularly related to the Baffinland-Mary River iron mine; tourism	"Special Concern" (COSEWIC, 2004) but not legally listed
6	Inglefield Bredning	Summer in Inglefield Bredning, wintering area unknown but narwhals seen in the North Water polynya in winter may be from this stock	8,368 (CV = 0.25, CI: 5,209–13,422) (2007); corrected for a and p; Heide-Jørgensen et al. (2010).	Stable	Considerable numbers (Greenland) but considered sustainable	Loss of sea ice, seismic surveys (in parts of non-summer range), ship traffic, icebreaking, increased halibut fishing in summering area (competition for prey)	"Special Concern" (COSEWIC, 2004) but not legally listed
7	Melville Bay	Summer in Melville Bay, winter in central Baffin Bay	3,091 (CV = 0.50; 95% CI 1,228 to 7,783) (2014); corrected for a and p; Hansen et al. (text fn 72)	Stable	Above quota advice	Overharvested, seismic surveys, icebreaking (winter), halibut fishing	None
8	Eastern Baffin Island	Summer in fjords along eastern Baffin Island, wintering area(s) unknown but assumed to be in Baffin Bay	17,555 (CV = 0.35) (2013); corrected for a and p; Doniol-Valcroze et al. (text fn 65)	Stable?	Hunted by various communities, increasing since 1970s but still considered sustainable	Uncertainty around abundance estimates, stock structure (could be several stocks), and movements; habitat loss related to climate change, icebreaking	"Special Concern" (COSEWIC, 2004) but not legally listed
9	Northern Hudson Bay	Summer in northwestern Hudson Bay, winter in eastern Hudson Strait	12,485 (CV = 0.26) (2011); corrected for a and p; Asselin et al. (text fn 74)	Stable?	Ca: 83/yr, likely sustainable	Loss of sea ice, proposed development in area, ship traffic	"Special Concern" (COSEWIC, 2004) but not legally listed
10	East Greenland	Summer in Scoresby Sound, Tasiilaq Fjord, and Kangerlussuaq Fjord, elsewhere in fall/winter, smaller wintering range than that of Baffin Bay narwhals	702 (CV = 0.33) (2016); NAMMCO (text fn 78)	Declining	Recently overharvested, advice for reduction in quotas	Recent overharvest; climate change—warmer temperatures, loss of sea ice and tidewater glaciers may mean loss of habitat; new species in area—may mean competition for prey, exposure to novel diseases	None
11	Northeast Greenland	No information	1,395 narwhals (CV=0.33) in Dove Bay (2017) and 2,908 (CV=0.30) in the Greenland Sea (2017) (Reeves and Lee, 2020)	Unknown	None	Loss of sea ice and tidewater glaciers may mean loss of habitat; new species in the area may mean competition for prey, exposure to novel diseases; future development	None
12	Svalbard-Northwest Russian Arctic	Unknown	Unknown through most of the range; 837 (CV=0.50) (2015) north of Svalbard (Vacquié-Garcia et al., 2017)	Unknown	None	Lack of data (abundance, movements, etc.), climate change, development, military activity	Protected in Norway and Russia

tions showed the animals returning to the aggregation of origin in most cases (Heide-Jørgensen et al., 2003a; Dietz et al., 2008; Westdal et al., 2010; Watt et al.[6]), and this supports the assumption that narwhals are similar to belugas in exhibiting fidelity to summering areas.

For many of the summer aggregations of both narwhals and belugas, migration routes have been determined and therefore individuals seen in other locations and seasons can be related back to one or more of the summer aggregations. As with belugas, most of the known summer aggregations of narwhals have been surveyed at least once since the last global or large-scale review. Thus, the GROM chose to consider recurrent summer aggregations of belugas or narwhals as potential stocks and then considered other data and lines of reasoning to determine which aggregations should be considered as separate stocks and which should be lumped together as a single stock (Table 1). It may prove necessary to change the lists of stocks in future reviews as more information becomes available.

Other Aggregations and Sightings

Reports of regular aggregations in other seasons were generally related to one or more of the known summer aggregations by reference to movement or genetics data, and thus they were not considered separate stocks. Also, small numbers of both species have been observed outside what is considered the normal range of any recognized stock or population. In areas where reliable observers have frequently been present, the occasional sightings of individuals or only a few monodontids were regarded as extralimital and not particularly significant as they were not seen to represent recurrent aggregations. It was noted, however, that if observations were to become regular in one of these areas, this could signify actual shifts or expansions in the species' distribution. Areas rarely visited by humans, where observation effort was insufficient to document recurrent aggregations but some sightings have been reported, were sometimes considered as potentially part of the seasonal distribution of a stock.

Stocks

The GROM identified 21 stocks of belugas and 12 stocks of narwhals (Table 1). Summer distribution as determined by local knowledge, tagging studies, and aerial surveys was considered sufficient, in most cases, to determine geographical separation of stocks (Fig. 1, 2; Table 1). In some areas where potential beluga stocks were in close proximity, the results of mtDNA analyses were used to decide whether they should be lumped or split. Potential narwhal stocks could not be separated using differences in mtDNA, making it necessary to rely principally on tracking data when potential stocks were in close proximity. The GROM generally followed what was regarded as a conservative (i.e., risk-averse) approach (from a conservation perspective) and chose to split such stocks.

Previous global reviews that focused on, or included, monodontids (IWC, 1993, 2000; Laidre et al., 2015; CAFF, 2017) recognized different numbers of stocks. To clarify and justify differences between the 21 stocks of belugas and 12 stocks of narwhals identified in this review, an attempt was made to explain the rationale for lumping or splitting previously recognized stocks (Table 3). Rapid environmental change in the Arctic and sub-Arctic may influence the distributions and movements of all monodontid stocks, which means that it will be important to reevaluate some of the conclusions and assumptions regarding stock identity made in this and previous reports during future reviews.

Summaries of Individual Stocks

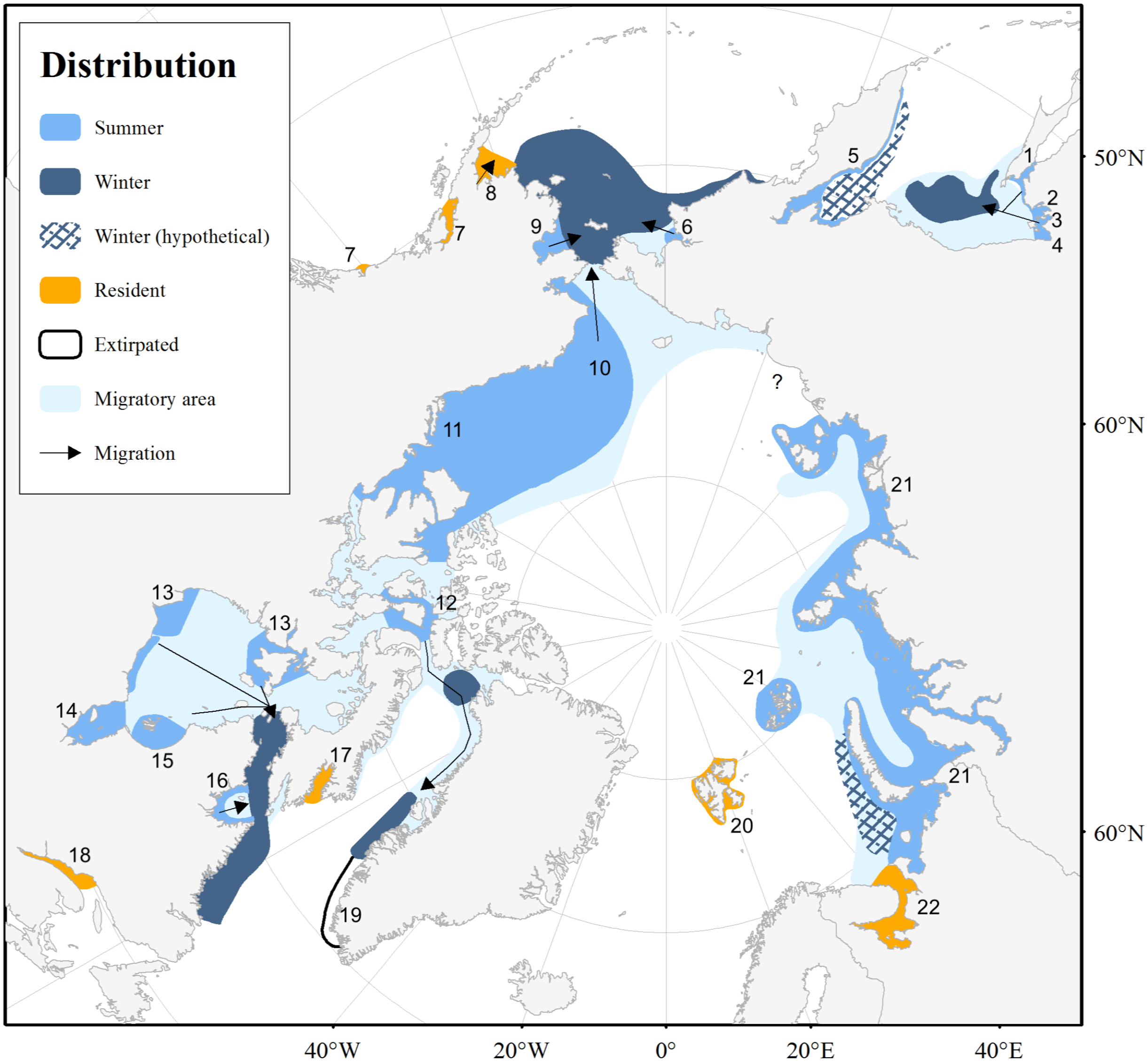
The summaries provided by researchers for each stock included a description of the stock, research used to determine distribution, abundance, and trend, data on removals and other sources of mortality, information on management, assessment of the "sustainability" of any hunting removals, a discussion of other threats to the stock, or an indication that the requested information was not available. During the workshop, we considered several questions including: 1) how well was the stock's distribution known; 2) was abundance estimated; 3) was the trend estimated; 4) were removals documented; 5) was the stock depleted; 6) were the known removals sustainable and if the stock was depleted, were removals low enough to allow recovery; and 7) what other threats were known for the stock and what was their impact?

Distribution, Abundance, and Trends

Distribution and abundance for most stocks were known from aerial surveys of the summer ranges (Table 2). In a few cases, when no survey data were available, expert opinion or traditional knowledge was taken into account. Estimates of abundance provided in the stock summaries were not reviewed and discussed in detail except where unusual methods were used; questions were raised concerning completeness of coverage, precision, or methods of correction for missed animals; or a basis was needed for evaluating expert opinion or traditional knowledge. Where two or more abundance estimates were available for a stock, a crude assessment of trend was sometimes possible, while recognizing that three or more comparable estimates are generally needed for confident conclusions concerning trends.

When survey data were used to estimate trend, the workshop considered whether the survey methods and coverage were comparable. It was emphasized that abundance estimates based on surveys (rather than solely on ex-

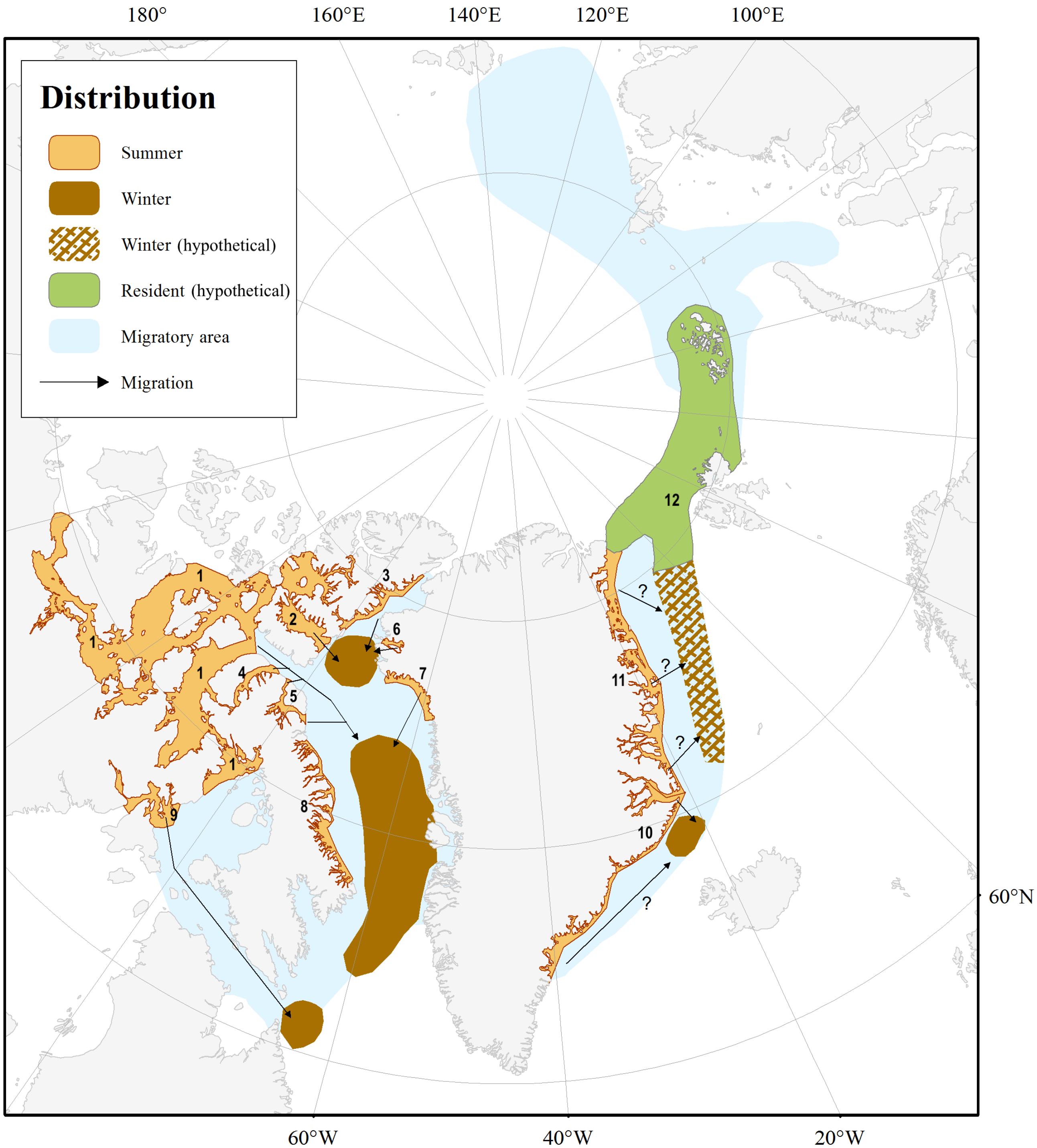
[6]Watt, C. A., J. Orr, B. LeBlanc, P. Richard, and S. H. Ferguson. 2012. Satellite tracking of narwhals (*Monodon monoceros*) from Admiralty Inlet (2009) and Eclipse Sound (2010–2011). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/046. iii + 17 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/Library/347232.pdf).



Beluga Stocks

Pacific Arctic/sub-Arctic	*Atlantic Arctic/sub-Arctic*
1) Sakhalin-Amur	12) Eastern High Arctic-Baffin Bay
2) Ulbansky	13) Western Hudson Bay
3) Tugursky	14) James Bay
4) Udskaya	15) Eastern Hudson Bay
5) Shelikhov	16) Ungava Bay
6) Anadyr	17) Cumberland Sound
7) Cook Inlet	18) St. Lawrence Estuary
8) Bristol Bay	19) Southwest Greenland
9) Eastern Bering Sea	20) Svalbard
10) Eastern Chukchi Sea	21) Barents-Kara-Laptev Seas
11) Eastern Beaufort Sea	22) White Sea

Figure 1.—Beluga stocks recognized by the Global Review of Monodontids. Stocks are identified by their summering grounds. Ranges of stocks that migrate are differentiated into summer areas (mid-blue), migration areas (light blue), and known winter grounds (dark blue) or hypothetical winter grounds (dark blue check); arrows show direction of fall migration. Ranges of stocks residing year-round in the same area are orange. Winter areas are not shown for the belugas in the Kara and Laptev Seas due to lack of information.



Narwhal Stocks

1) Somerset Island	4) Admiralty Inlet	7) Melville Bay	10) East Greenland
2) Jones Sound	5) Eclipse Sound	8) Eastern Baffin Island	11) Northeast Greenland
3) Smith Sound	6) Inglefield Bredning	9) Northern Hudson Bay	12) Svalbard-NW Russian Arctic

Figure 2.—Narwhal stocks recognized by the Global Review of Monodontids. Stocks are identified by their summering grounds. Ranges of stocks are differentiated into summer areas (tan), migration areas (light blue), and known winter grounds (brown) or assumed winter grounds (brown check), arrows show direction of fall migration.

Table 3.—Status of beluga and narwhal stocks. The global review took into account population size and trend, quality of data available, sustainability of removals, and habitat concerns. Trend symbols are n/a = not applicable, ↘ = declining, ↔ = stable, ↗ = increasing, ↗ ↔ = increasing or stable, ? = unknown, and ? along with a trend symbol = uncertainty in the trend. The statuses (i.e., levels of concern) are comparative to other beluga stocks and narwhal stocks, respectively, and are listed as 1 = highest concern, 2 = moderate concern, 3 = lowest concern. More information on abundance, stock identity, etc. can be found in Table 2.

Stock/location	Trend	Status	Comments on status
Beluga			
Southwest Greenland	n/a	Extinct	Likely driven to extinction more than 80 years ago
Ungava Bay	?	1	Possibly extirpated
Cook Inlet	↘	1	Very small stock (ca 300), decreasing trend, multiple known or potential threats, cumulative impacts
St. Lawrence Estuary	↘	1	Small stock (ca 900), decreasing trend, multiple known or potential threats, cumulative impacts
Cumberland Sound	↘	1	Small stock (ca 1,100), likely decreasing trend, likely overharvest
Eastern Hudson Bay		1/2[1]	Uncertainty concerning abundance, stock structure, and sustainability of removals; habitat concerns (icebreaking, hydroelectric dam)
Barents-Kara-Laptev Seas	?	1/2[1]	Data deficient (unknown size, trend, stock structure, likely several stocks), high past removals, rapidly changing habitat
Svalbard	?	2	Data deficient (unknown size and trend) but protected
Sakhalin-Amur	?	2	Unknown trend in abundance, recent removals (live-capture) exceed PBR, habitat concerns (large and increasing fisheries, pollution)
Ulbansky	?	2	Unknown trend, no direct removals, some concerns about fishing and potential pollution from mine development
Tugursky	?	2	Unknown trend in abundance, low numbers of removals, habitat concerns (fishing and pollution)
Udskaya	?	2	Unknown trend in abundance, low numbers of removals, habitat concerns (fishing, ship traffic, pollution)
Anadyr Gulf	↔	2	Data deficient (uncertain abundance, appears stable based on expert opinion), concerns over ship traffic
White Sea	↔	2	Data deficient (uncertainty around stock structure, could be several stocks), low numbers of removals (live-capture), habitat concerns (ship traffic, pollution)
Eastern Bering Sea	?	2	Outdated abundance estimate (from 2000), harvest exceeds PBR and may be underestimated due to limited struck-but-lost reporting and possible non-reporting of takes
Shelikhov	?	3	Unknown trend in abundance, zero to low numbers of removals, some concerns about fishing and habitat loss due to climate change
Bristol Bay	↗ ↔	3	Although not a large stock, it is data-rich (reliable abundance estimates, likely stable or increasing, reliable data on sustainability of removals, etc.)
James Bay	?	3	
Eastern Chukchi Sea	?	3	Large stock with relatively low harvest level
Eastern High Arctic-Baffin Bay	↔	3	
Eastern Beaufort Sea	?	3	
Western Hudson Bay	↔	3	May be several stocks but less of a concern because of high abundance
Narwhal			
Melville Bay	↔	1	Small stock, overharvest
East Greenland	↘	1	Low abundance, data deficient, possibly several stocks, overharvest, climate change-related habitat concerns
Eastern Baffin Island	↔?	2	Data deficient (stock structure, movements), low removals but likely several stocks
Eclipse Sound	?	2	May be part of Admiralty Inlet stock, concerns about icebreaking/shipping related to mining projects
Svalbard / NW Russian Arctic	?	2	Data deficient (abundance, stock structure), likely several stocks, protected
Northeast Greenland	?	2	Data deficient (abundance, stock structure), likely several stocks, climate change related concerns, protected
Inglefield Bredning	↔	3	Small-medium sized stock with low removals, general habitat concerns related to climate change, future development
Jones Sound	?	3	Medium sized stock with low removals, general habitat concerns related to climate change, future development
Smith Sound	?	3	Medium sized stock with few or no removals, general habitat concerns related to climate change, future development
Northern Hudson Bay	↔	3	Medium sized stock, removals sustainable but concerns regarding climate warming and loss of sea ice and increasing human activity (mining, shipping)
Admiralty Inlet	↔	3	Large stock, stable trend, may be connected to Eclipse Sound stock, sustainable removals, some concerns regarding icebreaking/shipping
Somerset Island	↗?	3	Large stock, likely increasing, removals sustainable, general habitat concerns related to climate change, future development

[1]Participants were unable to reach consensus. See Eastern Hudson Bay and Barents-Kara-Laptev Seas for discussions.

pert opinion or traditional knowledge) are required to determine status whenever the monodontid stock is exploited directly or there are concerns over other threats (known or plausible) to the population. Timeliness of an abundance estimate was also considered when determining status—estimates based on survey data within the last 5 years were preferred. Older estimates, while useful, left greater uncertainty concerning the current size of the stock

History of Removals

Removals by hunting, live-captures for display or research, and in some cases other human causes of mortality/removal were documented (Table 2). In a few stocks with long monitoring or management histories, the record of removals extended back for 20 or more years and included estimates of the number of animals struck-but-lost and of unreported takes. In a few stocks, little or no information on numbers or types of removals was available, and it was necessary to rely on the opinion of subject experts.

Sustainability of Removals

An important consideration to determine the status of a stock and hence to manage its conservation is the likelihood that rates of anthropogenic removals (e.g., by hunting, live-capture, or entanglement in fishing gear) are sustainable. The workshop did not develop a formal definition of sustainability but used a working definition that sustainable removals would not cause the stock to decline. For stocks that were thought to be depleted, the workshop also considered whether the takes were low enough to allow recovery but did not include this in the determination of sustainability.

The GROM acknowledged that a number of approaches have been used to assess sustainability and noted that all of the approaches used to date depend on knowing something about annual removals (preferably an estimate with associated uncertainty, or at least an upper bound), abundance (preferably an estimate with associated uncertainty, or at least a lower bound), and some understanding of how much the population would grow if there were no removals. Other information that is available, such as a series of abundance estimates or an estimate of trend, estimates of struck-but-lost and under-reporting of removals, age and sex structure of the removals, and the history of previous removals can be used to improve the assessment.

Risk tolerance on the part of management, i.e., the willingness to accept given levels of probability that removals are sustainable, often varies according to the type of removals being considered, as well as the information that is available. For example, management bodies may be willing to accept a higher level of risk (to the animal population) when the removals are part of a well-managed and well-documented subsistence harvest that will be evaluated every few years than when they are incidental to commercial fishing or industrial development where removals (and sub-lethal impacts) are not well-documented.

Common scientific approaches to assessment of sustainability include both a definition of sustainability and a level of risk tolerance. The two methods used in most of the stock reviews provided to the GROM were risk assessment modeling, in which risk levels are estimated directly for different levels of removals, and Potential Biological Removal (PBR) (Wade, 1998), which sets a threshold number of removals below which there is little concern (details below). The modeling approach requires more biological data whereas the PBR approach is useful for data-poor situations. Both methods use recent abundance estimates and estimated removal levels and can account for changes in distribution and seasonal movements. Local knowledge has value as both a historical record and a source of current observations of population trends. Local knowledge and feedback from hunters are often the first description of a stock and the first indication that its behavior (including trends in abundance) or habitat has changed.

Risk assessment modeling, as applied to monodontid stocks in Greenland and some stocks in Canada (Witting et al., 2019), uses a series of abundance estimates and history of removals in a Bayesian framework to estimate the depletion level and the probability that the population will not decline at various levels of removals over five years. This information is provided to managers who can then consider risk tolerance and recovery goals in setting allowable take levels.

PBR was developed in the United States to provide a risk-averse method of assessing a stock with limited information (a recent estimate of abundance and an estimate of removals: Wade, 1998). The assessment provides guidance for managing removals to assure sustainability and, if necessary, recovery of the stock to some desired or "safe" level ("optimum sustainable population" under U.S. law). The PBR, as defined in the U.S. Marine Mammal Protection Act, is calculated as,

$$PBR = N_{min} * 0.5 * R_{max} * F_R,$$

where N_{min} is a conservative estimate of population size, R_{max} is the maximum potential rate of population increase (unknown for monodontids and assumed to be 0.04, the default for cetaceans), and F_R is a recovery factor that varies between 0.1 and 1.0 depending on the stock's conservation status—e.g., from severely depleted (0.1) to recovered and not at risk (1.0). When an abundance estimate (N) with a coefficient of variation (CV) is available, N_{min} is calculated using the 20th-percentile (z = -0.842) of the lognormal distribution as,

$$N_{min} = N\text{*}\exp(-0.842\text{*}[\ln(1+\mathrm{CV}(N)^2)]^{1/2}).$$

In the formula above, N_{min} is calculated from the abundance estimate. However, in cases where only direct counts or estimates derived from surface density without correcting for submerged animals are available, these may be used directly. Many of the stock summaries provided as background to the GROM included PBR calculations as guidance to managers and as a precautionary way of assessing the sustainability of removals by hunting. It is important to bear in mind, however, that the PBR formula uses a relatively simplistic approach and was originally developed specifically to provide guidance for managing marine mammal bycatch in commercial fisheries. The PBR level for a given stock is set to be precautionary (risk-averse) and to allow the stock to return to, or to stay at or above, its optimum sustainable population size. The emphasis is on recovery of depleted stocks and prevention of significant declines of healthy stocks. Thus, the PBR value is not an estimate of the maximum number of individuals that can be taken sustainably each year, but rather it is seen as a "safe" limit—i.e., as long as removals are below the PBR, they should be sustainable and not deplete the stock.

In a few of the stock summaries, a PBR calculation was provided using data that were outdated (e.g., an abundance estimate from data older than 5 years) and/or the known or estimated removals exceeded the PBR level. In such cases, when no other analysis was provided, the workshop relied on other types data to make a non-rigorous assessment of sustainability, making sure to document the deliberations in the GROM final report.

Scales of "Concern"

For each of the stocks, the workshop assigned a level of "concern" relative to other stocks within the species and between the two species. The scale was 1) most concern, 2) moderate concern, and 3) least concern; notes are provided in Table 3 and in the stock summaries to explain the basis for these assignments of concern level. The higher levels of concern resulted from a lack of confidence that removal levels are sustainable, the possibility that environmental or habitat issues are affecting the stock, or a general lack of reliable information about the stock.

Belugas

Belugas have a discontinuous circumpolar distribution throughout the Arctic and sub-Arctic (Fig. 1). They usually exhibit some level of site fidelity, returning to and inhabiting the same summer and winter areas year after year (Caron et al., 1990; Brennin et al., 1997; Brown Gladden et al., 1997; De March et al., 2004). Most belugas are migratory, moving seasonally between separate summer and winter areas. However, some smaller populations do not undertake long-distance migrations and reside year-round in specific regions using summer and winter areas that overlap (e.g., Cook Inlet, Cumberland Sound, St. Lawrence Estuary).

The IUCN Red List classifies the beluga at the species level as Least Concern (Lowry et al.[7]); however, the rationale within the assessment documentation notes that some subpopulations (i.e., stocks) warrant separate assessment. One such subpopulation in Cook Inlet is already red-listed as Critically Endangered (Lowry et al.[8]).

As noted above, belugas are occasionally sighted outside of the recognized stock areas. There are occasional reports of sightings and catches of belugas in East Greenland, usually in the vicinity of Tasiilaq. The few individuals that occur in East Greenland are thought to belong to the population around Svalbard, the nearest stock geographically, and may represent an extension of the range of that stock.

Similarly, belugas (usually lone individuals) are known to wander into waters of the eastern United States (as far south as New Jersey) (Reeves and Katona, 1980; Cervenka[9]) and into European waters to as far south as northeastern England and the Baltic Sea (Sea Watch Foundation[10]). The GROM recognized 21 extant stocks, plus one stock, Southwest Greenland, that is known to be extirpated (Table 1). The beluga stocks recognized at the workshop as well as a comparison with the stocks listed in previous reviews are presented in Table 4.

Overview of Beluga Stocks

Many of the beluga stock designations in the 1999 IWC review (IWC, 2000) have been supported by research since 1999 on genetics, movements, and summer distribution, and they remain unchanged (Table 4). The designations were changed in a few areas. Belugas in the Okhotsk Sea have received considerable attention in the last decade, with much of the research effort directed toward determining sustainable levels of removals from the Sakhalin-Amur River area for live display (Shpak and Glazov, 2013). Research has included aerial surveys to determine distribution and abundance, biopsy sampling for genetic analysis, and capture and temporary restraint for health assessment and satellite tag attachment.

The results to date support the continued designation of Sakhalin-Amur River and Shelikhov Bay stocks (IWC, 2000). However, the former Shantar Bay stock (IWC, 2000) was split into three stocks based on the observed geographical separation of belugas during the summer in Ulbansky Bay, Tugursky Bay, and Udskaya Bay. This separation was partially supported by mtDNA analyses (Table 4).

The former Beaufort Sea stock (IWC, 2000) was changed to eastern Beaufort Sea stock in recognition that the belugas in the western Beaufort Sea during the summer belong to the eastern Chukchi Sea stock (Hauser et al., 2014). The 1999 IWC review had designated a West Chukchi Sea-Eastern East Siberian Sea stock, but the GROM reviewed the supporting data and concluded that the seasonal presence of belugas in that region was consistent with the migration patterns of the eastern Beaufort Sea and eastern Chukchi Sea stocks.

In the Atlantic Arctic, the Frobisher Bay and South Hudson Bay stocks (IWC, 2000) were subsumed into the western Hudson Bay stock based on the results of movement, distribution, and genetic studies. Tagging studies (Yurkowski et al., 2019) and the genetic profiles of hunted animals (De March and Postma, 2003) both showed that Frobisher Bay is the extreme eastern end of the winter migration of belugas that summer in western Hudson Bay.

The 1999 IWC review recognized four stocks of belugas in the western Russian Arctic based on very limited information. These were Franz Josef Land, Ob Gulf, Yenisey Gulf, and Southwest Laptev Sea (IWC, 2000). These designations were based on limited reports of aggregations and the considerable distances between the known aggregation areas. However, the GROM found little new information on the movements and distributions of these belugas, and the available data on mtDNA lineages, occurrence, and distribution did not support separation of these stocks (Meschersky et al., 2018). The workshop concluded that the available data were insufficient to justify more than one stock, and instead it designated a single stock in the Barents-Kara-Laptev Seas.

Similarly, the three formerly recognized stocks in the White Sea—Onezhsky Bay, Mezhenskyi Bay, and Dvinsky Bay (IWC, 2000)—were combined into a single White Sea stock. While the summer aggregations (at least five, in addition to those mentioned above) in the White Sea are well documented, they are not far apart and there are few data to suggest genetic or behavioral separation.

Western Okhotsk Sea Belugas

Belugas in the western Okhotsk Sea were previously thought to consist of two stocks (reproductively isolated units or biological populations): Sakhalin-Amur and Shantar (IWC, 2000). Extensive studies began in this area in 2007. Based on aerial surveys

[7]Lowry, L., R. Reeves, and K. Laidre. 2017. *Delphinapterus leucas.* The IUCN Red List of Threatened Species 2017: e.T6335A50352346 (avail. at http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T6335A50352346.en). Downloaded on 08 June 2018.

[8]Lowry, L., R. Hobbs, and G. O'Corry-Crowe. 2019. *Delphinapterus leucas* Cook Inlet subpopulation. The IUCN Red List of Threatened Species 2019: e.T61442A50384653 (avail. at http://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T61442A50384653.en). Downloaded on 10 May 2019.

[9]Cervenka, S. 2015. "Update on our beluga whales". Asbury Park Press. Asbury, NJ (avail. at https://www.app.com/story/news/local/land-environment/2015/06/01/beluga-whales-new-jersey/28327751/).

[10]Sea Watch Foundation. 2015. "More rare beluga whales spotted around the U.K. (avail. at https://www.seawatchfoundation.org.uk/more-rare-beluga-whales-spotted-around-the-uk/).

Table 4.—Beluga and narwhal stocks recognized by one or more status reviews: IWC (2000), Laidre et al. (2015), CAFF (CBMP-SAMBR), and this meeting – GROM. Stocks are ordered as they were in the IWC review, stocks from the other reviews that are not the same as one of the stocks in the IWC review are inserted below the most similar IWC stock. The CAFF review only considered stocks within the CAFF area thus some stocks are listed as "outside." The NAMMCO (text footnote 1) review is not included because it considered only the Atlantic Arctic and sub-Arctic and included other seasonal aggregations. Gray shading indicates when the same aggregation of belugas or narwhals was recognized as a stock by all four reviews. Y = recognized as an independent stock, N = not recognized as an independent stock, dd = where review indicated not enough information to delineate a stock. Comments explain differences between the GROM and the other reviews.

Stock/location	IWC, 2000 (no. in IWC report)	Laidre et al., 2015	CAFF (CBMP, SAMBR)	GROM (no. in this report)	Comments from GROM
Beluga					
Cook Inlet	Y (1)	Y	outside	Y (7)	
Bristol Bay	Y (2)	Y	Y	Y (8)	
Eastern Bering Sea	Y (3)	Y	Y	Y (9)	
Eastern Chukchi Sea	Y (4)	Y	Y	Y (10)	
Eastern Beaufort Sea	Y (5)	Y	Y	Y (11)	Called "Beaufort Sea" by IWC, 2000
Eastern High Arctic-Baffin Bay	N	`Y	Y	Y (12)	Also called "Somerset Island" and "Canadian High Arctic" stock in previous reviews; includes the West Greenland winter and North Water Polynya winter aggregations used by CAFF
North Water	Y (6)	N	N	N	Included in Eastern High Arctic-Baffin Bay
West Greenland	Y (7)	Y	Y	N	Included in Eastern High Arctic-Baffin Bay; called West Greenland winter by Laidre et al., 2015 and CAFF
Foxe Basin	Y (11)	N	N	N	Included in Eastern High Arctic-Baffin Bay
Southwest Greenland	N	N	Y	Y (19)	Extinct; called "South Greenland- Qaqortoq to Maniitsoq" in NAMMCO, 1999
Cumberland Sound	Y (8)	Y	Y	Y (17)	
Frobisher Bay	Y (9)	N	N	N	Included in Western Hudson Bay
Ungava Bay	Y (10)	Y	Y	Y (16)	Possibly extirpated
Western Hudson Bay	Y (12)	Y	Y	Y (13)	
South Hudson Bay	Y (13)	N	N	N	Included in Western Hudson Bay
James Bay	Y (14)	Y	Y	Y (14)	
Eastern Hudson Bay	Y (15)	Y	Y	Y (15)	
St. Lawrence Estuary	Y (16)	Y	outside	Y (18)	
Svalbard	Y (17)	Y	Y	Y (20)	
Barents-Kara-Laptev Seas	N	N	N	Y (21)	Isolated population with likely several stocks, however GROM decided that there was not enough evidence to separate belugas in this area into any of the putative stocks recognized in past reviews.
Franz Josef Land	Y (18)	N	N	dd	
Kara and Laptev Seas	N	Y	Y	dd	
Ob Gulf	Y (19)	N	N	dd	
Yenisey Gulf	Y (20)	N	N	dd	
SW Laptev Sea-	Y (24)	N	N	dd	
White Sea (WS)	N	Y	Y	Y (22)	Isolated population with likely several stocks, however not enough evidence to separate belugas in this area into any of the 3 putative stocks recognized by IWC (2000)
Onezhsky Bay	Y (21)	N	N	dd	
Mezhenskyi Bay	Y (22)	N	N	dd	
Dvinsky Bay	Y (23)	N	N	dd	
Western Chukchi Sea- Eastern East Siberian Sea	Y (25)	Y	Y	N	Belugas present in fall, winter, and spring, but likely a migration route; belugas are likely from several stocks, mainly Eastern Beaufort, Chukchi, and Bering Sea stocks
Anadyr Gulf	Y (26)	Y	Y	Y (6)	
Okhotsk Sea	N	Y	outside	N	Okhotsk Sea separated into 5 stocks (Shelikhov, Sakhalin-Amur, Ulbansky, Tugursky, and Udskaya)
Shelikhov Bay	Y (27)	N	outside	Y (5)	
Sakhalin-Amur	Y (28)	N	outside	Y (1)	
Shantar	Y (29)	N	outside	N	
Ulbansky Bay	N	N	outside	Y (2)	Previous reviews included this stock in a larger stock called "Shantar"
Tugursky Bay	N	N	outside	Y (3)	Previous reviews included this stock in a larger stock called "Shantar"
Udskaya Bay	N	N	outside	Y (4)	Previous reviews included this stock in a larger stock called "Shantar"
Narwhal					
East Greenland - Barents Sea	Y	N	N	N	Included GROM stocks EGL, NEG, Svalbard–NW Russian Arctic
Svalbard–NW Russian Arctic	dd	N	N	Y (12)	Likely several stocks but not enough data to separate
Svalbard, Franz Josef Land	dd	N	Y	dd	Included in "Svalbard – NW Russian Arctic"
Svalbard	dd	Y	N	dd	Included in "Svalbard – NW Russian Arctic"
North East Greenland (NEG)	dd	N	N	Y (11)	
East Greenland (EGL)	dd	Y	Y	Y (10)	
Baffin Bay Region	Y	N	N	N	Included GROM stocks SI, JS, SS, AI, ES, IB, EBI
Melville Bay (MB)	dd	Y	Y	Y (7)	
Inglefield Bredning (IB)	dd	Y	Y	Y (6)	
Eastern Baffin Island (EBI)	dd	Y	Y	Y (8)	
Jones Sound/Smith Sound	dd	Y	N	N	Separated into two stocks (Smith and Jones)
Jones Sound (JS)	dd	N	Y	Y (2)	
Smith Sound (SS)	dd	N	Y	Y (3)	
Somerset Island (SI)	dd	Y	Y	Y (1)	
West Greenland winter aggregation	dd	Y	Y	N	A winter aggregation of GROM stocks SI, AI, ES, MB, EBI
Admiralty Inlet (AI)	dd	Y	Y	Y (4)	
Eclipse Sound (ES)	dd	Y	Y	Y (5)	
Northern Hudson Bay	Y	Y	Y	Y (9)	

and observations from boats and shore (Solovyev et al., 2015; Solovyev et al.[11]), the population consists of several distinct summer aggregations in 1) Sakhalin Bay–Amur River, 2) Ulbansky Bay, 3) Tugursky Bay, and 4) Udskaya Bay. Nikolaya Bay is also occupied by belugas, but belugas from Sakhalinsky Bay were resighted in Nikolaya Bay in July so they are considered part of the Sakhalin Bay–Amur River aggregation.

Genetic studies demonstrated that belugas summering in the western Okhotsk Sea share a single nuclear gene pool and thus represent a single biological population (Shpak et al., 2019). Analysis of mtDNA markers subdivided belugas summering in different areas into three demographic units: 1) Sakhalin-Amur and Nikolaya Bay, 2) Ulbansky Bay, and 3) Tugursky-Udskaya Bays. Even though Nikolaya and Ulbansky Bays are, in geographical terms, the two arms of Academii Bay, i.e., they share the same entrance from the open sea, a comparison of the haplotype frequencies between Nikolaya and Ulbansky belugas resulted in the highest difference between any pair of bays (F_{ST}=31.1%, p=0.0006). Belugas in Nikolaya Bay also differ from Ulbansky whales in their response to boats, and in this respect they resemble Sakhalinsky Bay belugas (Shpak et al., 2019).

Pairwise comparisons of haplotype frequencies indicate that the maternal lineages of Sakhalinsky, Ulbansky, and Udskaya belugas differ significantly (F_{ST}=11.0–16.1%, p=0.0000). The lack of difference in haplotype frequencies between Tugursky and Udskaya was outweighed by geographical separation (200 km) and behavioral differences to determine that Tugursky Bay belugas and Ulbansky Bay belugas should be managed as separate stocks. For Sakhalinsky, Ulbansky, and Udskaya Bays, intra- and inter-annual resightings suggest sedentary behavior of at least some of the belugas throughout the summer, and fidelity to summer ranges.

There is uncertainty around the differentiation of beluga stocks in the western Okhotsk Sea, but the criteria applied for the structure proposed above (mtDNA frequency differences, observations of spatio-temporal occurrence, and behavior) are similar to those used for stock delineation in other areas. The GROM therefore concluded that, based on information currently available, belugas in the western Okhotsk Sea consist of four stocks: 1) Sakhalin Bay–Amur River, 2) Ulbansky Bay, 3) Tugursky Bay, and 4) Udskaya Bay.

1) Sakhalin-Amur

The Sakhalin-Amur stock occupies the Amur River estuary and Sakhalinsky Bay during the summer months and moves offshore into deeper ice-covered waters of the Okhotsk Sea during the winter (Shpak et al., 2019). This stock is the most extensively studied in the western Okhotsk Sea. Research has included abundance estimation, genetic analyses, satellite tracking, health assessment, and an initial study of contaminant levels. Genetics (mtDNA) and movement data supported this stock designation (Shpak et al., 2019). A small number (30–60) of belugas occupying Nikolaya Bay during the summer are also included in this stock. No differences in the mtDNA haplotype frequencies have been revealed between Sakhalin-Amur belugas and belugas biopsied in Nikolaya Bay (Shpak et al., 2019). An estimate of the average number of belugas available at the surface based on three aerial line-transect surveys (2009 and 2010) is 1,977 (CV=0.24, 1,574–2,293). The surface estimate was multiplied[12] by 2.0 to account for submerged whales (availability bias) in the murky waters of the southern part of Sakhalinsky Bay and the Amur estuary, so that the abundance estimate for this stock is 3,954 (CV=0.24) belugas.

Large-scale commercial beluga hunting in the Okhotsk Sea during the 20th century, primarily before 1960, substantially reduced the population. Starting in the 1980's, live-capture operations have been conducted in the southern part of Sakhalinsky Bay. The captured belugas are sold to aquaria for live displays; they are primarily juveniles 2 or 3 years old, with a sex ratio skewed toward females. Allowed take levels set by the Russian authorities do not consider this narrow age range and sex bias and thus may over-estimate the number of removals that can be sustained. Until 2012, annual live-capture removals were reportedly less than 40. From 2012 to 2015, however, belugas were taken annually in numbers ranging from 40 to over 100 (exact figures are not available). In 2016 there were no live captures, and starting in 2017, the Federal Fisheries Agency recommended that the annual live-capture take in the Sakhalin-Amur area be limited to 40 or fewer individuals.

Major concerns for the Sakhalin-Amur stock include interactions with coastal fisheries (including distur-

[11]Solovyev, B., D. Glazov, V. Chernook, E. Nazarenko, N. Chelintsev, and V. Rozhnov. 2012. Distribution and abundance of beluga whales (*Delphinapterus leucas*) in the White Sea and in the southern part of the Barents Sea based on aerial counts in August 2011. Marine Mammals of Holarctic: Collection of scientific papers of the 7th Intl. Conf., Suzdal, Russia, 24-28 Sept. 2012, vol. 2:264–269 (avail. at http://marmam.ru/upload/conf-documents/mmc2012_full.pdf).

[12]The multiplier 2.0, to account for availability bias (i.e. assuming that half of the belugas remained submerged and were unavailable to be seen and counted by the observer), has been used as a default correction factor for visual aerial surveys of belugas when no availability correction factor has been developed empirically for the stock. This value (2.0) is lower than correction multipliers developed using dive data and aerial survey observer data in some circumstances (e.g., 2.62 belugas in Bristol Bay (Lowry et al., 2008); 2.86, 2.33 and 2.27 belugas during winter in Baffin Bay (Heide-Jørgensen and Acquarone, 2002; Heide-Jørgensen et al., 2010a, 2017)) and higher than those developed in other circumstances (e.g., 1.82 in offshore water with visibility to 4 m deep and 1.15 in shallow near-shore water with visibility to 2 m deep (Innes and Stewart 2002)). This correction multiplier of 2.0 is arbitrary and does not have a CV.

In the Okhotsk Sea, belugas occupy highly turbid waters with visibility typically to less than one meter depth, similar to Bristol Bay. Also, during aerial surveys of the Sakhalin-Amur stock, the plane flew over sea pens with known numbers of belugas, which the observers would count. The counts averaged 44% of the belugas in the pens, which adds support to the notion that at least half of the belugas remained submerged. Unpubl. data, O. V. Shpak, Severtsov Inst. Ecol. Evol. Russian Acad. Sci., 33, Leninsky pr., 119071 Moscow, Russia.

bance, entanglement, and shooting) and contamination of Amur Estuary waters. An additional concern is the potential for competitive interactions with the fishery for chum salmon, *Oncorhynchus keta*, and pink salmon, *O. gorbuscha*. The carrying capacity of the region for belugas has likely declined in recent decades due to the intensive and constantly increasing fishing pressure, especially from the salmon fishery. Entanglement does not appear to be a serious problem despite the large fishing effort, including poaching of sturgeon (kaluga, *Huso dauricus*, and Amur sturgeon, *Acipenser schrenckii*). This comparatively low susceptibility to entanglement (when compared to many other cetaceans) apparently applies to belugas in other areas as well. Salmon fishermen likely shoot belugas at least occasionally. Pollution from the Amur River contains both chemical contaminants (e.g., heavy metals, PCB's; Glazov et al.[13]) and infectious disease agents, especially during flood events (a spike in infections of belugas was observed in 2013; Alekseev et al., 2017).

Workshop Discussion

The trend for this stock is unknown. However, based on a population model using commercial catch data beginning in 1915, recent removals for live display, and an estimate of subsistence removals, it was estimated that there were 13,200 to 20,800 belugas in this stock historically (Bettridge et al., 2016). Current abundance may be at only 20–40% of historical abundance but the model suggests that the current population is increasing.

Status

The workshop judged this stock to be of moderate concern because it is still reasonably abundant and there are no immediate major threats. The primary concerns are the unknown trend in abundance, the likely depletion caused by removals prior to the 1960's, and habitat issues that include the industrial and agricultural pollutants in discharge from the Amur River. Additionally, fisheries are increasing in the area and may be altering the habitat carrying capacity.

2) Ulbansky

The Ulbansky stock occupies Ulbansky Bay during the summer months and moves offshore, presumably into deeper ice-covered waters of the Okhotsk Sea, during the winter as does the Sakhalin-Amur stock (Shpak et al., 2019). This stock is considered a separate demographic unit based on multi-year observations of summer aggregations in the bay as well as genetic evidence (Meschersky et al., 2013; Yazykova et al.[14]). In autumn, some belugas from Sakhalinsky Bay move into Nikolaya Bay, and these belugas may also visit Ulbansky Bay. However, beluga numbers in all bays decrease in autumn. Winter migratory routes and feeding habitats are unknown. Nonetheless, analyses of biopsy samples collected during summer indicate that composition and frequency of the maternal lineages represented in Ulbansky Bay differ from those in the other bays: pairwise comparison of mtDNA yielded F_{ST} values of 16.1% (p=0.0000) for Udskaya Bay, 13.8% (p=0.0000) for Sakhalinsky Bay, and 11.3% (p= 0.0002) for Tugursky Bay. For Nikolaya Bay, which is geographically the closest to Ulbansky Bay, the F_{ST} values are highest, reaching 31.1% (p=0.0006, though this is from a small sample, n=9).

A direct count of 1,167 belugas during an aerial survey in August 2010 was corrected for availability using a correction factor[12] of 2.0 (due to the murky estuarine water), resulting in an abundance estimate of 2,334 whales. The stock is not known to have been commercially exploited nor have live captures occurred in this area. Although predation on belugas by killer whales, *Orcinus orca*, has not been observed directly, on numerous occasions researchers have witnessed a panic escape reaction by the entire aggregation when approached by killer whales. A fishing plant deploys salmon nets along the coast and in the Ulban River mouth, and a gold-mining company (with a mining claim on the Ulban River arm) uses an area on the coast to load and unload machinery and fuel. The main concerns, neither of them major at present, are occasional entanglement, shooting by fishermen, and the risk of habitat contamination by gold-mine discharge.

Workshop Discussion

A beluga satellite-tagged in September 2015 on a shoal in Ulbansky Bay later travelled to Nikolaya Bay, and the researcher suspected it was from the Sakhalin-Amur stock. This illustrates the need for further satellite tracking studies to understand the movements of these stocks after the period of summer residency.

Status

The trend in abundance is unknown, though Russian scientists think that the numbers are stable. The GROM workshop had moderate concern for this stock, primarily because of the unknown trend in abundance and the potential impacts of fishing activities and resource extraction and development in the area.

3) Tugursky

The Tugursky stock occupies Tugursky Bay during the summer months and moves offshore, presumably into deeper ice-covered waters of the Okhotsk Sea, during the winter as does the Sakhalin-Amur stock (Shpak et al., 2019). The identity of this stock as a separate demographic unit within the western Okhotsk population is based

[13]Glazov, D. M., O. V. Shpak, D. P. Samsonov, V. V. Krasnova , A. D. Chernetskiy, D. I. Litovka, R. A. Belikov, A. I. Kochetkov, E. M. Pasynkova, V. M. Belkovich, and V. V. Rozhnov. 2014. Persistent organic pollutants in tissues of marine mammals from the Russian Sub-Arctic. Marine Mammals of Holarctic. Abstract Book of the VIII Int. conf. (St. Petersburg, Russia, 22–27 Sept. 2014), p. 93 (avail. at http://marmam.ru/upload/conf-documents/mmc2014_full.pdf).

[14]Yazykova, M. G., I. G. Meschersky, O. V. Shpak, D. M. Glazov, D. I. Litovka, E. A. Borisova, and V. V. Rozhnov. 2012. Molecular genetic analysis of Sakhalin-Amur and Shantar beluga (*Delphinapterus leucas*) summer aggregation in the Sea of Okhotsk. Collection of scientific papers of the 7th Conf. Marine Mammals of Holarctic, Suzdal, Russia, 24-28 Sept. 2012, 2:400–406. (Avail. at http://marmam.ru/upload/conf-documents/mmc2012_full.pdf).

on information provided by local residents and on multi-year observations of geographical isolation from all the other beluga summer aggregations in the Okhotsk Sea. Genetic analysis (see below) also supports this separation from the other stocks, except Udskaya Bay (Shpak et al., 2019).

In summer, belugas are regularly seen in the upper part of the bay and occasionally along the west coast, but are not observed between Tugursky and Udskaya bays. Small groups have been reported near the south coast of Big Shantar Island and along the northeast coast of Tugursky Bay. Behavioral differences (e.g., response to boats) were noted between beluga groups in Tugursky and Udskaya bays. Winter migratory routes and feeding habitats are unknown. Genetic analyses of samples collected during summer indicate that the composition and frequency of the maternal lineages represented in Tugursky Bay differ from those in Sakhalinsky (F_{ST} =8.2%, p=0.0001) and Ulbansky (F_{ST} = 11.3%, p=0.0002) bays. However, no difference was found between Tugursky and Udskaya in a comparison of 32 and 90 specimens, respectively (F_{ST}=1.4%, p=0.1263; Shpak et al., 2019).

Historical data, together with multi-year shore, boat, and aerial observations, indicate that in summer belugas occupy estuarine areas in both bays, separated by around 200 km, and few animals are detected outside the estuaries, which suggests that there is little interchange during summer. Furthermore, behavioral differences between belugas concentrating in Tugursky and Udskaya Bays were noticed by two independent research teams. Until tracking studies of individuals show movement between the two bays in summer, Tugursky Bay belugas should be managed as a separate stock.

An abundance estimate of 1,506 whales was derived from a direct count during an aerial survey of Tugursky Bay in August 2010, multiplied[12] by 2.0 to account for availability bias, i.e., animals missed because they were submerged in murky waters (Shpak et al., 2019). The stock was exploited both for subsistence and commercially from the late 1800's and until the 1950's. Belugas are still taken occasionally by locals, either as a result of bycatch in salmon nets followed by a kill or by shooting. No live-captures have been made from this stock. There is a settlement, a fish plant, and a coastal gold-mining company based in the bay. The main concerns for Tugursky belugas are 1) fisheries, 2) potential habitat contamination caused by gold ore mining (heap leaching), and 3) discharges of human and livestock waste.

Workshop Discussion

No genetic evidence of differentiation between Tugursky and Udskaya belugas is currently available, but what is known about summer distribution and differences in behavior supports the idea of managing the whales that summer in the two bays separately. Genetic studies could be continued to clarify the stock identity of belugas summering in Tugursky Bay, however, given the lack of differentiation, satellite tracking studies showing summer movements of the Tugursky Bay and Udskaya Bay stocks may be the only way to resolve the issue.

Status

Abundance of Tugursky belugas is thought by Russian scientists to be fairly stable, but the actual trend is unknown. The GROM had moderate concern for this stock, primarily due to the uncertainty surrounding stock identity and trends in abundance as well as the issues related to fishing and pollution.

4) Udskaya

The Udskaya stock occupies Udskaya Bay during the summer months and moves offshore, presumably into deeper ice-covered waters of the Okhotsk Sea, during winter as does the Sakhalin-Amur stock (Shpak et al., 2019). The identity of this stock as a separate demographic unit within the western Okhotsk population is based on local knowledge, multi-year observations of summer and autumn aggregations in the bay, and genetic analysis (Shpak et al., 2019). Belugas are present in the estuary of the Uda River from June to October and often enter the Uda River itself. They are also known to concentrate in the estuary of the Torom River. No genetic samples from the Torom Estuary are available, but belugas are regularly seen along the coast between the two rivers (ca. 45 km distance between the mouths), which suggests that all animals in the bay belong to the same stock. Upon ice formation in the Uda Estuary, belugas move along the entire south coast of the bay, but keep near the coastline. Winter migratory routes and feeding habitats are unknown.

The composition and frequency of the maternal lineages represented in Udskaya Bay strongly differ from those in Sakhalinsky, Nikolaya, and Ulbansky bays, and pairwise F_{ST} values are 11.0–16.7%, p<0.002 for all pairs (Shpak et al., 2019). However, no difference was found between the Udskaya and Tugursky samples (F_{ST}=1.4%, p=0.1263). A larger genetic sample from Tugursky Bay collected before late August and sampling in the Torom River estuary in Udskaya Bay are required to better understand the summer stock structure of Tugursky and Udskaya belugas. Differences in behavioral responses to the presence of boats have been noted between Tugursky and Udskaya beluga groups (Shpak[15]).

Abundance of the Udskaya stock was estimated to be 2,464 whales; a direct count of 1,232 belugas during aerial surveys in August 2010 was multiplied[12] by 2.0 to correct for availability bias in murky waters (Shpak and Glazov, 2013). The stock was hunted by locals and commercially until the 1950's. At present, belugas are occasionally taken by local residents, either as a result of bycatch in salmon nets followed by a kill, or by shooting, even though all such takes are illegal. No live captures have been attempted from this stock. There are two

[15]Shpak, Olga V., Severtsov Institute of Ecology and Evolution of Russian Academy of Sciences, 33, Leninsky pr., 119071 Moscow, Russia.

settlements, three fishing plants with multiple fishing camps, three coastal gold-mining bases, and one gold ore loading terminal in the bay. Diesel fuel is unloaded in at least four locations. The main concerns for this stock are the potential impacts of fisheries, habitat contamination by toxic river discharge (discharges from gold mining and of human and livestock waste), and ship traffic (noise, leaks of diesel fuel).

Status

The Udskaya stock is a medium-sized stock (i.e., between 2,000 and 5,000 belugas), with an unknown trend in abundance. A moderate concern for this stock arises mainly due to ship traffic, fishery interactions, and pollution in the area.

5) Shelikhov

The Shelikov stock summers in coastal areas of the northeastern Okhotsk Sea—specifically in Shelikhov Bay and along the west coast of the Kamchatka Peninsula. Its winter range is not known but is thought to be in deeper waters offshore from the observed summer range (Shpak et al., 2019). Reproductive isolation of this stock from other belugas in the Okhotsk Sea was confirmed by genetic studies (Shpak et al., 2019). Strong differences in microsatellite loci alleles (F_{ST}=3.17–4.38%, p=0.0000) and mtDNA haplotype frequencies (F_{ST}=34.0–35.3%, p=0.0000) were found for Shelikhov belugas when compared (pairwise) to the Sakhalin-Amur stock and the combined Shantar region sample. Summer aerial surveys also showed discontinuity in the coastal distribution of these whales and that of whales in the western Okhotsk population. In summer, Shelikhov belugas concentrate both in river estuaries and along the coastline. Very limited information exists on the winter distribution of Shelikhov belugas. In the 1980's, belugas were found along the ice edge in Shelikhov Bay, along the Kamchatka Peninsula in January, and in Shelikhov Bay in April. A beluga tagged with a satellite-linked transmitter in Shelikov Bay remained at the mouth of the bay until at least December.

A direct count by an aerial survey in August 2010 found 1,333 belugas. This was multiplied[12] by 2.0 to correct for whales submerged in the murky waters to estimate abundance of the Shelikhov stock at 2,666 belugas (Shpak and Glazov, 2013). The total allowable take (TAT) level for the West Kamchatka fishing subzone (including both hunting removals and live-captures) varied from 0 to 400 belugas during 2006–11 and since 2012 has varied from 0 to 50, averaging 25/yr during 2012–18. No legal beluga harvest or live-capture effort is reported to have taken place, other than temporary captures for tagging followed by release. The annual illegal take by local residents (for human consumption or dog food) is thought to be fewer than 10 whales, if any. The population trend is unknown. The only potential threat is competition with fisheries in a few populated areas.

Workshop Discussion

This stock is isolated geographically and reproductively. The aerial survey covered only a portion of the range, so the abundance estimate (2,666) may be negatively biased. The small numbers of direct removals are likely sustainable. This area is sparsely settled, has little fishing activity, and therefore bycatch is considered negligible. There are no current development projects in the region. Climate change will likely result in a reduction of sea ice, which could open up the area to development.

Status

This stock is medium-sized with no information on trend. The quota (TAT) issued has not been used, but there are a few illegal removals. At present there is little development in the area. There was some concern about the poor knowledge of population structure but overall, the level of concern for this stock was low.

6) Anadyr

The Anadyr beluga stock consists of a single summer aggregation, which congregates in the shallow waters of the Anadyr River Estuary (western Bering Sea) during late summer, moves out into the Gulf of Anadyr and north to Kresta Bay in autumn, then south to shelf areas in the vicinity of Cape Navarin where it spends the winter. The whales return to the Anadyr Estuary the following summer after the ice has broken up (Shpak et al., 2019). This stock is separated genetically and geographically from the Okhotsk Sea belugas. The composition of mitochondrial lineages shows evident differences (seasonal isolation) between the Anadyr belugas and other stocks in the Bering, Chukchi, and Beaufort Seas (B-C-B stocks) (Meschersky et al., 2013; Borisova et al.[16]). Thus, this aggregation should be managed as a separate stock. To some extent, Anadyr belugas are also reproductively isolated from other B-C-B stocks (Shpak et al., 2019), although more studies are required to understand the degree of this isolation.

In the Anadyr Estuary, some of the same individuals (based on unique markings such as scars) have been resighted within and between years (Prasolova et al., 2014; Prasolova et al.[17]). Together with the results of genetic analysis, observations suggest that in summer, belugas form a residential aggregation in the estuary and return to the same area summer after summer.

[16]Borisova, E. A., I. G. Meschersky, O. V. Shpak, D. M. Glazov, D. I. Litovka and V. V. Rozhnov. 2012. Evaluation of effect of geographical isolation on level of genetic distinctness in beluga whale (*Delphinapterus leucas*) populations in Russian Far East. Collection of scientific papers presented at the 7th Int. Conf., Marine Mammals of the Holarctic, Suzdal, 2012, 1:107–111 (avail. at http://marmam.ru/upload/conf-documents/mmc2012_full.pdf).

[17]Prasolova, E. A., D. I. Litovka, and R. A. Belikov. 2018. The results of photo identifiation of beluga whales (*Delphinapterus leucas*) in the Anadyr Estuary of the Bering Sea in 2013–2015. Collection of scientific papers presented at the 9th Int. Conf., Marine Mammals of the Holarctic: Astrakhan, 2016, 2:109–115 (avail. at http://marmam.ru/upload/conf-documents/mmc2016_full.pdf).

Belugas spend the ice-free summer–autumn feeding period in the Anadyr Estuary (total of 5–6 months, with the latest sighting in late November). During this period, they concentrate in the river deltas but visit all reachable parts of the estuary and occasionally go as far as 300 km upstream in the Anadyr River (Litovka, 2002). According to satellite tracking data, the whales begin to leave the area with the beginning of ice formation in the estuary. First, they move north along the coast to Kresta Bay, and later to the middle and southern parts of Anadyr Gulf (Litovka et al., 2013; Shpak et al., 2019). Anadyr belugas spend the winter around Cape Navarin, in regions with ice coverage of up to 80–90% (Shpak et al., 2019; Litovka[18]).

Results of telemetry and aerial surveys suggest that, in the winter–spring feeding areas off Cape Navarin, Anadyr belugas overlap with some of the B-C-B stocks, most likely the eastern Beaufort Sea stock in particular (Citta et al., 2017). Genetic pairwise comparisons between the Anadyr stock and the others in the Bering Sea and the stocks in the Sea of Okhotsk show it to be differentiable from the other stocks but most similar to the eastern Beaufort Sea stock (Meschersky et al., 2013).

No summer aerial counts of belugas have been conducted in Anadyr Gulf. Litovka (2002) suggested that this summer stock numbers some 3,000 animals based on several years of observations of the numbers of belugas passing the city of Anadyr and entering the Anadyr River during the late spring.

The TAT for the Anadyr Estuary and Anadyr Gulf is 40 belugas. The known subsistence harvest is generally around 2 belugas per year (average of 1.8 from 1997 to 2016), and no live-capture operations have been conducted in this region since 2007. Incidental mortality is typically only 1–3 belugas per year (Litovka[19]). The population trend is unknown. Habitat and other concerns include potential competition with fisheries, increasing ship traffic, and reduced winter ice cover as a result of climate warming.

Workshop Discussion

The number of belugas in this stock is uncertain; the stock is believed to be stable based on the observations mentioned above, but this is not confirmed by survey or count data. Although the level of exploitation of the Anadyr stock is low (fewer than 10 animals removed per year), a more rigorous baseline of population data is needed, given concerns regarding the potential for oil spills and the anticipated increase in ship traffic in the Bering Strait region.

Status

The Anadyr stock is of moderate size and the level of exploitation is low. Moderate concern for this stock was based on the lack of more rigorous abundance data and the potential impacts of increasing ship traffic, urban expansion, and associated noise and pollution.

7) Cook Inlet

Cook Inlet belugas aggregate near river mouths in upper Cook Inlet, Alaska, during ice-free months (Rugh et al., 2000, 2010). In the fall–winter–spring months, the whales in this stock range more widely throughout the upper inlet (Hobbs et al., 2005; Lammers et al., 2013; Shelden et al., 2015; Castellote et al., 2016). Belugas are rarely seen in the Gulf of Alaska outside Cook Inlet with the exception of a small group that resides year-round in Yakutat Bay (Laidre et al., 2000; O'Corry-Crowe et al., 2015). The Alaska Peninsula geographically isolates this stock from the nearest beluga stock in Bristol Bay (Laidre et al., 2000; Hobbs et al., 2005; Shelden et al., 2015) and mitochondrial DNA analysis shows it to be distinct from other stocks in Alaska (O'Corry-Crowe et al., 2002).

The origin of the small group in Yakutat Bay has been studied using genetic samples collected by remote biopsy and was found to be distinct from but most closely related to the larger population residing in Cook Inlet (O'Corry-Crowe et al., 2015). However, a comparison of mtDNA and microsatellites indicates that the Yakutat Bay group is not likely to be a recent extension of that population, and its origin remains obscure.

The Cook Inlet stock was surveyed each year from 1993 to 2012 (Rugh et al., 2000, 2005; Hobbs et al., 2015a) and in even years thereafter (Hobbs, 2013; Shelden et al.[20,21]). Abundance, estimated to be 328 whales (CV=0.08) in 2016 (Shelden et al.[21]), was updated to 279 (CV=0.06) from a survey in June 2018 (Shelden and Wade[22])

Subsistence hunting of these whales was unregulated prior to 1999, with removals (landed catch plus estimated struck-but-lost) averaging over 60 belugas/yr during 1994–98. This resulted in a significant decline (47%) between 1994 and 1998 from around 653 to 347 whales (Hobbs et al., 2000; Mahoney and Shelden, 2000). The decline raised concern that the stock was depleted (Hobbs et al., 2000) and the Cook Inlet hunters voluntarily refrained from hunting in 1999. In 1999 and again in 2000 the U.S. Government established a moratorium on Cook Inlet beluga whale harvest-

[18]Litovka, D. I. 2013. Ecology of Anadyr stock of the beluga whale *Delphinapterus leucas* (Pallas, 1778). Ph.D. thesis, Voronezh State Univ., Russia, 149 p. [in Russian].

[19]Dennis Litovka is currently with the Office of Governor and Government of the Chukotka Autonomous Region, Str. Bering 20, Anadyr, Russia 689000.

[20]Shelden, K. E. W., C. L. Sims, L. Vate Brattström, K. T. Goetz, and R. C. Hobbs. 2015. Aerial surveys of beluga whales (*Delphinapterus leucas*) in Cook Inlet, Alaska, June 2014. AFSC Processed Rep. 2015-03, 55 p. (avail. at http://www.afsc.noaa.gov/Publications/ProcRpt/PR2015-03.pdf Accessed June 2016).

[21]Shelden, K. E. W., R. C. Hobbs, C. L. Sims, L. Vate Brattström, J. A. Mocklin, C. Boyd, and B. A. Mahoney. 2017. Aerial surveys of beluga whales (*Delphinapterus leucas*) in Cook Inlet, Alaska, June 2016. AFSC Processed Rep. 2017-09, 62 p. (avail. at http://www.afsc.noaa.gov/Publications/ProcRpt/PR2017-09.pdf).

[22]Shelden, K. E. W., and P. R. Wade (Editors). 2019. Aerial surveys, distribution, abundance, and trend of belugas (*Delphinapterus leucas*) in Cook Inlet, Alaska, June 2018. AFSC Processed Rep. 2019-09, 93 p. (avail. at: https://repository.library.noaa.gov/view/noaa/22918).

ing except for subsistence hunts conducted under a cooperative agreement between NOAA's National Marine Fisheries Service (NMFS) and Alaska Native organizations. Comanagement harvest plans were not agreed for 1999 and 2000. The plan covering the years 2001 to 2005 allowed takes of one or two whales per year, and no hunt has been allowed since 2005 (NMFS[23]). Nevertheless, the population has declined since 1999, with the most recent ten year trend (2008-2018) being -2.3%/yr (Shelden and Wade[22]). After the unsustainable subsistence hunt was controlled, the stock should have begun to increase; the continued failure to increase suggests that other factors are preventing stock recovery.

In May 2000 the Cook Inlet beluga stock was designated as "depleted" under the U.S. Marine Mammal Protection Act (MMPA), i.e., its abundance was below the maximum net productivity level (MNPL) and thus outside the optimal sustainable population (OSP) range. With no evidence that recovery was occurring, NMFS listed the Cook Inlet beluga as an "endangered" distinct population segment under the U.S. Endangered Species Act (ESA) in October 2008, after which it was listed as "strategic" under the MMPA. NMFS published a Recovery Plan for Cook Inlet belugas in December 2016 (NMFS[23]). Cook Inlet belugas have been listed as "Critically Endangered" on the IUCN Red List since 2006 (Lowry et al.[8]).

Habitat concerns include ship traffic, competition with fisheries, anthropogenic noise (including ship noise), urban and industrial development, chemical and biological pollution, and the cumulative effects of multiple stressors. Effects of climate change such as the loss of winter ice cover, changes in the distribution and abundance of prey, and exposure to parasites and diseases new to the region are also of concern.

A substantial decrease in the use of summer habitat has occurred in the last 40 years; whales were found throughout the upper inlet during summer surveys in the 1970's, but by the mid-1990's they limited themselves to river mouths at the north end of the inlet, Knik and Turnagain arms, and coastal shallows connecting these areas (Rugh et al., 2010; Shelden et al., 2015). It is unknown whether the open-water areas of the inlet became less suitable or a smaller population was concentrating in the best habitat. A significant relationship between salmon escapement and annual number of beluga newborns observed (Norman et al., 2019), when considered alongside a shift in diet from saltwater to freshwater species as determined by stable isotope analysis (Nelson et al., 2018), suggests that competition with salmon fisheries has limited the quality of prey available to belugas and this could explain the continued decline.

This stock is subjected to a great deal of disturbance from human activities (shipping, aircraft noise, oil and gas development, commercial and sport fishing, etc.), much of which occurs within the areas designated as "critical habitat" (Goetz et al., 2007, 2012; Small et al., 2017; Castellote et al.[24]). Hundreds of flights each day land and take off over critical habitat, and the shipping lane in and out of the Port of Anchorage passes through the critical habitat. Waste from the city of Anchorage (ca 300,000 people) undergoes only "primary treatment" (removal of solids) before discharge into Cook Inlet, and runoff, including substantial amounts of de-icing fluids from the Anchorage airport, flows directly into the inlet (Norman et al., 2015). While the large tidal flux may substantially dilute the sewage and runoff, these contaminants flow year round or through entire seasons so they are replaced each tidal cycle by subsequent outfall (Norman et al., 2015).

Smaller offshoots such as Knik Arm and Turnagain Arm, which are parts of the designated critical habitat for belugas, have lower flushing rates than the main inlet and may accumulate contaminants in their sediments (Moore et al., 2000; Hobbs et al., 2015b; Norman et al., 2015). There have been no studies of sediment composition and deposition processes in Cook Inlet. Tissue studies in the 1990's showed that the belugas of Cook Inlet had low levels of contaminants in their tissues compared to belugas in other parts of Alaska (with the exception of elevated copper levels in the kidneys), but there have been no more recent studies (Norman et al., 2015). A gas leak that began in December 2016 could not be repaired until the inlet was ice-free in 2017 (DeMarban[25]), and this provides a cautionary example of the risks of oil and gas development in a seasonally ice-covered area.

Natural hazards include live strandings and killer whale predation. There is an unusually high number of live strandings in Cook Inlet as a result of the large tidal heights (ca 9.2 m: Vos and Shelden, 2005). These hazards may interact. For example, a stranding of killer whales occurred at the same time as a mass stranding of belugas a few kilometers away, and it was suspected that the belugas had stranded while avoiding the killer whales. Predation by killer whales may be a significant source of mortality for Cook Inlet belugas (Vos and Shelden, 2005; Burek-Huntington et al., 2015) and therefore increase the risk of population decline and extinction (Hobbs et al., 2015b).

Workshop Discussion

Harvest regulations published in October 2008 indicated that a limited subsistence hunt by Alaska Natives

[23]NMFS. 2016. Recovery plan for the Cook Inlet beluga whale (*Delphinapterus leucas*). NMFS, Alaska Reg., Prot. Resour. Div., Juneau, AK.

[24]Castellote, M., B. Thayre, M. Mahoney, J. Mondragon, C. Schmale, and R. J. Small. 2016. Anthropogenic noise in Cook Inlet beluga habitat: sources, acoustic characteristics, and frequency of occurrence. Final Wildl. Res. Rep. ADF&G/DWC/WRR-2016-4. Alaska Dep. Fish Game, Juneau, AK.

[25]DeMarban, A. 2017. Divers halt leak in Cook Inlet gas pipeline. Alaska Dispatch News. Retrieved on 5 Oct. 2017 (avail. at https://www.adn.com/business-economy/energy/2017/04/14/divers-for-hilcorp-stop-months-long-cook-inlet-gas-leak/).

could resume only after the population has recovered to at least 350 animals (if other criteria are met, including a high probability of recovering to 780 whales by 2099) (NOAA, 2008). Some GROM participants considered 350 too low a threshold. This number (350) was originally set in 2004 in view of the expressed desire on the part of local people to continue beluga hunting and product use as soon as possible given its cultural significance, and it was believed at the time that if the population averaged over 350 for the previous 5 years and had an increasing trend over the previous 10 years, it could sustain a small harvest. As noted above, the population is now designated as "endangered" and therefore before any harvest is allowed, the management plan must be revised to meet whatever criteria apply under the ESA.

Status

This very small population continues to show no evidence that it is recovering. It is subjected to many anthropogenic stressors, and the cumulative impact of these stressors may explain the lack of recovery. The workshop expressed a high level of concern for this stock.

8) Bristol Bay

Belugas of the Bristol Bay stock are typically found in Nushagak and Kvichak bays and major rivers in the east end of Bristol Bay during summer (Frost et al., 1985; Lowry et al., 2008; Citta et al., 2016) and throughout the northern and eastern parts of Bristol Bay in winter (Citta et al., 2016). Satellite telemetry studies indicate that they remain in the greater Bristol Bay region throughout the year (Citta et al., 2016, 2017).

MtDNA analyses show that Bristol Bay belugas are distinct from other stocks that summer or winter in the Bering Sea. Satellite tagging and a comparison of mtDNA from whales in Nushagak and Kvichak bays found no indication of population substructure within Bristol Bay (O'Corry-Crowe et al., 1997, 2002; Citta et al., 2018).

Aerial surveys were conducted periodically between 1993 and 2016, and the estimate of abundance for Bristol Bay belugas in 2016 was 2,040 (CV =0.22, 95% CI=1,541–2,702, N_{min} = 1,809; Lowry et al., 2008; 2019). The trend in abundance estimated from the uncorrected aerial survey counts was +4.8% per year over the 12-yr period from 1993 to 2005. The 2016 survey produced an estimate similar to that in 2005, suggesting that the population has been stable in recent years.

Abundance in 2011 estimated from genetic mark-recapture analysis using skin biopsies collected annually over the period 2002–11 was 1,928 belugas (95% CI = 1,611–2,337: Citta et al., 2018). This provides support for the accuracy of the aerial survey abundance estimate but is based on older data than the most recent aerial survey estimate.

Data on Alaska Native subsistence harvests within Bristol Bay since 1987 indicate that over the period 2007–16, the annual landed harvest averaged 23 belugas (95% CL = 21–25; Frost and Suydam, 2010; Lowry et al., 2019). Fishery bycatch is not well documented. A PBR of 43 belugas (1,809 × 0.024 × 1.0) was calculated for this population, nearly twice the current annual reported subsistence harvest, which however does not account for struck-but-lost whales. Habitat concerns include loss of sea ice due to climate warming, fishery bycatch, oil and gas development, and mining.

Workshop Discussion

The trend for this stock appears to be stable (and it may be increasing). Removals by hunting and bycatch appear to be sustainable, and there are no major habitat concerns. There is a large salmon fishery in Bristol Bay, and while there is little reported bycatch or conflict, competition between the belugas and the fishery may occur since the fishery occurs in areas where belugas feed on the same species. This area has only small human communities, but there are plans for more development (e.g., a major mining project, the Pebble Mine, has been proposed in the watershed of Bristol Bay).

Status

The Bristol Bay stock is a medium-sized stock and is one of the most data-rich, with a time series of credible abundance and trend estimates and reliable data on landed catch. Therefore, concern for this stock is low.

9) Eastern Bering Sea

Eastern Bering Sea belugas aggregate near the mouth of the Yukon River and in Norton Sound in western Alaska throughout the summer (Lowry et al., 2019). As ice forms during the autumn they move offshore to wintering areas south and west of the Kuskokwim River Delta and east of Saint Matthew Island, and continuing south in the eastern Bering Sea as far south as Round Island in Bristol Bay (Citta et al., 2017). Analyses of mtDNA found these belugas to be genetically distinct from adjacent stocks (O'Corry-Crowe et al., 1997, 2002; Brown Gladden et al., 1997; Meschersky et al., 2008).

An aerial survey flown across Norton Sound and adjacent to the Yukon River Delta in 2000 resulted in a population estimate of 6,994 (CI= 3,162–15,472) whales (Lowry et al., 2017b). No previous survey results are available for assessing trend.

The hunting of eastern Bering Sea belugas is comanaged by the Alaska Beluga Whale Committee and NMFS. Belugas from this stock are an important subsistence resource for at least 21 villages in western Alaska. From 2007 to 2016, an average of 190 belugas were landed (i.e., not including struck-but-lost) per year (Frost and Suydam, 2010; Lowry et al., 2019). There are several commercial fisheries in State of Alaska and Federal waters that have the potential to catch belugas incidentally but no such catches have been reported. At least one beluga is known to have been taken in a subsistence fishing net, so bycatch occurs at least occasionally.

Based on the population estimate from 2000, PBR is calculated from: N_{BEST} = 6,994; CV = 0.37; N_{MIN} =

5,173, R_{MAX} = 0.048; F_R = 1.0; PBR = 103. The PBR for this stock is considerably lower than the cumulative reported landings in subsistence hunts (Lowry et al., 2019). Despite this, the harvest has been judged by U.S. authorities to be sustainable because the 2000 survey estimate is thought to be biased low and because local and traditional knowledge indicates that there has not been any decrease in abundance. Nonetheless, an updated population estimate is needed. There are concerns about how this stock may be affected by habitat changes, loss of winter sea ice, and increases in commercial shipping and commercial fishing as a result of climate change.

Workshop Discussion

The single abundance estimate for this stock is believed to be negatively biased due to 1) the use of an availability bias correction (2.0) that was considered low (c.f. 2.62 x 1.18 used for similar high-turbidity water conditions in Bristol Bay; Lowry et al., 2008, 2019), 2) the fact that survey coverage did not include some offshore and in-river areas where belugas are known to occur, and 3) the fact that some of the survey effort took place in sea states greater than Beaufort 3, which likely decreased the sighting rate. A new abundance survey occurred in 2017, but the results were not available to the GROM workshop.

The reported landed catch is nearly twice the PBR value calculated using the results of the 2000 survey, which is now 18 years old; struck-but-lost belugas are not accounted for in the harvest numbers and while 21 communities report takes, other communities that may hunt belugas do not report. Thus total removals are certainly higher than the reported landings.

Concern was expressed over the lack of a more recent abundance estimate and the fact that the relatively high level of removals, possibly twice the PBR, could be causing a decline. However, since the stock is not designated as "depleted" under the MMPA, its current abundance is implicitly assumed to be within the OSP range, i.e., larger than MNPL, for this population, and therefore hunting by Alaska Natives for subsistence is unregulated.

Status

This is a moderate-sized stock of over 5,000 belugas. However, the abundance estimate is from data that are 18 years old, and no information is available on trend. Given that the reported removal levels are likely biased low and the abundance estimate is outdated, but that plans are underway to update the abundance estimate, this stock is of moderate concern. A new estimate expected from a 2017 survey will inform a reassessment of the stock.

Update

In June 2017 NMFS conducted an aerial survey of this stock. The survey analysis estimated surface numbers of 4,621 belugas (CV=0.12); applying the availability bias multiplier[12] of 2.0 yields an abundance estimate of 9,242 belugas (CV=0.12; Lowry et al., 2019). As above, this arbitrary correction factor for missed animals of 2.0 has no associated CV. PBR is calculated from: N_{BEST} = 9,242; CV = 0.12; N_{MIN} = 8,357, R_{MAX} = 0.048; F_R = 1.0; PBR = 201. The 10-year average annual subsistence landed take of 191 is below this new PBR, but with struck-but-lost added, average annual removals are 215, or 7% above PBR and under-reporting is not included (Lowry et al., 2019).

10) Eastern Chukchi Sea

Eastern Chukchi Sea belugas aggregate along Kasegaluk Lagoon in northwestern Alaska in late June and early July (Frost et al., 1993). During summer, they occur in the Beaufort Sea and Arctic Ocean and can venture north as far as lat. 81° N, but they mostly use the continental slope. They migrate south into the Bering Sea in autumn and spend the winter between St. Lawrence Island and the Chukotka Peninsula. MtDNA studies found this stock to be genetically distinct from other stocks in the Bering-Chukchi-Beaufort region (O'Corry-Crowe et al., 1997, 2002; Brown Gladden et al., 1997; Meschersky et al., 2008).

Previously it was believed that the belugas in Kotzebue Sound in mid-June migrated north to near Kasegaluk Lagoon and that the whales in these two locations belonged to the same stock (Lowry et al., 2019). Genetic data from tissue samples obtained during the late 1970's and early 1980's showed that the animals from the two areas were actually from different stocks (O'Corry-Crowe et al., 2016). Numbers of belugas in Kotzebue Sound declined markedly in the mid-1980's. The small number of animals sampled for genetics in Kotzebue Sound since the 1990's may have come from the eastern Beaufort Sea stock.

Aerial surveys flown between 19 July and 20 August 2012 estimated the stock size at 20,675 (CV=0.66) animals (Lowry et al., 2017a), including correction for animals outside the survey area and below the surface based on satellite tag data. The previous abundance estimate from 1992 was 3,710, but it was negatively biased as it included only belugas seen near shore. Therefore, no information is available on population trend.

Belugas from this stock are an important subsistence resource for several villages in northern Alaska, especially Point Lay and Wainwright. From 2007 to 2016, an average of 57 belugas was harvested (i.e., landed) annually by these two villages (Frost and Suydam, 2010; Lowry et al., 2019). Some animals are caught in salmon fishing nets, but they are reported as part of the beluga subsistence take, which is considered sustainable. The PBR set using the 2012 population estimate suggests that removal of 249 belugas per year would be sustainable, and this is well above the current level of removals.

Concerns about beluga habitat include possible impacts of climate change, commercial shipping, oil and gas activities, and tourism. Commercial activities, scientific studies on a wide variety of topics, and tourism have increased as sea ice has diminished due to climate change. Changes in migration timing related to recent delayed sea ice formation and warming of the Arctic have been documented in this stock (Hauser et al., 2017).

Workshop Discussion

The question of whether there is one segment of the population that comes close to shore and is therefore more susceptible to harvest was discussed. While this is possible it is unlikely to be a small portion of the population as satellite telemetry shows that whales tagged near shore spend most of their time offshore (Suydam[26]). A portion of the stock aggregates in nearshore waters over a 2- to 4-week time period presumably to molt. They do not seem to come inshore to feed as belugas harvested near shore rarely have prey in their stomachs (Quakenbush et al., 2015).

Status

There are no previous abundance estimates that would allow assessment of trend, but this relatively large stock is thought to be stable, and the small number of removals is likely sustainable. Therefore, there is a low level of concern for the stock.

11) Eastern Beaufort Sea

Belugas of the eastern Beaufort Sea (EBS) stock summer in the eastern Beaufort Sea and Amundsen Gulf (Norton and Harwood, 1985; Harwood et al., 1996; Richard et al., 2001; Harwood and Kingsley, 2013; Harwood et al., 2014a; Citta et al., 2017) and over-winter in the Bering Sea (Citta et al., 2017). MtDNA analyses of samples from hunted animals identified EBS belugas as distinct from other stocks in Alaska and eastern Russia, and from central and eastern Canadian Arctic stocks, most likely due to maternally directed annual philopatry to the Beaufort Sea region (O'Corry-Crowe et al., 1997, 2002; Brown Gladden et al., 1997). Analyses of nuclear DNA microsatellite loci indicated that there is some interbreeding with other stocks that winter in the Bering Sea (Brown Gladden et al., 1999).

The only large-scale effort to estimate abundance of the EBS stock was an aerial survey conducted in 1992, resulting in a near-surface abundance estimate of 19,629 (CV=0.23; Harwood et al., 1996), which was multiplied[12] by 2.0 to account for submerged whales and whales outside of the survey area to get an estimate of 39,258 (CV=0.23; Allen and Angliss, 2015). The correction factor (2.0) was not based on data and was used without a CV. It was considered to be a reasonable minimum value, and it is supported by the observation of Richard et al. (2001) that 13 of 18 whales satellite-tracked in 1993 and 1995 remained outside of the 1992 survey area, suggesting that the survey covered only about 38% of the stock.

There has been a long history of beluga hunting by the Inuvialuit and their ancestors in the western Canadian Arctic, and by the Iñupiat in Alaska (Harwood et al., 2002). The EBS stock is hunted by the Inuvialuit during summer in the Mackenzie River estuary and by the Iñupiat in Alaska during the spring migration. Based on annual harvest numbers reported by Canada and the United States, the mean estimated annual subsistence take (landed plus struck-but-lost) between 1987 and 2015 was 164 whales (Harwood et al., 2002; Frost and Suydam, 2010; Harwood et al., 2015; Muto et al., 2016), which is well below the PBR of 487 (using a recovery factor of 0.75 because the survey estimate is outdated).

An average of ten belugas per year are taken in fall, winter, and spring in Chukotka, and these animals are generally considered to be from this stock based on genetic data and the timing and location of the takes (Boltunov and Belikov, 2002, updated by D. Litovka[19]). These takes are considered sustainable when added to the Canada and United States takes.

Size-at-age of belugas landed in the Mackenzie Delta has declined from 1989 to 2008 (Harwood et al., 2014b). The subtle changes in growth of belugas over the time-series may reflect ecosystem changes that have reduced the availability or quality and quantity of their prey or that the stock is approaching carrying capacity (Harwood et al., 2014b, 2015).

Workshop Discussion

In a previous assessment by the Department of Fisheries and Oceans Canada (DFO), the estimated total of direct removals by hunting prior to 2000 was 186 belugas per year (DFO[27]), which includes a correction for struck-but-lost; the catch was strongly biased toward males (60–80% of removals). That assessment concluded that the annual harvest was far below a level that might negatively affect such a large population.

Status

This is a very large stock (although the most recent abundance estimate is 25 years old) and the trend is unknown. The level of removals appears low relative to the stock's size and the concern level is low.

12) Eastern High Arctic–Baffin Bay

Belugas in the Eastern High Arctic–Baffin Bay stock consist of aggregations summering in the Canadian High Arctic archipelago and, to a minor extent, in Smith Sound. During summer, the main aggregations occupy estuaries, inlets, and small bays in and around Somerset Island (Smith and Martin, 1994; Richard et al., 1998a, 2001; Heide-Jørgensen et al., 2003b; Koski and Davis[28]). Specific locations include Radstock Bay, Maxwell Bay, and Crocker Bay on Devon Island; Cunningham Inlet, Creswell Bay, and Elwin Bay on Somerset Island; and Coningham Bay on eastern Prince of Wales Island. Telemetry information has shown that the stock is divided in

[26]Suydam, R. S. 2009. Age, growth, reproduction, and movements of beluga whales (*Delphinapterus leucas*) from the eastern Chukchi Sea. Ph.D. dissert., Univ. Wash., Seattle, 152 p.

[27]DFO. 2000. Eastern Beaufort Sea beluga. DFO Science Stock Status Report E5-38. (Avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[28]Koski, W. R., and R. A. Davis. 1980. Studies of the late summer distribution and fall migration of marine mammals in NW Baffin Bay and E Lancaster Sound, 1979. LGL Ltd. for Petro-Canada Explor. Inc.

winter into a portion that resides in the North Water polynya and a larger portion that resides in coastal ice-free areas along the Baffin Bay sea-ice edge off West Greenland (Doidge and Finley, 1994; Richard et al., 1998a, 1998b; Heide-Jørgensen et al., 2003b; Heide-Jørgensen and Laidre, 2004).

Abundance on the summer range was estimated from an aerial survey in 1996 to be 21,213 belugas (95% CI 10,985–32,619; Innes and Stewart, 2002). This is the only total abundance estimate for this stock. Winter surveys of belugas off West Greenland cover only a portion of the stock but indicate an increase in abundance in this wintering area since the imposition of catch limits in Greenland (Heide-Jørgensen et al., 2017). A fairly recent (2012) abundance estimate from these surveys was 9,072 whales (95% CI 4,895–16,815; Heide-Jørgensen et al., 2016).

During summer, approximately 100 belugas per year are removed from this stock by communities in Nunavut, and about 300 belugas are taken per year by communities in Greenland in winter when they are close to shore. Total removals in both areas have declined in recent years (non-quota in Canada and quota harvest in Greenland) (NAMMCO[29]). The decline in catches in winter off Greenland is related to the recent decline of winter sea ice in eastern Baffin Bay which has reduced access to belugas by Greenlandic hunters (Heide-Jørgensen et al., 2010a). In total, the harvest is considered sustainable, and recent declines in removals should allow the stock to increase. However, the stock is still depleted due to past commercial hunting. Numbers prior to the commercial hunting were estimated by a population model to be at least twice the current abundance (Innes and Stewart, 2002).

Habitat concerns include the effects of climate change and increasing industrialization and shipping. Continued ice loss may affect the availability of prey species and reduce the carrying capacity. Impacts will depend on the adaptability of belugas—e.g., their ability to change their summer and winter aggregation sites and migration timing and adjust to alternative prey. There are also habitat concerns related to the Baffinland Mary River Mine project (NAMMCO[29]), which has proposed to use ice breaking in winter and spring to resupply the mine and transport iron ore. The implications of this activity for belugas migrating and wintering in Baffin Bay are unclear at present.

Workshop Discussion

More information is needed about areas that are important for foraging, especially in Baffin Bay, as prey populations may have changed. For example, Atlantic cod, *Gadus morhua,* were important prey of belugas during the "cod invasions" in West Greenland in the 1920's but their importance as prey declined with the disappearance of cod in this region (Degerbøl and Nielsen, 1930). It is unknown if the recent increase in cod abundance in West Greenland has benefited the belugas. Additionally, capelin, *Mallotus villosus,* are increasing in Cumberland Sound and off Labrador (Rose and Rowe, 2015), and this may represent a new food resource for Baffin Bay belugas.

Uncertainty remains regarding the stock affinity of belugas in Foxe Basin; their range may overlap that of Somerset Island belugas at least during summer. While genetic results suggest that these belugas are related to the western Hudson Bay stock (Brown Gladden et al., 1997; De March and Postma, 2003), their distribution is not well known and the southern extent of the Somerset aggregation is poorly defined.

Status

It is not clear whether abundance of the Eastern High Arctic–Baffin Bay stock is stable or increasing—winter surveys off West Greenland indicate an increase in one wintering area since the imposition of catch limits (Heide-Jørgensen et al., 2017). This is a large stock (possibly 20,000 animals) and removals are considered sustainable, so the level of concern for this stock is low.

13) Western Hudson Bay

Western Hudson Bay (WHB) belugas are centered around the Seal, Churchill, and Nelson River estuaries during summer, although belugas occur along the entire west coast of Hudson Bay (Sergeant, 1973; Sergeant and Brodie, 1975; Richard et al., 1990; Richard, 1994). The distribution of WHB belugas overlaps that of the Eastern Hudson Bay (EHB) stock during the spring and fall migrations and in overwintering areas in Hudson Strait (Turgeon et al., 2012). WHB belugas are more diverse genetically than other Canadian beluga stocks, but they are genetically distinct from the neighboring EHB stock (De March and Postma, 2003). The previously recognized (but with reservations) Frobisher Bay and South Hudson Bay stocks (IWC, 2000) are included here in the western Hudson Bay stock based on the results of studies of movements and distribution (Yurkowski et al., 2019) and genetics (De March and Postma, 2003).

WHB beluga abundance was estimated using data from visual and photographic aerial surveys in 1987 (Richard et al., 1990), 2004 (Richard[30]), and 2015 (Matthews et al.[31]). The most recent estimate (adjusted for availability bias) is 54,473 (CV=0.098; CI = 44,988–65,957). Notably, this estimate excludes the coast of Ontario, where ~14,800 be-

[29]NAMMCO. 2017. NAMMCO-JCNB Joint Scientific Working Group on Narwhal and Beluga, 8–11 Mar. 2017, Copenhagen, Denmark (avail. at http://nammco.wpengine.com/wp-content/uploads/2017/06/nammco-jcnb-jwg-report-march-2017-final-with-ex-summ.pdf).

[30]Richard, P. R. 2005. An estimate of the western Hudson Bay beluga population size in 2004. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/017. ii + 29 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[31]Matthews, C. J. D., C. A. Watt, N. C. Asselin, J. B. Dunn, B. G. Young, L. M. Montsion, K. H. Westdal, P. A. Hall, J. R. Orr, S. H. Ferguson, and M. Marcoux. 2017. Estimated abundance of the western Hudson Bay beluga stock from the 2015 visual and photographic aerial survey. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/061. iv + 18 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

lugas were estimated during the 2004 survey (Richard[30]).

The average of estimated annual removals by communities around Hudson Bay and Hudson Strait from 1977 to 2015 was 503 (range 252–784, including struck-but-lost; Hammill et al., 2017). This removal level is well below the PBR of 1,004 as calculated using the most recent abundance estimate and a recovery factor of 1. The WHB beluga stock is large and the similar near-surface counts during aerial surveys conducted in 2004 and 2015 suggest that the size of this stock is stable.

Workshop Discussion

Ship traffic is a concern. About 2,000–3,000 belugas congregate in the Churchill River estuary where the port of Churchill is located, and shipping that connects communities along the west coast of Hudson Bay occurs throughout the main summer aggregation areas. Icebreaking in Hudson Strait, where the WHB and EHB belugas overwinter, is also a concern for these stocks. Hydroelectric development affecting seasonal river discharge rates into estuaries frequented by belugas in summer is an additional concern.

Status

There is low concern for this stock. This is because it is large and stable, and removals appear sustainable.

14) James Bay

The James Bay (JB) stock apparently occurs in and near James Bay year-round (Bailleul et al., 2012). Twelve animals tagged in the southeastern part of the bay showed no evidence of directional long-distance migration. Genetic analysis confirmed that JB belugas are distinct from the other stocks in Hudson Bay (Postma et al.[32]). However, the differentiation is weak, suggesting recent divergence.

Aerial surveys of James Bay and southern Hudson Bay conducted between 1985 and 2015 found large groups of belugas in northwestern James Bay and along the adjacent Ontario coast of Hudson Bay (Gosselin et al.[33, 34]). The belugas in northwestern James Bay have been included in the James Bay stock, but the stock affinities of these whales and of the whales along the adjacent coast of Hudson Bay have not been confirmed by genetic or movement data. Abundance estimates from aerial surveys of James Bay show large variability between surveys suggesting that there is an influx of animals from western Hudson Bay in some years. The aerial survey in 2015 resulted in an estimate of 10,615 (CV=0.25) which is used as the current estimate for the James Bay stock (Gosselin et al.[34]). No assessment of trends in abundance was attempted.

There was a limited commercial hunt for JB belugas in the 19th century, but this seems to have lasted only a few years, and there was also a limited hunt by some Cree communities (Reeves and Mitchell, 1987b). Since the early 2000's, management plans have encouraged Inuit from Nunavik (eastern Hudson Bay) to harvest belugas in James Bay to reduce the pressure on the endangered EHB stock. However, the hunting by Inuit from Nunavik in James Bay has removed only ~10 whales per year due to the large distance from the nearest community to the whales.

The PBR is set at 173 individuals using a recovery factor of 1. While there is no major concern about this relatively large stock that is exposed to little hunting pressure, knowledge about the stock is limited. Hunters have observed belugas in winter along the southern Belcher Islands, indicating potential northward movement of JB animals during this season. The impacts of changes in the hydrological cycle in the JB habitat caused by hydroelectric development are uncertain.

Workshop Discussion

JB belugas should be considered as a separate stock, although there is some uncertainty regarding the stock's size and seasonal movements. All belugas tagged to date in James Bay have been on the east side and there is no information on the movement patterns of whales on the west side. The habitat in James Bay is changing with a decrease in sea ice, resulting in increased primary productivity. This may be improving habitat quality for belugas.

Status

There is low concern for this stock because it appears to be fairly large despite the uncertainty about which animals are being surveyed in James Bay at times. Additionally, the harvest numbers are low.

15) Eastern Hudson Bay

In summer, the EHB beluga stock occupies an area bounded by the Hudson Bay arc in the east and extending westward to approximately 60 km west of the Belcher Islands. Historically, core summering areas included the Little Whale River and Nastapoka River estuaries, although fewer whales use these areas now likely due to past commercial hunting and overharvesting. Satellite telemetry tracking showed that this stock does not mix with other stocks in Hudson Bay during summer (Lewis et al., 2009), but it moves into Hudson Strait and the Labrador Sea during fall and winter where the animals mix with belugas from the WHB stock (Lewis et al., 2009; Hammill, 2013). Genetic analysis showed that EHB and WHB belugas are from the same breeding population, however, maternally taught migration

[32]Postma, L. D., S. D. Petersen, J. Turgeon, M. O. Hammill, V. Lesage, and T. Doniol-Valcroze. 2012. Beluga whales in James Bay: a separate entity from eastern Hudson Bay belugas? DFO Can. Sci. Advis. Sec. Res. Doc. 2012/074. iii + 23 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[33]Gosselin, J.-F., V. Lesage, and M. O. Hammill. 2009. Abundance indices of beluga in James Bay, eastern Hudson Bay and Ungava Bay in 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/006. iv + 25 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[34]Gosselin, J.-F., M. O. Hammill, and A. Mosnier. 2017. Indices of abundance for beluga (*Delphinapterus leucas*) in James and eastern Hudson Bay in summer 2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/067. iv + 25 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

patterns limit mixing of summering aggregations (Turgeon et al., 2012; Colbeck et al., 2013).

The most recent abundance estimate, from a 2015 survey, is 3,819 animals (CV=0.43) (Gosselin et al.[34]). Abundance estimates obtained from seven surveys conducted between 1985 and 2015 suggest that the EHB stock's size has remained stable over that period (Gosselin et al.[34]). Commercial hunting in the 19th century substantially reduced the abundance of this stock (Reeves and Mitchell, 1987b). Even though the intensity of commercial hunting lessened in the 1870's, subsistence hunting continued and probably limited the stock's recovery potential. Harvest limits and seasonal closures were not implemented until the 1980's. The EHB area was closed to hunting from 2001 to 2006. Harvesting resumed in 2007, although the Nastapoka and Little Whale estuaries remained closed.

The beluga sampling program in northern Quebec, which has been operating since 1995, allows samples to be collected from approximately 30% of the belugas landed. Genetic-mixture analysis uses those samples to define the proportions of EHB and WHB belugas taken in the various hunts, both spatially and temporally (Doniol-Valcroze et al.[35]; Mosnier et al.[36]). These proportions are used to determine catch limits for each community and each hunting period. An average of 63 EHB belugas per year were taken (landed catch) during the last 3-year (2014–16) management plan.

A population dynamics model incorporating information on removals, proportions of each stock in the catch, and aerial survey estimates of abundance suggests that the EHB stock declined between 1974 and 2001 and then increased slightly (3,078 to 3,408) until 2016 (Hammill et al., 2017). The recent apparent increase (or stabilization) of the population may have been due to the efforts to focus the harvesting in Hudson Strait where EHB animals constitute a lower proportion of the animals hunted. Harvest limits were set by the Nunavik Marine Region Wildlife Board using an objective of a maximum 50% probability of population decline over a 10-year period, corresponding to a total allowable harvest (landed catch) of 62 animals/yr. These harvest levels accounted for an average 41% struck-but-lost rate (Doniol-Valcroze et al.[35]). The objective for the new management plan has yet to be defined.

Genetic analysis has revealed the summer presence of belugas around the Belcher Islands that may come from one or more stocks other than the EHB stock (Mosnier et al.[36]). However, waters around the Belcher Islands are included in the summering area overflown during the aerial surveys conducted to estimate abundance, and EHB belugas cannot be distinguished from others; thus, there is potential for the size of the EHB stock to be overestimated.

Habitat concerns include icebreaking and shipping and changes in seasonal salinity in estuaries. Icebreaking activities in Hudson Strait during winter and spring to meet the transportation needs of remote mines are a cause for concern. Additionally, hydroelectric dams in the Great Whale and La Grande river drainages may have impacts on belugas as large volumes of fresh water are released into Hudson Bay and James Bay during winter due to the high demand for electricity in that season. The freshwater plumes from these discharges change the nature of the sea-ice in the estuaries and coastal areas, making it much less pliable or friable and more difficult for the whales to gain or maintain access to air, thus increasing the risk of mortality from ice entrapment. The freshwater plume from the Great Whale River may also affect those belugas (if any) from James Bay that overwinter near the Belcher Islands.

Workshop Discussion

The winter harvest of belugas at Sanikiluaq, where recent catch levels appear to be higher than in the past, may include ice-entrapped whales. It is not clear from genetic analyses whether the winter-harvested animals are only from the EHB stock, from another stock, or from a mixture of stocks.

Although the current management regime appears to be maintaining a stable population, there is concern that flexibility for quick response in the event of a population decline is lacking. There is no allowance for errors in allocation of harvested animals to the appropriate stock, and the current management plan fails to incorporate a margin of precaution to ensure population recovery (a central feature of the PBR approach).

Status

There is concern regarding removal levels for the EHB stock; therefore, it is considered to be of high/moderate (1/2) concern (Table 3). While this stock is medium-sized and appears to be stable or increasing slowly, the abundance estimates from surveys may include animals from multiple stocks. If this is true, it would confound conclusions regarding abundance, harvest levels (and division among communities), and the overall sustainability of the harvest. Additional information is needed on the stock identity of belugas and the proportion of each stock (perhaps via a biopsy survey) observed during aerial surveys used for abundance estimation. Besides the harvest, the possible impacts of icebreaking activities in Hudson Strait and of the fluctuations in freshwater flow into the belugas' nearshore habitat in eastern Hudson Bay caused by the hydroelectric project in the Great Whale River drainage are regional concerns.

[35]Doniol-Valcroze, T., J.-F. Gosselin, and M. O. Hammill. 2012. Population modeling and harvest advice under the precautionary approach for eastern Hudson Bay beluga (*Delphinapterus leucas*). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/168. iii + 31 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[36]Mosnier, A., M. O. Hammill, S. Turgeon, and L. Postma. 2017. Updated analysis of genetic mixing among beluga stocks in the Nunavik marine region and Belcher Islands area: information for population models and harvest allocation. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/016. v + 15 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

16) Ungava Bay

Sizeable annual estuarine aggregations of belugas occurred in southern and western Ungava Bay until the end of the 19th century, by which time commercial hunting had caused a severe decline in numbers (Boulva, 1981; Finley et al., 1982; Reeves and Mitchell, 1987a). Subsistence hunting continued until the late 20th century when regional hunting closures came into effect. Based on commercial catch data, this stock numbered ~1,900 individuals in the 1800's (DFO[37]), and catches and direct observations in the 1960's and 1970's suggested that only a few hundred belugas remained in the region (Reeves and Mitchell, 1989). A quota system was implemented in 1986, and the Mucalic River estuary was closed to hunting (Lesage et al.[38]).

Five aerial surveys were conducted between 1982 and 2008, and no belugas were seen on-transect in the surveys after 1985 (Smith and Hammill, 1986; Hammill et al., 2004; Gosselin et al.[34]). Off-transect observations in 1993 suggested that there were fewer than 200 individuals in the region (Kingsley, 2000). In 2012, a mean estimate of abundance based on the last four surveys was 32 belugas (95% CI 0-94) (Doniol-Valcroze and Hammill[39]).

No trend can be estimated from currently available data. There are still occasional sightings in the area of the Mucalic Estuary and the Whale River; however, there is no information on the frequency of use of these areas by belugas, and no recent estimate of abundance or genetic information is available.

Workshop Discussion

This stock may be extirpated. Occasional sightings of belugas during the summer in Ungava Bay and nearby parts of Hudson Strait raise questions about whether they are sightings of animals from the Ungava Bay stock. No genetic material from the whales that historically congregated in the Ungava Bay estuaries is available for comparisons with neighboring stocks or recent samples from belugas in Ungava Bay. Consequently, it is not possible to determine if the few whales occasionally seen in Ungava Bay are from the original Ungava Bay stock or how much the stock differed from surrounding stocks. DNA might be extracted from old tissue or bone samples; it is not clear how thoroughly this possibility has been explored.

Status

There is high concern about this stock because it is either extremely small or extirpated.

17) Cumberland Sound

Cumberland Sound (CS) belugas are thought to remain in Cumberland Sound throughout the year with a substantial aggregation occupying Clearwater Fiord during summer months (Richard and Stewart[40]). Aerial surveys of the stock's summer range have found 50–60% of the total abundance to be in the northern portion of the sound outside of Clearwater Fiord (Richard[41]; Marcoux et al.[42]).

Genetic and contaminant analyses show CS belugas to be distinct from other Canadian stocks, including animals harvested by other south-eastern Baffin Island communities (Brown Gladden et al., 1997; De March et al., 2002; De March et al., 2004; Turgeon et al., 2012). However, local traditional knowledge identifies more than one type of beluga in Cumberland Sound with differences noted in body size and shape, coloration, and the taste of the skin (mattaq) (Kilabuk[43]).

Nine aerial surveys of the CS beluga stock's range were conducted between 1980 and 2014 (Richard and Orr, 1986; Richard, 1991b; Richard and Stewart[40]; Richard[41]; Marcoux et al.[42]), and the most recent abundance estimate was 1,151 (CV=0.21). Direct comparisons among all of the surveys to assess trends are not possible because the earlier surveys covered only Clearwater Fiord and would have missed belugas in other parts of the Sound; the most recent four surveys (1990, 1999, 2009, 2014) covered the entire summer range and are comparable.

Hunters from Pangnirtung landed 41 belugas per year, on average, during 2006–15. Struck-but-lost is estimated as 18% of landings, so removals averaged 47 belugas per year. The stock was depleted by commercial hunting in the 1800's and early 1900's (Mitchell and Reeves, 1981).

A population model fit to the survey data (1990–2014) and the reported harvest data (1960–2015, landings only) indicated a declining population with a current abundance of ~1,000 animals (Marcoux and Hammill[44]) Using the modeled CS beluga abundance and a recovery factor of 0.5, which DFO has used as a standard in the past to calculate PBR levels for

[37]DFO. 2005. Proceedings of the meeting on recovery potential assessment of Cumberland Sound, Ungava Bay, Eastern Hudson Bay and St. Lawrence beluga populations (*Delphinapterus leucas*); April 5-7, 2005. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2005/011.224 (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[38]Lesage, V., D. W. Doidge, and R. Fibich. 2001. Harvest statistics for beluga whales in Nunavik, 1974-2000. Fish. Oceans, Sci. Can. Sci. Advis. Sec., Res. Doc. 2001/022. 35 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[39]Doniol-Valcroze, T., and M. O. Hammill. 2012. Information on abundance and harvest of Ungava Bay beluga. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/126. iv + 12 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[40]Richard, P. R., and D. B. Stewart. 2008. Information relevant to the identification of critical habitat for Cumberland Sound belugas (*Delphinapterus leucas*). DFO Can. Sci. Advis. Secr. Res. Doc. 2008/085. iv + 24 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[41]Richard, P. R. 2013. Size and trend of the Cumberland Sound beluga whale population, 1990 to 2009. DFO Can. Sci. Advis. Secr. Res. Doc. 2012/159. iii + 28 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[42]Marcoux, M., B. G. Young, N. C. Asselin, C. A. Watt, J. B. Dunn, and S. H. Ferguson. 2016. Estimate of Cumberland Sound beluga (*Delphinapterus leucas*) population size from the 2014 visual and photographic aerial survey. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/037. iv + 19 p. (Erratum: October 2016) (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[43]Kilabuk, P. 1998. A study of Inuit knowledge of the southeast Baffin beluga. Nunavut Wildl. Manage. Board, 74 p.

[44]Marcoux, M., and M. O. Hammill. 2016. Model estimate of Cumberland Sound beluga (*Delphinapterus leucas*) population size and total allowable removals. DFO Can. Sci. Advis. Sec. Res. Doc. 2016 (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

populations assessed by COSEWIC as "threatened," the PBR for this stock was set at seven whales (Marcoux and Hammill[44]).

Workshop Discussion

Previously this stock was considered migratory, but belugas seem to remain in Cumberland Sound throughout the year and therefore it is now considered to be resident (and non-migratory). A population model using aerial survey results and available information on removals (Marcoux and Hammill[44]) indicates a 30% chance of future decline in abundance even with no harvest. It is uncertain how well this model and data represent the state of the population, so the model results were not considered reliable to inform management. Local people acknowledge that there has been a decline in beluga numbers; they believe that this was mostly due to historical commercial hunting. Interestingly, blubber cortisol levels, an indicator of chronic stress, are higher for CS belugas than for other stocks, but it is not clear why (Trana[45]).

Status

The CS stock is small in both number and range. It is believed to be declining, and recent harvest levels are considered unsustainable. For these reasons, the concern level is high for this stock.

18) St. Lawrence Estuary

The current distribution of the St. Lawrence Estuary (SLE) beluga stock represents a fraction of its historical range (Mosnier et al.[46]). This population can be differentiated using both nuclear and mtDNA markers (Brown Gladden et al., 1997, 1999; De March and Postma, 2003). Significant ongoing immigration is considered unlikely.

An age-structured population model was used to estimate the 2012 population size at 889 (Mosnier et al., 2015). The model incorporates abundance estimates and the proportion of under-2 year olds from eight aerial photographic surveys between 1988 and 2009 and data on numbers of known deaths by age class as documented through carcass monitoring.

The SLE beluga population was severely depleted by a sustained hunt from the late 1800's to the mid-1900's, and hunting was finally prohibited in 1979 (Reeves and Mitchell, 1984). From 1983, a carcass monitoring program (reviewed in Lesage et al., 2014) documented 472 deaths, 222 of which were investigated through necropsies. Of the 222 carcasses that were examined, human activities were directly responsible for about 5%; other causes included entanglement in fishing gear (1%; n = 2) and vessel strikes (4%; n = 8). Cause of death was undetermined for 55 individuals (25%). Malignant neoplasms were responsible for the deaths of 31 of the 222 belugas (14%), whereas parturition-associated complications caused the death of 22 adult females (10%). Chronic exposure to environmental contaminants is one of the hypotheses put forward to explain the unusually high occurrence of some of the pathological conditions observed in this population (Lair et al., 2016).

A model using the catch history suggested that the SLE beluga population numbered between 5,000 and 10,000 in the 1800's but only 1,000 in the late 1970's. As recently as 2007 the population was considered stable (Hammill et al.[47]), but subsequent carcass monitoring showed an increase in mortality of young-of-the-year and in perinatal mortality of adult females. This triggered a detailed review of the stock's status in 2013 (DFO[48]). A population model suggested a period of relative stability until 1999, followed by a period of demographic instability (2000–12), including peaks of high neonatal mortality interspersed with peaks of high pregnancy rates (Mosnier et al., 2015). The current view is that the population was stable or increasing very slowly (0.13%/yr) until 2000, then declined (at ~1%/yr) until 2012, reaching a population of 889 individuals in 2012. Using this estimate and a recovery factor of 0.1 (for an endangered species or population) resulted in a PBR of one.

SLE belugas live in one of North America's major commercial waterways, which means they are exposed to elevated sound levels from passing ships and boats (McQuinn et al., 2011; Gervaise et al., 2012), and the risk of being struck by ships (or more likely small boats) in some parts of their range is high (Lair et al., 2016). Whale-watching tourism sometimes is centered on belugas (Ménard et al.[49]), and this is regarded as an additional potential source of disturbance, particularly in calving and nursing areas. The stock is also exposed to numerous contaminants due to the highly industrialized nature of the St. Lawrence watershed (DFO[50]).

While the prevalence of some contaminants such as PCB's seems to have declined since the 1980's, that of others such as PBDE's has increased or remained high. Although the effects of contaminants on belugas are difficult to demonstrate conclusively, impacts on reproduction, offspring development, and immune system function have been shown in other mammals

[45]Trana, M. R. 2014. Variation in blubber cortisol as a measure of stress in beluga whales of the Canadian Arctic. MS Thesis, Dep. Biol. Sci., Univ. Manitoba.

[46]Mosnier, A., V. Lesage, J.-F. Gosselin, S. Lemieux Lefebvre, M. O. Hammill, T. Doniol-Valcroze. 2010. Information relevant to the documentation of habitat use by St. Lawrence beluga (*Delphinapterus leucas*), and quantification of habitat quality. DFO Can. Sci. Advis. Sec., Res. Doc. 2009/098. iv + 35 p. (avail. at http://www.dfo-mpo.gc.ca/csas).

[47]Hammill, M. O., L. N. Measures, J.-F. Gosselin, and V. Lesage. 2007. Lack of recovery in St. Lawrence estuary beluga. DFO Sci. Advis. Sec., Res. Doc. 2007/026. 19 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/)

[48]DFO. 2014. Status of beluga (*Delphinapterus leucas*) in the St. Lawrence River estuary. DFO Can. Sci. Advis. Sec. Sci., Advis. Rep. 2013/076 (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[49]Ménard, N., R. Michaud, C. Chion, and S. Turgeon 2014. Documentation of maritime traffic and navigational interactions with St. Lawrence Estuary beluga (*Delphinapterus leucas*) in calving areas between 2003 and 2012. DFO Sci. Advis. Sec., Res. Doc. 2013/003. v + 24 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[50]DFO. 2012. Recovery strategy for the beluga whale (*Delphinapterus leucas*), St. Lawrence Estuary population in Canada. Species at Risk Act Recovery Strategy Ser. Fish. Oceans Can., Ottawa. x + 87 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

(Martineau, 2010; Lair et al., 2016). Cancer rates in these belugas are extremely high (20% in individuals more than 19 years old; Lair et al., 2016). Environmental perturbations such as recurrent harmful algal blooms are suspected to be affecting SLE belugas as well. For example, a bloom in 2008 was implicated in the deaths of seven animals (both adults and calves) in one week (Scarratt et al.[51]). Moreover, a study combining several physical and biological indices indicated that the quality of beluga habitat has been relatively poor since the late 1990's and may have worsened since 2009 (Plourde et al.[52]).

Workshop Discussion

There appears to be considerable inter-annual variation in reproductive output in SLE belugas. The variable rates of pregnancy and calf mortality may be related to the cumulative effects of several environmental stressors. For example, harmful algal blooms in combination with contaminants may affect belugas in some years, whereas in other, less stressful years, reproduction may improve.

Concerns were expressed regarding the potential impacts of whale-watching, an activity that is not permitted within designated beluga critical habitat but is unrestricted in other areas where belugas are often found. Aspects of unregulated whale-watching may contribute to cumulative impacts.

Status

There is a high level of concern for this stock owing to its small size, declining trend, and chronic exposure to relatively intense industrial activity and other commercial activities in much of its range.

19) Southwest Greenland (Extirpated)

The Southwest Greenland beluga stock, which is effectively extirpated, migrated south in autumn, arrived in Nuuk between October–December, and went at least as far south as Qeqertarsuatsiaat (Fiskenæsset). These belugas were also frequent visitors to South Greenland in the 19th century, which is confirmed by reports and catch statistics. Large numbers were also seen in winter in fjords between lat. 61° N and lat. 63° N, although the main distribution was farther north in Nuuk and Maniitsoq. The northward migration started in February and the last individuals left the southern districts by June or July (Winge, 1902; Møller, 1928; Møller, 1964). Degerbøl and Nielsen (1930) mentioned another pulse of migrating whales arriving in South Greenland in December. These were apparently fatter and in better condition and sometimes had fresh bullet wounds. It is possible that these animals were of Canadian origin.

There were large catches of belugas in Greenland from the middle and late 1800's until the late 1920's (Heide-Jørgensen, 1994). The largest catches (up to 1,500 individuals in a single year) were in Maniitsoq, but Nuuk also had large catches. The hunting season in Nuuk was mainly in spring and early summer. In the 20th century, the whales were caught by netting and driving. In Maniitsoq, driving started in 1917. The cumulative catch in Maniitsoq between 1917 and 1930 was 8,000–10,000 belugas. During this time, most of the catches were of whales on their southward migration, whereas previous catches had been mainly of animals on their northward migration.

Møller (1928) stated that the occurrence of belugas in Godthåb Fjord crashed, and after 1920 they left the fjord earlier in the spring and were caught only occasionally. A decline in catches was evident during the late 1920's (Heide-Jørgensen, 1994). Following this decline, local people in Greenland referred to a change in the timing of migration of belugas from Uummannaq and Upernavik. Some local people claimed that the disappearance of belugas from Nuuk and Maniitsoq was due to changes in sea temperatures after 1926.

Workshop Discussion

The hypothesis that there was a connection between the extinct stock of belugas in Southwest Greenland and the Cumberland Sound stock in Canada might be investigated further with DNA from museum specimens. Belugas are occasionally reported, on average one per year, in the historical migration and hunting areas of this stock, but systematic surveys for large whales, while regularly sighting harbor porpoises, *Phocoena phocoena*, do not find belugas in these areas (Hansen et al., 2019).

Status

This stock was likely extirpated more than 80 years ago.

20) Svalbard

The Svalbard stock of belugas inhabits coastal waters of the Svalbard Archipelago during ice-free months, and the whales are thought to occupy nearby offshore areas adjacent to Svalbard in winter. Telemetry data show that Svalbard belugas are extremely coastal in their distribution during the ice-free season. They spend most of their time close to glacier fronts, and when they move from one front to another, they do so in an apparently directed and rapid manner very close to shore (Lydersen et al., 2001).

When sea ice forms in winter, the whales move offshore somewhat but still stay in the Svalbard area (mostly to the southeast of the archipelago), often occupying areas with more than 90% ice cover (Lydersen et al., 2002). A multi-species cetacean survey in the marginal ice zone north of Svalbard during August 2015 detected no belugas, only bowhead whales, *Balaena mysticetus*, and narwhals (Vacquié-Garcia et al., 2017). However, during

[51]Scarratt, M., S. Michaud, L. Measures, and M. Starr. 2014. Phytotoxin analyses in St. Lawrence Estuary beluga. DFO Can. Sci. Advis. Sec., Res. Doc. 2013/124 v + 16 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[52]Plourde, S., P. Galbraith, V. Lesage, F. Grégoire, H. Bourdage, J.-F. Gosselin, I. McQuinn, and M. Scarratt. 2014. Ecosystem perspective on changes and anomalies in the Gulf of St. Lawrence: a context in support to the management of the St. Lawrence beluga whale population. DFO Can. Sci. Advis. Sec., Res. Doc. 2013/129. vi + 27 p. (avail. at http://www.dfo-mpo.gc.ca/csas).

the same time period belugas were observed (as is normal) along the coast of Svalbard, further documenting the lack of affiliation with drifting sea ice for this whale species in Svalbard during summer.

A study of genetic differences between the belugas around Svalbard and those in West Greenland revealed limited gene flow over ecological time (O'Corry-Crowe et al., 2010). The same study suggested that Svalbard and Beaufort Sea belugas diverged 7,600–35,000 years ago, but experienced recurrent periods with gene flow since then, most likely via the Eurasian Arctic during warm periods.

There is no abundance estimate or trend information, and the status of this stock is unknown. It is classified as Data Deficient on the Norwegian Red List. A first-ever dedicated survey was planned for July–August 2018. Belugas in Svalbard have been totally protected since the 1960's, with no removals allowed. Prior to being given protected status, they were hunted heavily in commercial operations and were certainly depleted at the time when protection came into place (Gjertz and Wiig, 1994).

The impacts of climate change on sea-ice conditions, prey base composition, competition from more boreal marine mammal species, and exposure to parasites and diseases are general concerns. Levels of some pollutants in belugas from Svalbard are also very high, with the levels of many compounds being higher than those found in polar bears, *Ursus maritimus*, in the region (Andersen et al., 2001, 2006; Wolkers et al., 2004, 2006; Villanger et al., 2011). These levels are in many cases also higher than what has been shown to affect the physiology and especially the immune systems of laboratory animals. A diet study based on analyses of fatty acids in the blubber of Svalbard belugas found the composition to be most similar to that of Arctic cod, *Boreogadus saida* (Dahl et al., 2000).

Status

There was moderate concern about this stock because of the lack of information (specifically on abundance, though this was expected to change following the planned 2018 survey), the high tissue levels of pollutants, and the possible impacts of climate change.

21) Barents-Kara-Laptev Seas

The information on belugas in the Barents, Kara, and Laptev seas (Franz Josef Land, Ob Gulf, Yenisey Gulf, and southwest Laptev Sea) presented in previous assessments (IWC, 2000; Belikov and Boltunov, 2002; Boltunov and Belikov, 2002) was based on the expert opinion of the two scientists with access to limited opportunistic data, which are now outdated. Sightings data from 2001 to 2016 also came mostly from opportunistic observations during oil/gas exploration, tourist cruises, and scientific expeditions. Based on this information, belugas are thought to concentrate in summer mostly in the estuaries of large rivers (Ob, Yenisey) and in the waters of the archipelagos (Franz Josef Land, south of Novaya Zemlya, Severnaya Zemlya). Satellite tracking of a single individual tagged in north-eastern Ob Gulf (Kara Sea) was consistent with the hypothesis that during summer and autumn these belugas stay mostly in shallow coastal waters. No data are available on migratory routes. Most of the recent observations of belugas in winter were in the Kara Sea. The winter distribution likely depends at least partly on ice conditions (polynyas and ice cracks) which in turn could be influenced by icebreaker traffic, and consequently increased observation effort, in certain areas.

Analysis of mtDNA was carried out on samples from 21 belugas either found dead or harvested between 1940 and 1960 or 2012 and 2015. Most of the samples were from the Kara Sea and one was from the Laptev Sea. The analysis revealed mitochondrial haplotypes in common with or similar to those of belugas in Svalbard, the Chukchi Sea, and the Bering Sea (Meschersky et al., 2018). However, the number of genetic samples from the Russian Arctic is too limited to determine structure within this stock. There are likely several different aggregations in the major bays, estuaries, and archipelagos that could be considered stocks if more information was available.

Habitat concerns include rapidly increasing development and shipping activity in the region; there is also increased military activity in Franz Josef Land and possibly other parts of the region. Major anthropogenic threats include oil/gas (Barents and Kara seas) and military (Wezeman[53]) (all seas) activities, increasing vessel traffic (oil/gas fleet, tourism, military, shipping on the Northern Sea Route), and chemical and radioactive contamination from river discharges.

Workshop Discussion

There is not enough information to delineate stocks in the western and central Russian Arctic except within the White Sea (see item 22 below). Belugas appear to have a broad distribution across the entire region, likely at low densities in many areas, with concentrations around Franz Josef Land and in some river mouths. There is no information on current abundance or trends, genetic differences, or movements, and only limited information on distribution. Many of the aggregations in this region may have been depleted by historical commercial exploitation. Although genetic structure within the region is likely to exist, it will be difficult to delineate without additional information and samples.

There is no information to suggest a link between belugas in this area to Svalbard belugas other than that they share some haplotypes (Glazov et al.[54]). Satellite-tracked belugas remained near Svalbard through the summer, indicating geographical separation between

[53]Wezeman, S. T. 2016. Military capabilities in the Arctic: A new cold war in the high north? SIPRI (avail. at https://www.sipri.org/sites/default/files/Military-capabilities-in-the-Arctic.pdf).

[54]Glazov, D. M., O. V. Shpak, I. G. Meschersky, D. M. Kuznetsova, V. V. Krasnova, and M. V. Gavrilo. Revision of information on the white whale (*Delphinapterus leucas*) population in the White, Barents, Kara and Laptev seas. Unpubl. ms.

the Svalbard and Russian stocks at least during the summer (Lydersen et al., 2001). Quotas set by Russian authorities for allowable removals of belugas in the Arctic are reportedly based on information prior to 1995, and no more recent information on abundance (or catch levels) is available.

Status

The concern level is high for belugas in the western and central Russian Arctic, in part because little is known about stock structure, movements and distribution, current abundance (numbers may be depleted), and removals, and in part because of the rapid increase in development and other human activity as the Northern Sea Route becomes more accessible for navigation.

22) White Sea

Data on distribution and movements (from stationary coastal observation sites, ship-based and aerial surveys, satellite tracking) suggest that belugas in the White Sea form a resident population which consists of several aggregations (Andrianov et al., 2009; Kuznetsova et al., 2016; Glazov et al.[54]; Chernetsky et al.[55]; Alekseeva et al.[56]; Glazov et al.[57]; Glazov et al.[58]; Svetochev and Svetocheva[59]). Field observations indicate that White Sea belugas occur in discrete summer aggregations associated with major bays: Onezhsky, Dvinskoy, and Mezen'sky. However, more data are necessary to understand population structure in detail.

Data on abundance in different seasons were obtained from aerial surveys in 2005–11. The lowest (minimum) summer abundance estimate from these surveys was more than 5,000 animals (Glazov et al.[58,60,61]). The winter (March) estimates were 3.5–4 times lower than the July estimates in the corresponding years. Reports on earlier surveys do not contain enough information on survey design, analysis methods, and area coverage to assess population trends. The estimates from the six surveys conducted from 2005 to 2011 show a slight decline within this period, but the general pattern is variable from year to year (Glazov et al.[54]).

Records of hunting from this population go back to the 15th century (Alekseeva[62]). Commercial hunting of belugas ended in the White Sea in the 1980's (Matishov and Ognetov, 2006). In recent years, small numbers have been live-captured in the Varzuga River mouth for scientific research and "cultural display" purposes (exact numbers are unavailable, but usually not more than five or six were taken during a given capture operation). No information is available on illegal killing of belugas by local people. If this occurs at all, it probably does not exceed several whales in a year (Glazov et al.[54]). The total allowed take of belugas in the White Sea, issued annually by the Ministry of Agriculture, has been 50 for at least the last five years. No information is available on incidental mortality.

Concerns include direct disturbance of nursery aggregations by tour boats and other boat traffic, conflict with salmon fishermen, coastal oil storage bases and oil transport, and pollution, mostly from discharges from the Severnaya Dvina River. No official status is assigned to this stock, but the general opinion of Russian scientists is that the White Sea stock should be closely monitored due to the increasing human activity and high pollution levels in the region. Certain resident nursery groups of belugas, especially the one near Bolshoy Solovetsky Island (Solovetskoe local aggregation), require special protection.

Genetic information regarding White Sea belugas is limited. However, a study comparing Svalbard, West Greenland, and a few samples from the White Sea suggested some level of divergence between the White Sea and the other Atlantic strata (O'Corry-Crowe et al., 2010). Many of the mtDNA haplotypes previously documented in the Beaufort Sea and the Canadian High Arctic were also found in Svalbard and the White Sea, although one unique haplotype was found in the White Sea.

[55]Chernetsky, A. D., V. M. Belkovich, and V. V. Krasnova. 2002. New data on population structure of white whales in the White Sea. Marine Mammals of Holarctic: Materials of The 2nd International Conference, Lake of Baikal, Russia, Sept. 10–15, 2002: 279-282 (avail. at http://marmam.ru/upload/conf-documents/mmc2002_full.pdf).

[56]Alekseeva, Ya. I., V. V. Krasnova , R. A. Belikov, and V. M. Bel'kovich. 2012. The comparative characteristic of three regular summer gathering of belugas (*Delphinapterus leucas*) in the White Sea. Marine Mammals of Holarctic: Collection of scientific papers of the 7th Intl. Conf., Suzdal, Russia, 24–28 Sept. 2012, Vol. 1: 33-37 (avail. at http://marmam.ru/upload/conf-documents/mmc2012_full.pdf).

[57]Glazov, D. M., V. I. Chernook, E. A. Nazarenko, K. A. Zharikov, O. V. Shpak, and L. M. Mukhametov. 2010. Summer distribution and abundance of belugas in the White Sea based on aerial survey data (2005–2008). Marine Mammals of Holarctic: Collection of scientific papers of the 6th Intl. Conf., Kaliningrad, Russia, 11–15 Oct. 2010:134–140 (avail. at http://marmam.ru/upload/conf-documents/mmc2010_full.pdf).

[58]Glazov, D. M., O. V. Shpak, D. M. Kuznetsova, D. I. Ivanov , L. M. Mukhametov, and V. V. Rozhnov. 2012. Preliminary results of tracking the beluga whale (*Delphinapterus leucas*) movements in the White Sea in 2010–2011. Marine Mammals of Holarctic: Collection of scientific papers of the 7th Intl. Conf., Suzdal, Russia, 24–28 Sept. 2012:172–177 (avail. at http://marmam.ru/upload/conf-documents/mmc2012_full.pdf).

[59]Svetochev V. N., and O. N. Svetocheva. 2012. Study of marine mammals in the White and Barents seas using satellite telemetry: results and prospects Marine Mammals of Holarctic: Collection of scientific papers of the 7th Intl. Conf., Suzdal, Russia, 24–28 September, 2012, Vol. 2:209–213 (avail. at http://marmam.ru/upload/conf-documents/mmc2012_full.pdf).

[60]Glazov, D. M., V. I. Chernook, K. A. Zharikov, E. A. Nazarenko, L. M. Mukhametov, and A. N. Boltunov. 2008. Aerial surveys of white whales (*Delphinapterus leucas*) in July in the White Sea (2005–2007), distribution and abundance. Marine Mammals of the Holarctic. Collection of Scientific Papers. Odessa, p. 194–198 (avail. at http://marmam.ru/upload/conf-documents/mmc2008_full.pdf).

[61]Glazov, D. M., E. A. Nazarenko, V. I. Chernook, D. I. Ivanov, O. V. Shpak, and B. A. Solovyev. 2010. Assessment of abundance and distribution peculiarities of beluga whales (*Delphinapterus leucas*) in the White Sea in March 2010. Marine Mammals of Holarctic: Collection of scientific papers of the 6th Intl. Conf., Kaliningrad, Russia, 11–15 Oct. 2010:140–145 (avail. at http://marmam.ru/upload/conf-documents/mmc2010_full.pdf).

[62]Alekseeva, Ya. I. 2008. The history of harvest of marine mammals of the White Sea–Barents Sea region (15th century through 1915). Marine Mammals of Holarctic: Collection of scientific papers of the 5th Intl. Conf., Odessa, Ukraine, 14–18 October, 2008:35–38 (avail. at http://marmam.ru/upload/conf-documents/mmc2008_full.pdf).

Workshop Discussion

Although the IWC review listed three stocks of belugas in the White Sea (IWC, 2000), and subsequent notes and publications have recognized up to eight different aggregations (Chernetsky et al.[55]), more data are needed to determine whether, and how, stocks in this region should be separated. Genetic studies have detected differences between belugas in the Varzuga River estuary and Onezhysky Bay (Meschersky et al., 2018), but these differences are not significant due to the small sample sizes. Additionally, researchers in the area note that there is movement between the bays, and that these belugas all appear to remain in the White Sea throughout the winter.

Status

The White Sea stock appears to be stable, but it is of moderate concern. The main reasons are the insufficiency of data (specifically the uncertainty around stock structure) and habitat concerns related to pollution (especially discharge from the Severnaya Dvina River), ship traffic (Arkhangelsk is one of the major ports for Northern Sea Route traffic), and tourism.

Narwhals

Overall Introduction

Narwhal distribution is centered in the Atlantic Arctic. Narwhals are most numerous in the eastern Canadian Arctic and along the west coast of Greenland, but they are also found in low densities in East Greenland and the northern parts of the Svalbard and Franz Josef Land archipelagos. There are rare sightings outside this range, particularly in both High Arctic Russian and Alaska waters (Fig. 2: distribution map). Narwhals are mostly migratory and closely associated with the seasonal distribution of sea ice.

Narwhals have remarkably low levels of genetic diversity based on mtDNA (Palsbøll et al., 1997), a condition which may date back 50,000 years (Garde[63]). The low levels of genetic variability in populations in Greenland and Canada suggest a bottleneck in "recent" history (Palsbøll et al., 1997). Studies using ancient DNA to determine when this bottleneck occurred and to infer the reasons behind it continue. While it is possible to distinguish different populations of narwhals on a broad scale (e.g., Baffin Bay vs. East Greenland), it is currently not possible, due to the lack of genetic diversity, to tease apart stocks on smaller scales (e.g., to differentiate separate stocks within Baffin Bay). New genomic sequencing techniques may be used for this purpose in the future.

Stable isotope analyses of carbon (δ13C) and nitrogen (δ15N) found that the tissues of narwhals from three narwhal populations—Baffin Bay, Northern Hudson Bay, and East Greenland—have distinct stable isotope values, suggesting that these populations feed on different prey (Watt et al., 2013).

Narwhals are migratory, and the concept of "summer aggregations" has been used as the primary basis for identifying separate stocks, particularly in Baffin Bay (Heide-Jørgensen et al., 2013b). The workshop recognized 12 stocks of narwhals (Fig. 2, Tables 1–3), and this list is compared with those produced by previous assessments in Table 4.

Extralimital sightings (or what may be changes in narwhal distribution and movements in response to changing environmental conditions) have become more frequent in recent years in the Inuvialuit Settlement Area of the eastern Beaufort Sea, which is further west than the normal distribution of the closest stock, the Somerset Island stock. In addition, there have been a few scattered sightings in eastern Siberia, and along the north coasts of Chukotka (including a few tusks found) and Alaska. It is unknown whether narwhals sighted in these latter areas are from the East Greenland population to the west or instead the Baffin Bay population to the east.

Baffin Bay Introduction

Baffin Bay narwhals are divided into eight stocks, or summer aggregations, that migrate between, and are susceptible to hunting in, Greenland and Canada. These stocks are: Somerset Island, Eclipse Sound, Admiralty Inlet, Eastern Baffin Island, Jones Sound, Smith Sound, Inglefield Bredning, and Melville Bay. All of these whales were treated as a single regional stock in the 1999 IWC review (IWC, 2000; Table 4); however, since that time tagging studies have demonstrated fidelity to summering areas, and management has treated the summer aggregations as stocks. A bilateral management body, the Canada/Greenland Joint Commission on the Conservation and Management of Narwhal and Beluga (JCNB), is responsible for managing the exploitation and ensuring conservation of these narwhals. To this end, the JCNB provides advice on research, conservation, and management of narwhals and belugas to the management bodies of the two countries. The JCNB Scientific Working Group meets jointly with the NAMMCO Scientific Committee Working Group on the Population Status of Narwhal and Beluga in the North Atlantic.

The NAMMCO-JCNB Joint Scientific Working Group has developed a "catch-allocation model" to assign the catches of narwhals, by season and for different hunting communities in Canada and Greenland, to stocks (NAMMCO[64]). The model is based on information concerning narwhal seasonal movements (e.g., from satellite tracking, local and expert knowledge of hunters and scientists from Greenland and Canada) and hunting locations, so that takes by communities that hunt both on a summer aggregation and on migrating narwhals

[63]Garde, E. 2011. Past and present population dynamics of narwhals *Monodon monoceros*. PhD Dissert., Faculty Sci., Univ. Copenhagen, 2011, 252 p.

[64]NAMMCO. 2015. NAMMCO-JCNB Joint Scientific Working Group on Narwhal and Beluga, 11–13 March 2015, Ottawa, Canada (avail. at http://nammco.wpengine.com/wp-content/uploads/2016/09/JCNB-NAMMCO-JWG-March-2015-Main-Report-FINAL.pdf).

during fall, winter, or spring are assigned appropriately. Where more than one stock is thought to be migrating past a community in the same season, the takes are allocated on the basis of the relative sizes of the two (or more) stocks (Watt et al., 2019).

The NAMMCO catch-allocation model is used with a multi-stock risk assessment model which uses population dynamics models for each of the eight summer aggregations simultaneously (Witting et al., 2019). In an iterative process, the eight populations are projected forward one year (i.e., one year of growth), then the allocation model is updated and the removals (landings + struck-but-lost) from that year are allocated and removed from the stocks to get the population sizes after accounting for hunting. The process is then repeated for the next year. Management advice is derived from this risk assessment process which uses a Bayesian framework and estimates the population parameters and the probability of decline under various removal levels. A few of the Baffin Bay summer aggregations have just one abundance estimate and no information on trends to inform the models. For these data-poor stocks, a PBR is calculated post hoc using the abundance estimated by the model to provide an alternative to the management advice based on the model.

The multi-stock risk assessment model, i.e., the combined population dynamics and catch-allocation model, can be used to determine where more research, such as satellite tracking or updated abundance estimation, is needed and to assess the benefits of such research in the form of improved management advice. The ability to assign individuals to their appropriate summer aggregation via genetic or other data would greatly improve the input data for the allocation model.

1) Somerset Island

The Somerset Island (SI) narwhal stock is defined on the basis of a consistently observed summer aggregation in Peel Sound in late July–early August according to local knowledge, telemetry tracking, aerial surveys, genetics, and stable isotopes. The SI stock is the largest narwhal stock in terms of both area of distribution and number of whales. The summering area includes Prince Regent Inlet and the Gulf of Boothia, Peel Sound, Barrow Strait, and northern Foxe Basin, and in recent years the summer distribution has occasionally extended west to the Cambridge Bay area. Satellite-tagged narwhals remained in the Somerset region during summer and returned there after spending the winter in an area of Baffin Bay slightly north of where other summer aggregations spend the winter (Heide-Jørgensen et al., 2003a; Dietz et al., 2008). There is some genetic support for delineation of this stock (Petersen[4]) and stable isotope values from skin samples differ from some of the other Baffin Bay whales hunted in other regions, suggesting a degree of separation based on foraging (Watt et al. [5]).

The most recent (2013) abundance estimate for the SI stock is 49,768 (CV=0.20), including a correction for perception bias using mark-recapture line transect data collected during the survey and an availability bias correction factor of 2.94 (CV =1%) for water with visibility to 2 m depth based on dive data from 27 tagged narwhals (Doniol-Valcroze et al.[65]). This stock, or portions of it, were surveyed in 1981, 1984, 1996, 2002–2004, and 2013, and results of the five surveys conducted over the past 30 years suggest an increasing stock (Witting et al., 2019; NAMMCO[64]).

In Canada, the SI stock is hunted primarily during summer in the central Canadian Arctic by hunters from Gjoa Haven, Hall Beach, Igloolik, Kugaaruk, Resolute/Creswell Bay, and Taloyoak (Heide-Jørgensen et al., 2013b); however, hunters from other communities can hunt these whales on their migration to and from the summering areas in Nunavut and in the wintering areas off Greenland (NAMMCO[64]) (see below).

The current Canadian quota known as Total Allowable Landed Catch (TALC) is set at 532 for this stock, based on the abundance estimate from the 2002 survey, whereas a new recommendation (which has not yet been implemented) based on the 2013 aerial survey results is for a TAT of 658. The reported annual take (including estimated struck-but-lost using a multiplier based on observations of open-water hunting) in the summer during 1970–2015 ranged from 0 to 220 whales.

The SI stock is hunted in its winter habitat off Greenland. Ninety-seven percent of the Greenland harvest of this stock is by Uummannaq hunters (yearly quota=61). Narwhal catches in some years prior to the introduction of the quota at Uummannaq in 2004 were close to 1,000 animals (e.g., 1990).

Removals from this and other stocks in the Baffin Bay population are now managed according to the NAMMCO-JCNB catch-allocation model and are considered sustainable[64]. Despite the quota for Uummannaq, attention is still needed to document and/or reduce struck-but-lost rates in this area. Another aspect needing attention is that substantial numbers of animals from this stock are taken in the floe-edge and ice-crack hunts at Pond Inlet and Arctic Bay, which can have relatively high associated loss rates.

Habitat concerns include increased shipping and icebreaking in the Northwest Passage, much of it to service development activities in the region. Reduction of sea ice and other changes resulting from climate warming in the Arctic are other concerns.

Workshop Discussion

This is the largest narwhal stock, numbering around 50,000 animals. The summer distribution is extremely variable, depending on pack-ice movements as narwhals with young calves show a strong preference for staying near the ice. It is likely that this stock will be subdivided as more becomes known about it, given the vast summer

[65]Doniol-Valcroze, T., J. F. Gosselin, D. Pike, J. Lawson, N. Asselin, K. Hedges, and S. Ferguson. 2015. Abundance estimates of narwhal stocks in the Canadian High Arctic in 2013. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/060. v + 36 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/Library/362110.pdf).

range in the Canadian Arctic that is currently attributed to this stock.

In recent years, because of reduced sea ice (possibly exacerbated by icebreaking) narwhals presumed to be from this most western Canadian stock have been appearing more regularly and in larger numbers in settlements to the west of Somerset Island. This has required reallocation of the quota tags used to control and monitor removals by Canadian hunters. According to residents of the Gulf of Boothia region (Kugaruuk—formerly Pelly Bay), whose communities were formerly supplied by aircraft, in recent years icebreaking ships have been used instead and this has resulted in narwhals appearing there more regularly than in the past, presumably because they took advantage of leads and cracks created by the icebreakers.

Status

Although removals are significant, they appear to be sustainable given the large size of the stock. There is no evidence that the stock is depleted. There are environmental concerns related to the loss of sea ice, icebreaking, and industrial development in some areas. Overall, there is a low level of concern for this stock.

2) Jones Sound

Narwhals in Jones Sound are genetically distinguishable from other Canadian stocks, and from those sampled in Inglefield Bredning, Greenland (Petersen et al.[4]). Thus, they are considered a distinct stock. Additionally, organochlorine contaminant profiles in whales sampled in Grise Fiord, which are believed to be part of the Jones Sound stock, were notably different from whales sampled in Pond Inlet from the Eclipse Sound stock (de March and Stern[2]). Little is known about movements or dive behavior of narwhals in Jones Sound since there have been no telemetry studies there.

An aerial survey conducted in 2013 resulted in an abundance estimate of 12,694 (CV = 0.33) narwhals (Doniol-Valcroze et al.[65]). This is the only survey that has been conducted in the area occupied by the Jones Sound stock, and no trend information is available.

In the Jones Sound region, the stock is hunted primarily by Inuit of Grise Fiord in summer (Heide-Jørgensen et al., 2013b). A recommended TALC of 40 has been in place since 2013, but fewer than 20 narwhals/yr have been landed by Jones Sound hunters since then. Hunters from other communities (including those in Greenland) may hunt these whales along their migration route to and from the summer range, and on the winter range. However, there are no satellite-tagging data from Jones Sound, and the migration corridors and winter range of these whales are not known.

Workshop Discussion

The only current habitat concern for the Jones Sound stock is the loss of sea ice, although the possible development of a coal mine on northern Ellesmere Island was discussed in Canada several years ago. It is likely that additional development projects will occur in the area in the future as sea ice continues to decline.

Status

The level of concern for this fairly large stock of around 12,000 animals, which is not heavily hunted, is low. There is little development in the region thus far, although this is likely to change as sea-ice conditions change.

3) Smith Sound

Stock identity of Smith Sound narwhals is based on observations and catches of narwhals there during summer. Tissue samples have not been collected and very limited telemetry studies have been carried out on narwhals in Smith Sound; thus their relationship to narwhals in Inglefield Bredning is uncertain.

An aerial survey in 2013 resulted in an abundance estimate of 16,360 (CV=0.65) for the Smith Sound stock (Doniol-Valcroze et al.[65]). As this is the only survey that has been conducted in Smith Sound, there is no information on trend.

Little is known about the movements or total range of narwhals that occupy Smith Sound seasonally. A male tagged along the ice edge at Renselaer Bay on the Greenland side of the sound was tracked for only three days, during which time it moved across Smith Sound to Cape D'Urville on the Canadian side (Heide-Joergensen[66]).

No communities in Canada are known to hunt narwhals from the Smith Sound stock, although the stock is hunted by Greenlandic hunters from Qaanaaq. A TALC of 77/yr was recommended in Canada based on the abundance estimate from the 2013 survey. The current quota for narwhals taken from the Smith Sound stock in Greenland (Etah hunting region) is 5/yr.

There is a small amount of development in the area, and future development possibilities exist.

Workshop Discussion

In the complete absence of sampling and analysis, there is no basis, other than geographical, to differentiate the Smith Sound stock from other narwhal stocks such as the Inglefield Bredning or Jones Sound stock.

Status

As with the Jones Sound stock, there is low concern for this fairly large stock (around 16,000 animals) that is apparently subjected to little hunting.

4) Admiralty Inlet

The Admiralty Inlet (AI) stock is defined on the basis of a consistent summer aggregation reported via local knowledge, telemetry tracking, and aerial surveys. Satellite-tagged narwhals have remained in Admiralty Inlet during summer and returned there after spending winter in the Baffin Bay region (Dietz et al., 2008; Watt et al.[6]). There is no strong genetic support for delineation of this stock; however, stable isotope values from skin samples differed significantly from those of

[66]Mads Peter Heide-Jørgensen, Greenland Institute of Natural Resources c/o Greenland Representation, Strandgade 91, 2. sal, 1401 København K, Denmark.

whales in other regions, indicating a degree of separation based on foraging tendencies (Watt et al.[5]).

The most recent (2013) abundance estimate for the AI stock was 35,043 (CV=0.42), including a correction for perception bias using mark-recapture line transect data collected during the survey and an availability bias correction factor of 2.94 (CV =1%) for water with visibility to 2 m depth based on dive data from 27 tagged narwhals (Doniol-Valcroze et al.[65]). Five surveys of the AI stock have been conducted over the past 30 years, with no indication of a significant change in abundance over time (Richard et al., 2010; Witting et al., 2019; Asselin and Richard[67]).

The AI stock is hunted primarily by the community of Arctic Bay (Heide-Jørgensen et al., 2013b). However, hunters from other communities hunt these whales on their migration to and from the summer range and on the winter range (Watt et al., 2019). While the current TALC for this stock is 233, based on the abundance estimate from the 2010 survey (DFO[68]), the recommended TALC based on the 2013 aerial survey is 389 whales (Doniol-Valcroze et al.[65]). The reported annual removals (including struck-but-lost estimates applied for open-water hunting) from the summer hunt during 1970–2015 ranged from 32 (in 1987) to 276 (in 2015) whales, with an average of 181 per year for the 10-yr period between 2006 and 2015. The stock is also hunted on the winter range in Greenland, where 2% of the landed catch in Uummannaq (yearly quota=61) is from the AI stock and 32% of the landed catch in Disko Bay (yearly quota=108) consists of AI animals (NAMMCO[64]).

The distribution of the AI narwhal stock likely overlaps that of the Eclipse Sound (ES) stock in summer. The AI and ES stocks were both surveyed in 2010 and 2013. The sums of the abundance estimates for the two stocks were similar in 2010 and 2013. However, the AI estimate increased between 2010 and 2013 by approximately the same amount as the ES estimate decreased, suggesting that narwhals counted in the ES stock in 2010 moved to AI prior to the survey in 2013. Also, 4 of 12 narwhals tagged during summer in Eclipse Sound in 2010 and 2011 traveled into Admiralty Inlet in September/October of the same year (n = 3), or during the following summer (n = 1) (Watt et al.[6]). Nevertheless, a precautionary approach has been applied by continuing to manage the narwhals in AI and ES as separate stocks pending stronger evidence to support combining them. This is seen as a means of minimizing the risk of stock depletion.

Ship traffic in Baffin Bay may affect this stock in its winter range. Although abundance estimates vary across surveys, the AI stock is considered stable, and current removals are thought to be sustainable (Witting et al., 2019; NAMMCO[64]).

Workshop Discussion

This stock is hunted in summer by Inuit from Arctic Bay, at the floe edge in spring by hunters from Pond Inlet, and in at least the Disko Bay area of Greenland in winter. Hunters from Arctic Bay previously took many narwhals at the Admiralty Inlet floe edge, which included whales from both the Somerset Island and Admiralty Inlet stocks. Now much more of the Arctic Bay hunting occurs in summer, which means there is greater pressure on the Admiralty Inlet stock to supply the relatively large Arctic Bay quota.

The time series of abundance estimates suggests that this stock is fairly stable, although the estimates are quite variable across years (differing by over 10,000 animals) and have large confidence intervals.

There are concerns over increased disturbance in the summer habitat by freighters, cruise ships, and supply vessels. Closure of the Nanisivik lead-zinc mine in 2002 may have resulted in reduced icebreaking activity in and immediately outside Admiralty Inlet.

Status

In spite of the habitat concerns related to shipping and icebreaking, the concern level for this stock is low because of its relatively large size and the assumption that removal levels are sustainable.

5) Eclipse Sound

Designation of Eclipse Sound narwhals (ES) as a separate stock is supported by telemetry studies which showed that most individuals tagged in the sound stayed there through the summer and returned the following summer (Dietz et al., 2001; Heide-Jørgensen et al., 2002; Watt et al.[6]). However, one whale tagged in Eclipse Sound returned the following year to Admiralty Inlet after overwintering in Baffin Bay, and a telemetry study in 2010–11 showed that 3 of 12 narwhals tagged in Eclipse Sound during summer moved into Admiralty Inlet in September/October (Watt et al.[6]), indicating that there is some movement between the two stock areas.

The most recent (2013) abundance estimate for the ES stock was 10,489 (CV = 0.24) (Doniol-Valcroze et al.[65]). Given that only two surveys of the ES stock have been undertaken, a trend in abundance cannot be determined. In Canada, the stock is hunted primarily by the community of Pond Inlet in summer (Heide-Jørgensen et al., 2013b), but hunters from other communities in both Canada and Greenland hunt ES narwhals on their migration to and from the summer range and in the wintering areas (Witting et al., 2019; NAMMCO[64]). The current Canadian TALC is set at 236 for this stock, although a new TALC of 134 was recommended (but has not yet been implemented) based on the 2013 aerial survey results (Doniol-Valcroze et al.[65]). The reported annual removals (landed catch multiplied by a 1.28 struck-but-lost factor) by Pond Inlet hunters from 1970 to 2015

[67]Asselin, N. C., and P. R. Richard. 2011. Results of narwhal (*Monodon monoceros*) aerial surveys in Admiralty Inlet, August 2010. DFO Can Sci Advis Sec Res Doc 2011/065: iv + 26 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

[68]DFO. 2012. Abundance and total allowable landed catch for the Admiralty Inlet narwhal stock in 2010. DFO Can Sci Advis Sec Sci Advis Rep 2012/048 (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

ranged from 41 (in 1972) to 256 (in 1973) narwhals, and the average for the 10-yr period from 2006 to 2015 was 130.

Like the SI and AI stocks, animals from this stock are subject to hunting at the Lancaster Sound floe edge in spring (by hunters from Pond Inlet), off eastern Baffin Island in the fall, and in West Greenland in winter.

In the wintering areas in Greenland, 1% of the landed catch in Uummannaq (yearly quota=61) and 52% of the landed catch in Disko Bay (yearly quota=108) are believed to be from the ES stock (NAMMCO[64]).

As noted earlier, the summer and autumn ranges of ES and AI narwhals may overlap. Eclipse Sound has been identified as an important area for narwhal calving (Mathewson[69]), and increased shipping and icebreaker traffic associated with mineral resource development are potential threats to this stock on both its summer and winter range.

Habitat concerns include boat disturbance from hunting, shipping, and tourism, and icebreaking. Narwhals are hunted intensively in summer in Eclipse Sound, and, in addition, they are exposed to heavy and increasing large-vessel traffic, including cruise ships and the freighters traveling to and from the Milne Inlet port for the Baffinland-Mary River iron mine. Pond Inlet experienced a threefold increase in vessel traffic between the 1990's and 2015, primarily cruise ships and transport vessels related to the iron mine (Dawson et al., 2018), which is likely to have significant impacts on the behavior and distribution of the whales in this important summer habitat (DFO[70]).

[69]Mathewson, S. 2016. Narwhal nursery located in busy Canadian waters; are the elusive sea animals at risk? *Nature World News* (avail. at https://www.natureworldnews.com/articles/19238/20160108/narwhal-nursery-found-busy-waters-canada-elusive-sea-animals-risk.htm).

[70]DFO. 2014. Science review of the final environmental impact statement addendum for the early revenue phase of Baffinland's Mary River Project. DFO Can. Sci. Advis. Sec. Sci. Resp. 2013/024 (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

Two large ice-entrapment events, resulting in the deaths of over 900 narwhals, have been documented in the last 10 years for this stock. In 2008, over 650 narwhals were trapped and in 2015 at least 250 narwhals were trapped. Although the cause of these entrapments cannot be confirmed, it has been suggested that seismic surveys (Heide-Jørgensen et al., 2013a) and ship traffic delayed the narwhals' movements out of their summering areas, making them more susceptible to entrapment by fast-forming sea ice.

Workshop Discussion

Telemetry results and the summer residency of narwhals in Eclipse Sound constitute the basis for distinguishing between the Eclipse Sound and Admiralty Inlet stocks. There is some movement of animals between these two summering areas, including the "switching" from Eclipse Sound the first year to Admiralty Inlet the next year by the one whale whose tag continued transmitting long enough to monitor its return northward migration after being tagged in Eclipse Sound in the previous summer. Inuit in the area believe strongly that two different kinds of narwhals, which differ in appearance, visit Eclipse Sound. Additional telemetry work is therefore important to clarify movement patterns and stock delineation.

Status

Although a trend in abundance cannot be determined, this stock appears to be stable at around 10,000 narwhals and removals are thought to be sustainable. However, there is considerable uncertainty about the abundance estimates and some uncertainty about stock differentiation (from the Admiralty Inlet stock). A major and growing concern is ship traffic related to the Baffinland-Mary River iron mine and tourism. Overall, the Eclipse Sound stock of narwhals is of moderate concern.

Update

In 2017 three of nine narwhals tracked with satellite transmitters attached during August in Eclipse Sound moved to Admiralty Inlet that same month and did not return to Eclipse Sound that summer (Marcoux[71]). This shows that some narwhals use both areas during summer.

6) Inglefield Bredning

The Inglefield Bredning narwhal stock (IB) is defined on the basis of a consistent summer aggregation, aerial survey results, local knowledge, and hunting patterns. Migration timing and routes for this stock are unknown but a portion of the whales that winter in the North Water polynya (NOW) could be the same narwhals that summer in Inglefield Bredning. An aerial survey of the eastern part of the NOW conducted in April 2014 resulted in an estimate of 3,059 narwhals (95 % CI 1,760–5,316; Heide-Jørgensen et al., 2016), however the western portion was not surveyed so the total number wintering in the NOW could not be estimated.

Genetic differences have been documented between Melville Bay narwhals and narwhals from the Avernersuaq district, which includes Inglefield Bredning (Palsbøll et al., 1997). Hence, little gene flow is thought to occur between these areas.

The most recent abundance estimate for the Inglefield Bredning stock was 8,368 (cv=0.25; 95% CI 5,209–13,442) from a visual aerial line transect survey conducted in the summer of 2007 (Heide-Jørgensen et al., 2010b). The estimate was corrected for whales missed by observers using data from paired observers in a sight-resight line transect analysis and multiplied by 4.76 (CV=0.04) to account for submerged whales based on the portion of time spent above 2 m depth for two whales tagged with satellite-linked time-depth recorders. The distribution of narwhals in Inglefield Bredning was in good agreement with what was documented during aerial surveys in 1985–86 and 2001–02 (Born et al., 1994; Heide-Jørgensen, 2004).

[71]Marcoux, Marianne. Dep. Fish. Oceans Canada, 501 Univ. Crescent, Winnipeg, Manitoba R3T 2N6, Canada.

Abundance estimates have been stable for this population over time. The estimated trajectory for the stock comes from a population dynamics model, based on a Bayesian framework, that is age- and sex-structured (Witting et al., 2019). According to the model, the Inglefield Bredning stock is depleted to below its Maximum Sustainable Yield Level (MSYL).

The IB stock is hunted in the Qaanaaq region during April–September (by hunters from the communities of Qaanaaq, Qeqertat, and possibly Siorapaluk). Quotas are set on the basis of the NAMMCO-JCNB catch allocation model (Watt et al., 2019). In the municipality of Qaanaaq, local hunting rules require that hand-harpoons are used to strike the whales (and thereby tether them to a drag or float) before they can be shot (harpoon-first requirement). This reduces the loss rate considerably. A loss rate of 5% is arbitrarily applied to the catches to account for both whales that are killed-but-lost and calves that lose their mothers. Annual removals averaged 112 narwhals for the 10-year period from 2005 to 2014; these include 94 animals taken from two ice entrapments so that removals by hunting averaged around 103/yr.

The total allowable take for the Inglefield Bredning stock is 98 individuals per year (2015–20), which allows for a 70% probability that the stock's abundance will be increasing by 2020.

Concerns for the IB stock include changes in the sea-ice regime, ship traffic, seismic surveys, and competition with fisheries for Greenland halibut, *Reinhardtius hippoglossoides* (Laidre et al., 2008, 2015).

Workshop Discussion

The stock appears to be stable, but there are several environmental concerns and the depletion level estimated by the model is also a concern. The depletion below MSYL indicates that future harvest levels should be set to ensure recovery to at least MSYL. Information is lacking on the distribution of this stock in winter when it may be hunted in other locations. An additional consideration, however, is that some narwhals from other stocks may still be present in the NOW when hunting begins in April, therefore it is possible that not all of those taken in the NOW are from the IB stock (Watt et al., 2019).

Status

This is a moderate-sized, apparently stable stock. While the recent average number of removals has been around 5% above the TAT for the next management period, the current removal levels are considered sustainable. Overall, the concern level for this stock is low, assuming that no major change occurs in human activities in the region.

7) Melville Bay

Stock identity of narwhals in Melville Bay (MB) is based on consistent summer aggregation, telemetry tracking, genetics, aerial surveys, local knowledge, and hunting patterns. The most recent (2014) abundance estimate for the MB stock is 3,091 (CV=0.50; 95% CI 1,228–7,783) (Hansen et al.[72]). The estimate was corrected for both perception and availability bias. The correction factor for at-surface availability was based on monitoring of five tagged whales from August to September in Melville Bay (a=0.22; CV=0.09); note that the at-surface abundance is divided by the correction in this case (equivalent to multiplying by 4.55).

Animals in this stock are hunted primarily by communities in the Upernavik region during July–October, but they are also hunted in Uummannaq during November–May and Disko Bay during December–April. Quotas were first implemented in 2004 and are now set on the basis of the NAMMCO-JCNB catch allocation model (Watt et al., 2019). During the period 2004 through 2014 total removals by hunting (including estimated struck-but-lost) averaged 305/yr. During the same period 219 narwhals were taken from three ice entrapments.

For Greenland overall, it is assumed that a struck-but-lost correction factor of 1.30 covers both the open-water hunt and the hunt from ice cracks and the ice edge (for the Melville Bay-Upernavik area a factor of 1.15 is used). Catches of whales from the MB stock are however made in both the municipality of Uummannaq and in Upernavik. Roughly half of the narwhals taken in Upernavik and Melville Bay are taken under the harpoon-first requirement (5% loss rate) and the other half are taken in ice-edge and open-water situations where the loss rate is higher (Garde et al., 2019).

The MB stock is considered depleted to below MSYL, indicating that future removal levels should be set to ensure the population will increase. The total allowable take recommended by the NAMMCO-JCNB Joint Scientific Working Group (JWG) for the MB stock is 84 individuals per year (in the period 2015–20), allowing for a 70% probability that abundance will be increasing by 2020 (NAMMCO[64]). However, quotas set by Greenland do not follow the advice of the JWG.

The greatest concern for the MB stock is that removals in the Upernavik hunting region greatly exceed the recommended limit. Habitat concerns include changes in the sea-ice regime, disturbance by commercial fishing, shipping, icebreaking associated with shipping, and seismic surveys, and resource competition with commercial fisheries for halibut in central Baffin Bay (Laidre et al., 2008, 2015).

Workshop Discussion

An important concern for this stock is quota levels that may cause the stock to decline. As this stock is considered depleted to below MSYL, future removal levels should be set to ensure recovery to at least MSYL.

Habitat concerns include increased commercial halibut fishing, and the likely eventual resumption of seismic survey activity in Baffin Bay. During 2012–14, there was extensive seis-

[72]Hansen, R. G., S. Fossette, N. H. Nielsen, M. H. S. Sinding, D. Borchers, and M. P. Heide-Jørgensen. 2015. Abundance of narwhals in Melville Bay in 2012 and 2014. NAMMCO/SC/22-JCNB/SWG/2015-JWG/14. Request from R. Hansen, Greenland Inst. Nat. Resour. c/o Greenland Representation, Strandgade 91, 2. sal, 1401 København K, Denmark.

mic survey activity in the summering area of this stock. Observational studies during those years suggested that habitat use by narwhals was affected, though estimated numbers of narwhals in the summering area pre- and post-seismic survey activity did not differ significantly (Hansen et al.[72])

Status

There is a high level of concern for this stock. The stock is small and likely overexploited (i.e., catches above recommended quotas), and it is subject to multiple potential threats besides hunting (e.g., disturbance from seismic surveys, icebreaking in winter).

8) Eastern Baffin Island

The recognition of Eastern Baffin Island (EBI) narwhals as a separate stock is based mainly on the consistent summer aggregation reported by local people. No tagging studies have been carried out on narwhals in the region. Although this stock cannot be distinguished using genetics, organochlorine contaminant (de March and Stern[2]) and stable isotope profiles (Watt et al.[5]) of the whales in eastern Baffin Island differ significantly from those of other narwhal stocks.

The EBI stock has been surveyed twice, resulting in a 2003 abundance estimate of 10,073 (CV = 0.34) and a 2013 estimate of 17,555 (CV = 0.35) (both adjusted for availability and perception biases) (Doniol-Valcroze et al.[65]). It is not possible to make a robust assessment of the trend from these data. The stock is hunted primarily by the Canadian communities of Clyde River and Qikitarjuak in summer and fall (Heide-Jørgensen et al., 2013b). Removal levels in these two communities are low, with about 130 narwhals reported as being landed per year since 2000. However, the two communities hunt narwhals primarily in autumn when animals from other stocks are migrating along the Baffin Island coastline, making it difficult to know which stock is being hunted (Watt et al., 2019). Other communities may hunt EBI narwhals during fall, winter, and spring. Their migration route is unknown but thought to be similar to those of the ES and AI stocks that migrate past eastern Baffin Island in fall, which would make them available to hunters in Greenland in winter (Watt et al., 2019). However, a tagging study is needed to confirm this. The EBI stock is quite large with no major conservation concerns at this time. However, relatively little information is available to inform stock assessment.

Workshop Discussion

This moderate-sized stock's status is uncertain in a number of ways. In the absence of satellite-tracking studies, it is not known how much movement there is among the various fjords along the Baffin Island coast, and the animals' wintering range is unknown. Different groups of narwhals may affiliate with different fjords, and therefore as more becomes known, this stock may require subdivision.

Although recent catch levels on eastern Baffin Island appear to have been sustainable and fairly constant (97 to 183 reported as landed per year, 2000–15), there is considerable uncertainty about stock structure. The TALC is currently set at 122, but annual removals in Canada have been about 160 (using a 1.23 struck-but-lost correction factor). The new TALC recommendation based on the 2013 aerial survey results is 206 for the stock. The stock is thought to be available to Greenland hunters for part of the year even though there is no direct evidence of movement between eastern Baffin Island and Greenland.

If the whales follow a migration route similar to those of the AI and ES stocks and overwinter in central Baffin Bay, they may be affected by icebreaker activity taking place in this region. Concerns have been expressed by communities in Nunavut about the effects on narwhals of seismic survey activities off the east coast of Baffin Island[73]. Also, impacts of climate change may render the fjord areas used by the whales in summer less suitable as habitat.

Status

Although the EBI stock is fairly large and reported removals are relatively low, there is moderate concern for the stock. Concerns relate mainly to the lack of data on movements and stock structure, the possibility that several stocks (rather than only one) inhabit the EBI region in summer, and the uncertainty about whether, and if so where, narwhals from this stock are hunted in Greenland.

9) Northern Hudson Bay

The Northern Hudson Bay (NHB) stock is considered distinct based on genetic differences (de March and Stern[2]; Petersen et al.[4]), telemetry results (Westdal et al., 2010), and contaminant and biomarker profiles (de March and Stern[2]; Watt et al.[5]). This stock was surveyed in the early 1980's (Richard, 1991a), 2000 (Asselin and Ferguson[74]), and 2011 (Asselin et al.[75]) but at different spatial scales, with different data collection methods (visual or photographic) and estimation procedures (e.g., whether perception and availability biases were accounted for or not). The 2011 visual survey data were reanalyzed using the methods of the visual surveys in 1982 and 2000 to improve comparability of the survey results. This yielded surface (i.e., uncorrected) estimates of 1,737 (95% CI: 1002–3011) in 1982, 1,945 (95% CI: 1089–3471) in 2000, and 4,452 (95% CI: 2707–7322) in 2011 (Asselin and Ferguson[74]). The 2011 surface number, corrected for per-

[73]'We thought no one would care': Clyde River Inuit flooded with support. Elyse Skura, CBC News, posted 29 Nov. 2016 5:38 PM CT. Last updated 30 Nov. 30, 2016 (avail. at https://www.cbc.ca/news/canada/north/supreme-court-indigenous-duty-to-consult-clyde-river-seismic-testing-1.3873059).

[74]Asselin, N. C., and S.H. Ferguson. 2013. A reanalysis of northern Hudson Bay narwhal surveys conducted in 1982, 2000, and 2011. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/019. v + 9 p. (avail at: http://waves-vagues.dfo-mpo.gc.ca/

[75]Asselin, N. C., S. H. Ferguson, P. R. Richard, and D. G. Barber. 2012. Results of narwhal (*Monodon monoceros*) aerial surveys in northern Hudson Bay, Aug. 2011. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/037. iii + 23 p. (avail. at http://waves-vagues.dfo-mpo.gc.ca/).

ception and availability biases, estimated abundance at 12,485 narwhals (CV = 0.26) (Asselin et al.[75])

NHB narwhals are hunted in Cape Dorset, Chesterfield Inlet, Coral Harbour, Kimmirut, Rankin Inlet, Repulse Bay, and Whale Cove (DFO unpubl. data; Watt[76]). Reported landings from this stock increased from an average of 21 (SD=8.6) whales/yr during 1979–98 to an average of 102 (SD=55) whales/yr in 1999–2001, and then declined to 83 (SD=30) during 2002–15. A Loss Rate Correction (LRC) of 1.28 has been used to account for struck-but-lost narwhals during the hunt of this stock (Asselin et al.[75]). Using the LRC gives an average of total removals of 106/yr during 2002–15. Results of the earlier surveys raised concerns about the sustainability of harvest levels; however, the abundance estimate of 12,485 narwhals in 2011 has allayed these concerns.

Modeling of the aerial survey data from the early 1980's, 2000, 2008, and 2011 using a population dynamics model with Bayesian methods and using adjustments for different survey methods suggested a rate of increase of 1.2% per year for this stock and a population size that could support a landed catch of no more than 75 narwhals per year (Kingsley et al.[77]). Another survey was planned for summer 2018.

The PBR for the NHB stock is 201 animals. With the PBR value and a LRC of 1.28, a TALC for the Northern Hudson Bay stock is 157 narwhals (Asselin et al.[75]). With the average landed catch of 83 narwhals for the period 2002–15, the current level of removal is considered sustainable. However, this region is undergoing considerable environmental change due to climate warming and loss of sea ice as well as increases in human activity (mining, shipping), which may negatively affect the stock.

Workshop Discussion

Harvest monitoring in Canada is the responsibility of local hunters and trappers organizations and the Repulse Bay hunt is generally regarded as one of the better-managed narwhal hunts. Hunters from Arviat often travel to the Repulse Bay area to hunt narwhals. Repulse Bay has relatively strict bylaws concerning hunting practices (e.g., a harpoon-first requirement) thus using the LRC of 1.28 may overestimate the struck-but-lost removals.

The loss of multi-year ice in this population's summer range means that these narwhals are increasingly vulnerable to predation by killer whales. Another concern is that shipping, often including icebreaking, is increasing rapidly in Hudson Strait. Existing or planned mines in Baker Lake and Rankin Inlet require freight shipments and visitation by resupply vessels. As the most southerly stock of narwhals in the world, the Northern Hudson Bay stock should be monitored closely for impacts of climate change and increased human activities.

Status

The NHB stock is fairly large, numbering some 12,500 animals, with no clear evidence of a trend. The current level of hunting removals is considered sustainable. Although the loss of sea ice and concomitant increases in shipping and other industrial activities are of concern, the overall level of concern for this stock is low.

10) East Greenland

The East Greenland stock of narwhals occurs along the east coast of Greenland from about lat. 64° N to lat. 72° N. In summer, the animals are found mainly in a small number of fjords and bays, the most important being the Tasiilaq Fjord (north of lat. 65° N), Kangerlussuaq Fjord (lat. 68° N), and Scoresby Sound (north of lat. 70° N), although many smaller fjords are also visited by narwhals in summer (Heide-Jørgensen et al., 2010b; NAMMCO[29]). Hunting takes place regularly only in Tasiilaq and Scoresby Sound; hunters travel to Kangerlussuaq occasionally. Reported annual landed catches have varied widely in East Greenland (Ittoqqortoormiit and Tasiilaq) with lows of 0 in 1965 and 2 in 1978 and a high of 158 in 1990; the average during 2005–17 was 77 narwhals/yr. Applying a LRC of 1.30 to the landed catch results in an estimated average of 100 removals/yr (2005–17). Aerial surveys covering areas where hunting occurs (Scoresby Sound in 1983–84, Tasiilaq to Scoresby Sound in 2008 and 2016) indicate a widely scattered population (Heide-Jørgensen et al., 2010b; NAMMCO[29]). The survey in 2016 found no narwhals south of the Kangerlussuaq area and abundance was estimated at 702 whales (CV = 0.33) down from 2759 (CV = 0.43) in 2008 (NAMMCO[78]). A decline has been observed over the past decade and reductions in the quotas (first established in 2010) have been recommended by the JWG (NAMMCO[29]). Subsequent to the GROM a workshop convened by NAMMCO in 2019 reviewed the new estimate of abundance and other observations including the apparently low reproductive rates and recommended that the quotas in the three management areas of East Greenland be set to zero (NAMMCO[78]). The catch quotas set by the Greenland government have been reduced but are higher than the recommended takes. Hunting does not fully explain the observed decline in abundance. East Greenland has experienced significant habitat changes, including a dramatic decline in sea ice and an increase in sea temperatures, with the movement of several boreal cetacean and fish species into the narwhals' habitat (Jansen et al., 2016; Hansen et al., 2019).

Workshop Discussion

Multiple environmental changes are occurring in the region, including

[76]Watt, Cortney A., Dep. Fish. Oceans Can., 501 University Crescent, Winnipeg, Manitoba R3T 2N6, Canada.

[77]Kingsley, M. C. S., N. C. Asselin, and S. H. Ferguson. 2013. Updated stock-dynamic model for the Northern Hudson Bay narwhal population based on 1982–2011 aerial surveys. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/011. v + 19 p. (avail. at: http://waves-vagues.dfo-mpo.gc.ca/).

[78]NAMMCO. 2019. Report of the ad hoc working group on narwhal in East Greenland. Sept. 2019, Copenhagen, Denmark (avail. at https://nammco.no/topics/sc-wg-reports/).

increased sea surface temperatures, rapidly retreating ice cover, and disappearance of tidewater glaciers. This may be degrading and reducing the habitat for narwhals. The arrival of temperate-zone species is likely affecting narwhals, whether through competition for prey, exposure to novel diseases, or some combination of these and/or other processes (Hansen et al., 2019). Humpback whales, *Megaptera novaeangliae,* are now regularly observed in areas where narwhals were previously present (Hansen et al., 2019). Given such changes, the indirect negative effects of climate change may overwhelm any positive effect resulting from the elimination of hunting.

Status

There is a high level of concern for narwhals in East Greenland due to the shortage of data (particularly on stock structure), low abundance, the declining trend, the likelihood of overharvest, and the numerous climate-related changes in habitat.

11) Northeast Greenland

North of Scoresby Sound, narwhals are frequently observed in Young Sound (lat. 74° N) and Dove Bay (lat. 76° N) and along the coast as far north as Nordost Rundingen (lat. 82° N) (Boertmann et al., 2009; Boertmann and Nielsen, 2010). Given the long coastline, it is possible that there are several stocks in Northeast Greenland; however, there are currently no data to determine stock structure.

The narwhals north of Scoresby Sound are protected by the Northeast Greenland National Park. No hunting takes place in marine waters along the Park's boundary and no attempt has been made to assess narwhal abundance there. Northeast Greenland is subject to exploration for oil and gas resources and small-scale seismic surveys have been conducted there over the past decade (Ahonen et al., 2017).

Workshop Discussion

This coastline is long, and it is likely that there are multiple stocks; however, there is little to no information to delineate them at this time. More information is also needed on abundance, distribution, and movements of narwhals in this region. (Update: Surveys conducted after the workshop in 2017 resulted in estimates of 1,395 narwhals (CV=0.33) in Dove Bay and 2,908 (CV=0.30) in the Greenland Sea (Reeves and Lee, 2020).

Status

There is a moderate level of concern for narwhals in Northeast Greenland. Similar to the situation for East Greenland, there is a shortage of data on abundance and stock structure, and there are climate change-related habitat concerns. Narwhals in Northeast Greenland are currently protected at least partly by the National Park. In addition to being legally protected, the narwhals have generally not been accessible to hunters due to the remoteness of their habitat and the ice coverage in this region.

12) Svalbard-Northwest Russian Arctic

Svalbard

Narwhals are only rarely observed along the coasts of Svalbard (Storrie et al., 2018). However, groups of several hundred are seen on occasion, and three juvenile narwhals from such a group were satellite-tagged in 1998 in the Wahlenberg fjord, west of Nordaustlandet. These tags operated only for short periods (4–46 days) and the whales remained relatively close to Svalbard. The two animals that moved the longest distances went to the north and east of Nordaustlandet (Lydersen et al., 2007).

There has not been a whale survey around Svalbard specifically designed to assess narwhals, but a multi-species survey in the marginal ice zone north of Svalbard in August 2015 resulted in an abundance estimate of 837 narwhals (CV= 0.50) within the 52,919 km^2 study area, with many observations close to the distal ends of the transects in very dense ice, indicating that narwhals may occur even further north (Vacquié-Garcia et al., 2017).

Effects of climate change with impacts on sea-ice conditions and prey-base composition, competition from boreal marine mammal species, and new parasites and diseases are general concerns. Also, tissue levels of some pollutants in narwhals at Svalbard are even higher than the high levels recorded in belugas or polar bears from this region (Wolkers et al., 2006).

Northwest Russian Arctic

Narwhals are seen infrequently in the Russian Arctic (Barents and Kara Seas) with the majority occurring in the vicinity of Franz Josef Land (Belikov and Boltunov, 2002). Recent information on narwhal sightings comes mostly from the annual National Park "Russian Arctic" monitoring program, as well as opportunistic observations during oil/gas geological explorations, a few scientific expeditions, and tourist cruises. Most narwhal sightings in northwestern Russia have been recorded in the waters of western Franz Josef Land from May to September with a peak in August (1990–2013) (Gavrilo and Ershov[79]; Gavrilo[80]). One sighting southeast of Franz Josef Land was made in April 2013 (Gavrilo[80]), while several sightings were recorded in the Kara Sea in autumn (September and October, 2012–13) (Rosneft[81,82]). Most sightings were of small groups with a maximum group size of around 50 whales. Presumably, narwhal movements to the waters of

[79]Gavrilo M. V., and R. V. Ershov. 2010. Notes on cetaceans of the Franz-Josef Land – Victoria region // Marine Mammals of the Holarctic. 2010. Coll. Sci. Pap., Kaliningrad, p. 120–125 (doi: https://doi.org/10.13140/2.1.3008.2248).

[80]Gavrilo, Maria. Unpubl. data: observations and data collected via pers. commun. from visitors in Franz-Josef Land. Assoc. Maritime Heritage, Icebreaker Mus., Krassin, 22, Naberezhnaya Leitenanta Shmidta, corner of 23rd Liniya, 199106 Saint-Petersburg, Russia.

[81]Rosneft. 2012. Unpubl. data on marine mammal monitoring in Rosneft license areas, provided by Rosneft to Olga Shpak and Dmitri Glazov, A. N. Severtsov Inst. Ecol. Evol. Russian Acad. Sci., 33, Leninsky Pr., 119071 Moscow, Russia.

[82]Rosneft. 2013. Unpubl. data on biological monitoring during seismic surveys in the Rosneft "Medynsko-Varandeysky" license area, provided by Rosneft to Olga Shpak and Dmitri Glazov. A. N. Severtsov Inst. Ecol. Evol. Russian Acad. Sci., 33, Leninsky Pr., 119071 Moscow, Russia.

Franz Josef Land, as with belugas in that area, are related to their feeding on Arctic cod, *Boreogadus saida* (Dahl et al., 2000). There is no information on abundance of narwhals in this region. No studies have been conducted on migratory routes or stock structure.

There have been several sightings of narwhals and discoveries of narwhal tusks in the Chukotka region in the last 20 years, and this led to listing the narwhal in the Red Book of Chukotka (Andreev et al.[83]). There is no evidence for a separate stock; rather, it is supposed that individual whales (vagrants) occasionally enter Chukotka waters. There is no traditional harvest or live-capture of narwhals in Chukotka.

Major anthropogenic threats in the Barents and Kara Seas are thought to be similar to those for belugas and include various oil/gas activities, increasing tourist and military vessel traffic (Wezeman[53]) in Franz Josef Land waters, oil/gas fleet, and other vessel and cargo traffic along the Northern Sea Route (Glazov et al.[57]).

Workshop Discussion

Narwhals are present recurrently if not regularly in this region, but there is no detailed information on their distribution, movements, stock identity, or abundance. It is not possible with the available information to determine whether there are multiple stocks and whether any of the narwhals in the region are affiliated with stocks in East or Northeast Greenland.

Most of the recent sightings of narwhals in Svalbard have been in fjords in Nordaustlandet or in Hinlopenstretet in the northeastern part of the archipelago (see Storrie et al., 2018). However, observations of individual narwhals have also occurred in recent years on the west coast of Spitsbergen (e.g., innermost Kongsfjorden and deep within Adventfjorden). Narwhals are detected regularly on passive acoustic monitoring devices to the west of Svalbard in Fram Strait (Moore et al., 2012; Stafford et al., 2012; Ahonen et al., 2017). There also seems to be a concentration of sightings around Franz Josef Land, and there are recent sightings in the Kara Sea. There are no sightings in the Laptev Sea although there has been no dedicated search effort there for narwhals and there is little traffic in the area and hence few opportunities for sightings. Most ships pass through the Laptev Sea where it is shallow and productivity is low. It is possible that narwhals are present far offshore, but at this point the gap in narwhal distribution between the Laptev Sea and the Beaufort Sea far to the east appears to be real.

The stock(s) in this area is (are) likely small but may be distributed primarily in areas that are not well surveyed. Therefore, there is considerable uncertainty regarding abundance and distribution as well as stock identity.

Status

There is moderate concern for narwhals in this region, mainly due to the lack of detailed information and the apparently low abundance. Narwhals are protected in Svalbard and throughout Russia.

Belugas and Narwhals: Global and Regional Environmental Issues

A number of threats and other issues with known or suspected impacts on monodontid stocks were identified within the background documentation and during the discussions of each stock. Here, as with the stock by stock reviews above, we include citations where reference material is available but note that in many instances it was necessary to rely on expert judgment to help characterize a given issue.

All beluga and narwhal stocks are likely to be affected to some extent, both directly and indirectly, by the rapid warming taking place in the Arctic and sub-Arctic. As the water has warmed, sea-ice cover has decreased, enabling access by humans to formerly remote areas. The resultant increase in ship traffic and other kinds of human activity is of general concern for monodontid populations (Reeves et al., 2014), as it invariably will lead to increased disturbance, habitat degradation and disruption, noise, and chemical pollution (e.g., Kovacs et al., 2011).

The changing environment also creates other challenges for belugas and narwhals, such as differences in prey availability, exposure to novel diseases and parasites, and competition from other species. The level of concern for each type of threat varies from area to area, and there are specific concerns regionally that are currently having impacts on, or likely will have impacts on, individual monodontid stocks.

In general, the northernmost stocks of belugas are of less concern than the more southern stocks. This north-south gradient may be explained largely by the greater intensity and broader range of human activities in lower latitudes, and the effects of climate change. However, the largest beluga stock, centered in western Hudson Bay, is "southern" and apparently robust. The diet of belugas is quite diverse and they use various types of habitat. Their apparent flexibility could make belugas more resilient to Arctic warming than some other Arctic species, including narwhals (Laidre et al., 2008).

Narwhals have a more northern distribution but are almost as numerous as belugas, many of their aggregations are quite large, and their summer ranges tend to be more remote than those of belugas, which limits their exposure to disturbance to some extent. The main habitat concern for narwhals as the Arctic warms is the loss of sea ice, as narwhals are more directly ice-associated than belugas (see Laidre et al., 2008).

[83]Andreev, A. V., D. I. Berman, P. Yu Gorbunov, N. E. Dokuchaev, V. S. Kononenko, B. A. Korotyaev, A. A. Kochnev, A. V. Krechmar, D. I. Litovka, Yu M. Marusik, L. A. Prozorova, I. A. Chereshnev, F. B. Chernyavsky, O. A. Khruleva. 2008. The red book (endangered species list) of the Chukotka autonomous okrug // Chukotka Dep. Ind. Agricult.;RAS Far Eastern Branch, Northeastern Sci. Center, Inst. Biol. Prob. North. Magadan. - Vol. 1 Animals, p. 235 (avail. at https://www.ipae.uran.ru/sites/default/files/publications/ipae/0876_2008_RedBook_ChukotAO_T1.pdf).

Environmental Changes

Ongoing warming of Arctic waters has already led to major declines in sea ice and changes in the timing and spatial sequence of freeze-up and break-up, which has led to physical changes (distribution, characteristics, and movement of ice—not only as a barrier but also in terms of the protective cover it affords) as well as biotic changes (species presence and abundance) in the habitat (Laidre et al., 2015; CAFF, 2017). Warmer water and reduced sea ice enable boreal species to move into higher latitudes, which means that the species endemic to the Arctic are experiencing changes in prey composition and availability, increased competition for food, greater pressure from predators, and exposure to novel pathogens.

Both monodontid species, but especially narwhals, are closely associated with sea ice, and the movement and migratory patterns of some stocks have already been altered (e.g., Hauser et al., 2017; Stafford et al., 2018). The seasonal changes in ice conditions are less predictable than in the past, putting monodontids at greater risk of ice entrapment in some areas (Laidre and Heide-Jørgensen, 2005). Reductions in sea ice can lead to increased productivity and greater abundance of prey but also to shifts in dominant prey species from benthic to pelagic (Grebmeier et al., 2006). Increased productivity or changes in prey may have a positive effect on monodontids in some regions, at least temporarily. However, they may not be particularly well adapted to make use of newly available prey and they may lose out to competitors that are better adapted to the new habitat structure.

Belugas—Areas Impacted:

- Global concern
- Cook Inlet where there has been a contraction of the range. The range occupied in the last five years is smaller than that occupied in the previous ten years, and the range continues to contract. It is unknown whether this range contraction is due to a smaller population or represents a response to changes in the environment (Shelden et al., 2015).
- Okhotsk, Bering, Chukchi, and Beaufort Seas where climate change has brought considerable changes in sea ice. Changes in behavior, e.g., in the timing of migrations, have been observed that are likely related to changes in sea ice (Hauser et al., 2017).

Narwhals—Areas Impacted:

- All stocks will be affected by changes in the seasonal distribution of ice and the warming of water as narwhals exhibit a seasonal movement pattern that follows the distribution of the sea ice through much of the year (Laidre and Heide-Jørgensen, 2005).
- Narwhals in Baffin Bay feed heavily in winter on Greenland halibut (Laidre et al., 2008, 2015). Reduction in and earlier break-up of sea ice, resulting in a habitat shift away from benthic species such as halibut to pelagic species (Grebmeier et al., 2006), will represent a loss of winter feeding habitat.
- Southern stocks will likely be affected sooner than northern stocks. This may already be evident in the southern parts of East Greenland where narwhals have disappeared (NAAMCO[78]).

Pathogens

Pathogens typically found in warmer regions are beginning to be detected in Arctic and sub-Arctic cetaceans. For example, Bristol Bay belugas have recently (2008 sample, marine mammal sampling began in 1999) tested positive for the presence of *Vibrio parahaemolyticus* (a pathogen commonly associated with gastroenteritis, that proliferates at temperatures above 15°C; Goertz et al., 2013). In Cook Inlet and the Okhotsk Sea, belugas are exposed to pet and livestock pathogens, which is a concern (Norman et al., 2013; Alekseev et al., 2017). Even pathogens that have been present in the Arctic for a considerable time may become virulent under a warmer temperature regime or if lowered immune response is induced by environmental stressors such as increased pollution or toxic algal blooms, causing individuals to become more susceptible to both local and newly arrived pathogens (Burek et al., 2008).

General Industrial Activities

Most industrial activities in the Arctic result in disturbance of some kind to monodontids, e.g., ocean noise, chemical pollution, displacement, habitat modification.

Both Species—Areas Impacted:

- Mainly the southernmost areas; however, as sea ice declines and opens up more areas to development, this will affect northern areas as well.

Shipping/Vessel Traffic

Shipping is increasing in the Arctic (Arctic Council[84]). The Russian Northern Sea Route (NSR) and the Canadian–United States Northwest Passage (NWP) in many cases offer faster travel between North Pacific and North Atlantic ports than is possible following the traditional, more southern routes. Transpolar routes are also under discussion. Major shipping routes are developing from Asia and the U.S. west coast in the south, heading north toward the Bering Strait, and then west through the Russian Arctic and east through the Canadian Arctic—and vice versa. Development of these routes requires construction of support harbors—with associated disturbance caused by construction and icebreaking activities, shipping, and resupply of port communities by ships rather than aircraft.

Shipping has several potential impacts on belugas and narwhals, such as noise disturbance (Finley et al., 1990; Cosens and Dueck, 1993; Lesage et al., 1999; Reeves et al., 2014),

[84]Arctic Council. 2015. Status on implementation of the AMSA 2009 report recommendations (avail. at https://pame.is/images/03_Projects/AMSA/AMSA_Documents/Progress_Reports/AMSArecommendations2015_Web.pdf).

displacement, and exposure to spills of fuel and toxic cargo. Also, ballast water discharged from ships can introduce invasive species or novel pathogens that are capable of surviving in the warmer ocean temperatures in an altered Arctic (Miller and Ruiz, 2014; Ware et al., 2016).

The severity of the impacts of ship traffic and noise on whales will differ according to the type and quality of habitat, on whether the animals are resident or migratory, and on whether the animals are in key habitat areas or in transit between areas. For instance, in open water, the whales can avoid ships, but at the same time ships travel faster than in restricted areas (making more noise) and sound travels farther so the area ensonified will be greater. This could mean that displacement distance is greater than in coastal areas and fjords but that displacement is to a similar habitat of comparable value. In restricted areas where habitat patches are more varied and limited (e.g., inlets, small bays, fjords) there is less room for avoidance without abandoning the preferred habitat and moving to a different habitat. If this results in displacement of the animals, they are moving from preferred habitat, such as foraging, nursing, resting, or socializing areas, to lower-value habitat or habitat that was of similar value but now is supporting more animals. As sea-ice seasons shorten, and remaining sea-ice areas become more restricted, these conflicts will increase. If a shipping lane passes through preferred habitat, the whales are faced with choosing between moving to poorer habitat or remaining in degraded habitat.

Some degree of habituation to noise has apparently occurred in some areas, especially where vessel traffic is regular and somewhat predictable. Commercial ship traffic generally adheres to standard routes, but tour-vessel and recreational boat traffic is less predictable and is expanding both spatially and temporally. This trend is already a major concern in areas such as Cook Inlet and the St. Lawrence Estuary and Gulf and is becoming a major concern in other areas, such as Pond Inlet (Canada), West Greenland, and the White Sea (Russia). Additionally, there is increased military activity in all northern waters, for example a new military base has been established inside the Franz Josef Land National Park (Wezeman[53]).

Spills of fuel and other toxic substances can occur wherever there is ship traffic; however, spills are far more common in harbor and port areas than in open water. Shipping in or near ice-covered waters or during winter weather increases both the risk of spills and the likelihood that the spilled material cannot be contained or cleaned up readily. Cetaceans have little ability to detect and avoid spills or the consequences of a spill. Spilled substances can be inhaled, ingested, or absorbed through the skin, or can enter the food web; the route of exposure depends, in large part, on the chemical nature of the substance (Norman et al., 2015).

Belugas—Areas Impacted:

Belugas are rarely reported as being struck by ships, even in areas with high levels of traffic, likely because they are noise-sensitive and avoid ships. However, such avoidance can itself present a risk because it implies that they are easily displaced from habitat that is critical to them in one way or another.

- Cook Inlet: All shipping into and out of Anchorage, the biggest port in Alaska, goes through beluga habitat. Military vessel traffic is also increasing in the area. The Port of Anchorage is in the passage between the two primary habitat areas for these whales (Shelden et al., 2015).
- Eastern Bering Sea: The southern approach to the Bering Strait passes through or is adjacent to beluga habitat.
- Bering Strait: Both the NSR and NWP pass through the strait. Shipping can therefore affect stocks that use the strait as a migration corridor, particularly in fall when the migration occurs before freeze-up.
- Chukchi Sea: The northern approach to the Bering Strait passes through or is adjacent to spring, summer, and fall habitat of belugas.
- Beaufort Sea and western channels of the Canadian Archipelago: The NWP passes through or adjoins spring, summer, and fall habitat of belugas.
- Western Hudson Bay: All stocks that use this region are affected.
- Baffin Bay: Industrial development and associated shipping are increasing.
- St. Lawrence Estuary and Gulf: The situation is similar to Cook Inlet (see above).
- Northeast Atlantic Arctic: Shipping and marine tour-vessel traffic are increasing in East Greenland and around Svalbard.
- White Sea: Shipping from Arkhangelsk (Severnaya Dvina) through the White Sea to the NSR is increasing with reduced sea ice.
- Russian western and central Arctic (Barents, Kara, and Laptev Seas): Shipping is heavy and increasing. The likely impact is difficult to assess, as very little is known concerning how belugas use these waters, but petroleum development in the Pechora and Kara seas has expanded rapidly with minimal environmental assessment in advance.
- Okhotsk Sea: Shipping of ore and other cargo is increasing and of concern.
- Russian waters generally: Hovercraft shipping, which is very noisy, is developing.

Narwhals—Areas Impacted:

Narwhals are very sensitive to ship noise, more so than belugas, and they will be affected in all parts of their range by increases in shipping.

- Baffin Bay, especially and most immediately in Eclipse Sound and Pond Inlet, but also throughout Lancaster Sound.
- Northern Hudson Bay especially in Hudson Strait, Repulse Bay, and Frozen Strait.

Icebreaking

Icebreaking and the associated ship traffic are increasing throughout the circumpolar Arctic. The loudest sounds are created by cavitation from propellers when ships back up (often to ram ice), but they can also be produced from normal operation of the engines and physically breaking ice. When icebreaking occurs in areas where ice is now thin enough to traverse (e.g., at the beginning of break-up and when leads have formed or refrozen areas are still thin enough for animals to break through), it may lead belugas and narwhals to abandon important habitat (Finley et al., 1990). The impact will depend on the nature and scale of the operation, with large-scale continuous or repeated icebreaking in heavy pack ice being of greatest concern, both as a source of noise disturbance and as the cause of increased risk of ice entrapment. Smaller-scale icebreaking, e.g., for port or harbor maintenance or when the ice is already breaking up but needs to be cleared, is of less concern.

The noise from icebreaking activity may affect belugas' and narwhals' sensory capabilities and make it more difficult for them to find breathing holes, communicate, and use echolocation to find prey. This effect can occur at distances of up to 70 km (Erbe and Farmer, 1998, 2000). Displacement distances could be large and if monodontids are unwilling to pass through an area that is significantly ensonified (Heide-Jørgensen et al., 2013a), icebreaking could effectively block channels even as wide as Lancaster Sound (81 km wide just west of the entrance to Eclipse Sound), a major corridor for several stocks that winter in Baffin Bay, and increase the likelihood of ice entrapment in some areas.

Besides increasing underwater noise, icebreaking changes ice characteristics and movement patterns, which makes the ice less predictable to narwhals and belugas, thereby increasing the risk to them. In some circumstances, icebreaker channels may provide escape routes for entrapped animals. However, belugas have been observed to avoid areas with icebreaking for up to 2 days after the activity has ceased (Cosens and Dueck, 1993), so it may take several days for belugas to make use of an opened channel.

Belugas—Areas Impacted:

Shifts in distribution associated with icebreaking have been observed in Lancaster Sound (Finley et al., 1990; Cosens and Dueck, 1993), although belugas have also shown an ability to habituate under some circumstances (Erbe and Farmer, 1998).

- Hudson Strait: Impacts have been modeled (DFO[70]), but no empirical data have been collected.
- Baffin Bay–Davis Strait: Icebreaking has been proposed to service the Mary River iron mine project in northern Baffin Island (DFO[70]).
- White Sea: Icebreakers pass through the wintering area.

Narwhals—Areas Impacted:

Given their sensitivity to noise, narwhals are likely to be affected by icebreaking, particularly when it occurs in their winter habitat.

- All winter habitat.
- Baffin Bay (including Eclipse Sound and Lancaster Sound; Finley et al., 1990; Cosens and Dueck, 1993).
- Hudson Strait.
- Northeast Greenland: possible icebreaking associated with the Citronen ore project.

Oil and Gas and Other Mining Activities

Seismic Surveys

Oil and gas development generally depends on seismic surveys to explore for deposits and monitor depletion of the deposits over time. Such surveys generate a large amount of high-energy underwater noise, sometimes for months and often in areas that are largely pristine. Seismic operations are planned in advance but take place sporadically in any given area and therefore are not necessarily amenable to habituation by wildlife.

Sound can travel long distances in Arctic waters, and both belugas and narwhals can react to noise from icebreaking activity and ship noise tens of kilometers away, resulting in displacement or disruption of behavior (Finley et al., 1990; Cosens and Dueck, 1993; Erbe and Farmer, 1998, 2000; Miller et al., 2005). If belugas and narwhals abandon areas as a response to disturbance by seismic surveys, this would be equivalent to a loss of habitat. Seismic surveys in fall or winter are problematic because they can delay migration or force the animals into sub-optimal areas, and may also increase the risk of ice entrapment (Heide-Jørgensen et al., 2013a).

The long distances at which monodontids respond to noise creates cross-border problems, as sound generated on one side of a border may impact animals on the other side. Ideally, seismic survey planning should be carried out on a regional, coordinated basis and include consideration of the potential impacts on belugas and narwhals.

Construction and Production

Besides shipping (for supply and export) and seismic surveys, offshore oil and gas development normally requires construction or upgrading of infrastructure (e.g., platforms, drilling rigs, pipelines, sometimes artificial islands). This becomes a constant or nearly constant local source of underwater noise over large areas for years (or even decades) (Lammers et al., 2013). Port development involves dredging and pile-driving as well as support shipping, all of which can disturb monodontids.

Oil Spills

Oil spills in the Arctic are of great concern, especially in ice-covered waters. Arctic conditions make spills difficult or impossible to control and clean up, and the cold temperatures slow the breakdown of spilled oil. Any spill carries the potential for major impacts, especially as the capacity for emergency response remains limited. Oil spills can harm whales as a result of both direct exposure and the contamination of their prey if the prey organisms ingest the oil or are smothered by it. Additionally, efforts to clean up after a spill can themselves cause noise and other forms of disturbance.

Belugas—Areas Impacted:

- All areas where exploration or development occurs.
- Cook Inlet has extensive oil and gas development in a confined area. Besides it being the passageway into and out of Anchorage, there are rigs in the middle of the inlet and pipelines that transport oil and gas to onshore storage facilities where tankers are loaded for shipment. Cook Inlet is an area with significant seismic and volcanic activity and oil and gas infrastructure is always at risk. Earthquakes and active volcanoes create the potential to compound the impacts of infrastructure on belugas. Response plans exist and are being refined and updated, but such plans can, at best, only moderate, not eliminate, the harm that would come from a major spill in Cook Inlet.
- Ungava Bay: Construction of a port is under way near Aupaluk on Hopes Advance Bay at the northwestern corner of Ungava Bay to support shipping in conjunction with an iron ore mine (Oceanic Iron Ore Corp.). However, it is not known if or how this will affect the few remaining Ungava belugas (assuming they have not been extirpated).
- St. Lawrence Estuary: Port development is likely to continue.
- Russian western and central Arctic: The Pechora Sea is of special concern because of major coastal oil and gas development projects in areas of beluga concentrations.
- Western Okhotsk Sea: There is increasing ore development accompanied by construction of terminals and shipping.

Narwhals—Areas Impacted:

Seismic survey activity is now taking place in narwhal habitat. In areas such as Fram Strait, the activity continues 24 h/day during the open-water season, which can mean that narwhals are delayed or prevented from moving away from their coastal summering areas during late summer or early fall, and they may be forced to remain in areas with fast ice, increasing the risk of ice entrapment and delaying their chance to feed in their winter habitat. Seismic surveys should be avoided at the start of or during migration periods.

- All areas with seismic surveys will be affected.
- Eclipse Sound: Port development in Milne Inlet for the Mary River iron mine is ongoing.
- Melville Bay: Seismic surveys displaced narwhals into coastal areas and fjords during the survey period (Hansen et al.[72]).
- East Baffin Island: Seismic surveys.
- East Greenland/Fram Strait: More exploration and eventual development is planned.
- Russian Arctic: Seismic surveys and planned oil and gas development.

Hydroelectric Development

Hydroelectric development is of particular concern in Canada, especially with dam construction in rivers flowing into Hudson Bay and James Bay (damming of rivers along the north shore of the Estuary and Gulf of St. Lawrence was essentially completed by around 1970). These dams change the hydrological characteristics of estuaries and coastal waters, potentially affecting belugas because they associate with estuaries. The altered flow regime downstream of dams can influence seasonal temperature and salinity in estuaries and make them less suitable for belugas, and change distribution and abundance of prey species. Dams interrupt the flow of sand and silt in rivers, which over time can result in changes to the substrate and distribution of shallow areas that belugas occupy. Freshwater releases in late fall or winter can affect the timing of freeze-up, making the sea ice less labile and thereby possibly increasing the risk of ice entrapment.

Belugas—Areas Impacted:

- St. Lawrence Estuary.
- Eastern Hudson Bay and James Bay.

Interactions with Fisheries

Fisheries impact marine mammals through competition for resources, injury and entanglement in gear, and loss or degradation of habitat. Injury and entanglement is reported on occasion but does not appear to be a major problem for belugas or narwhals. However, in many areas there is little or no monitoring which means that incidents are unlikely to be reported and animals entangled in lost gear are unlikely to be found (Treble and Stewart[85]). Also, in some areas subsistence hunters use large-mesh nets to harvest whales (e.g., western Hudson Bay and eastern Bering Sea) and incidentally caught whales are often reported as catch rather than as bycatch (e.g., in Greenland and Alaska).

Competition for resources, including preferred prey items, is the main issue with regard to fishery interactions. Narwhals have a narrow dietary niche and increased commercial fishing for their dominant prey, Greenland halibut, is of concern, particularly in Baffin Bay. Halibut have traditionally been harvested in the fjords of West Greenland using long-lines and gillnets. An additional offshore commercial fishery developed in the 1960’s in Davis Strait. This fishery continues to expand to the deep waters of central Baffin Bay where narwhals feed during winter.

A number of stocks of belugas de-

[85]Treble, M. A., and R. E. A. Stewart. 2009. Impacts and risks associated with a Greenland halibut (*Reinhardtius hippoglossoides*) gillnet fishery in inshore areas of NAFO Subarea 0. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/032. vi + 18 p. (avail. at https://waves-vagues.dfo-mpo.gc.ca/Library/340821.pdf).

pend on anadromous fish runs, particularly salmonid species, smelt, and whitefish which support commercial, sport, or subsistence fisheries. These fisheries often intercept returning adult fish offshore from the shallow estuarine areas where belugas feed. Also, in some areas fishing is carried out with shallow set nets in areas where belugas also feed, and these nets remove prey and disrupt both the behavior of prey and the pursuit of prey by belugas. Finally, where fisheries have been scaled back due to overfishing, the spawning stock is reduced and outrunning juvenile fish that belugas also feed on are reduced.

Destruction or degradation of habitat may be caused by trawl fisheries. An example is trawling through the corals inhabited by the halibut in Baffin Bay (Yesson et al., 2016). As the fisheries expand northward, more and more habitat is likely to be degraded or destroyed.

Belugas—Areas Impacted

Belugas can swim backward, and fishing nets are probably detectable by their echolocation although as noted above, some hunting communities use entanglement to catch belugas so they are not always able to avoid or escape from nets. Entanglement in fishing gear does not occur as frequently as might be expected given the intensity of fishing, particularly for salmon, in beluga feeding areas. In the St. Lawrence Estuary, for example, there is significant fishing activity in beluga habitat, yet very little beluga bycatch is reported (Bailey and Zinger[86]; Lair[87]), suggesting that the whales usually avoid entanglement. Entanglements are reported annually in the Okhotsk Sea, but reports are infrequent.

In areas where belugas forage in estuaries, they tend to feed in the shallow upper parts of estuaries, whereas fishing tends to be concentrated in the mouths of the estuaries, limiting direct interactions, but still creating a situation that could limit the amount of prey available to the whales. This is of particular concern for belugas in the Pacific Arctic and for populations that have a fairly narrow summer dietary niche focused on anadromous fish species.

Better information is needed on the diet of many stocks of belugas to assess the possibility of competition with fisheries more rigorously.

- Sakhalin-Amur: The salmon fishery may be reducing the carrying capacity for belugas (Shpak et al., 2019).
- Anadyr: Competition from salmon fishery (Shpak et al., 2019).
- Cook Inlet: Competition from salmon (species) and eulachon, *Thaleichthys pacificus*, fisheries (Norman et al., 2015, 2019).

Narwhals—Areas Impacted

Competition occurs with several fisheries but notably the Greenland halibut fisheries, which are expanding northward because of ice recession.

- Baffin Bay, Davis Strait: Competition with Greenland halibut and shrimp fisheries probably affects all stocks wintering in these areas (Laidre et al., 2008, 2015).
- Hudson Strait: There is likely competition with Greenland halibut and shrimp fisheries.
- East Greenland: There is likely competition with Greenland halibut fisheries.
- Svalbard: There is likely competition with fisheries for polar and Arctic cod, *Arctogadus glacialis* and *Boreogadus saida*, respectively), Greenland halibut, and possibly shrimp.

Organic Contaminants and Heavy Metals

In some areas pollution, especially by heavy metals, polychlorinated biphenyls (PCB's), plastics, and microplastics, is a concern for belugas and narwhals. Some contaminants (particularly organic contaminants) are transported from lower latitudes (via the atmosphere or ocean currents) and some also originate in certain areas from local run-off, sewage, and mine outfalls. Studies have shown pollution to be an acute problem for belugas in some areas; however, studies on narwhals are limited. Extensive studies of the belugas in the St. Lawrence Estuary (Béland et al., 1993; Martineau et al., 1994; Martineau, 2010) have indicated that elevated rates of cancers, and of bacterial, viral, and parasitic infections, are correlated with high levels of pollutants (Martineau et al., 1988, 1999, 2002; De Guise et al., 1994, 1995; Lair et al., 2016). Contaminant studies have been conducted on belugas in Alaska (Becker et al., 2000; Norman et al., 2015), the Canadian Arctic (Loseto et al., 2015), Svalbard (Wolkers et al., 2006), and the western Okhotsk Sea (Glazov et al.[13]). Svalbard belugas have relatively high levels of several contaminants (Wolkers et al., 2006). A pilot study in the western Okhotsk Sea showed that belugas summering in the estuaries of large rivers are relatively heavily contaminated with pesticides (Glazov et al.[13]). More information is needed on the impacts of plastics and microplastics on the health of both monodontids.

Belugas—Areas Impacted

- Cook Inlet: There is runoff from roadways, airports, agriculture, and military facilities as well as sewage outfalls from Anchorage and other municipalities and private septic systems (Norman et al., 2015).
- Canadian Arctic waters: This was a particular problem in the eastern Beaufort Sea, where mercury concentrations in beluga tissues were increasing through the 1990's but

[86]Bailey, R., and N. Zinger. 1995. St. Lawrence beluga recovery plan. World Wildlife Fund, Toronto, and Fish. Oceans Can., Mont-Joli (Québec), 73 p.

[87]Lair S. 2007. Necropsy program: health monitoring of the St. Lawrence Estuary beluga population using post-mortem examination of stranded carcasses. *In* Proceedings of the workshop on the St. Lawrence Estuary beluga—review of carcass program, November 14-17, 2005, Mont Joli. L. Measures (Ed.). Dep. Fish. Oceans, Can. Sci. Advis. Secretariat, Proc. Ser. 2007/005. p. 11–14 (avail. at http://www.dfompo.gc.ca/csas/Csas/Proceedings/2007/PRO2007_005_E.pdf).

levels now seem to be declining slightly (Loseto et al., 2015).

- St. Lawrence Estuary: Currently, runoff from roadways, airports, agriculture, and industrial and port facilities drains into the St. Lawrence watershed, and historically considerable industrial pollution entered the tributaries of the Great Lakes and St. Lawrence River. As a result, St. Lawrence belugas have very high loads of organochlorine compounds and heavy metals in their tissues (Béland et al., 1993; Martineau et al., 1994; Martineau, 2010).
- Svalbard: Levels of various pollutants in Svalbard belugas are very high and for many compounds higher than what is found in polar bears in the area (Andersen et al., 2001, 2006; Wolkers et al., 2004, 2006; Villanger et al., 2011).
- White Sea: Industrial pollution, organochlorine compounds, and heavy metal contaminants (Glazov et al.[54])
- Sakhalin Bay–Amur River: The Amur River carries industrial pollution, mine waste, agricultural runoff, and sewage (Shpak et al., 2019)
- Udskaya Bay: Agricultural runoff.

Narwhals—Area Impacted

- Studies on contaminants in narwhals are needed in all areas but particularly in areas such as Svalbard where belugas are known to have high levels of contaminants.

Cumulative Impacts

Individual stressors might not have significant impacts on individual animals or populations, but stressors rarely occur in isolation. The repetitive and combined pressure of multiple stressors is not always simply additive—the effects can also be synergistic (see examples in Norman et al., 2015). Cumulative effects can lead to mortality and morbidity of individuals, whereas the stressors when considered separately may not. Many stressors have similar effects such as reduced foraging success, reproductive capacity, and immune function, and thus must be considered together to understand the net impact on the population.

Cumulative impacts are a global concern for both species, but most of the focus on assessing and attempting to mitigate such impacts has been on stocks that are already believed to be at greatest risk because of low abundance, declines in abundance, and known exposure to acute stressors. It is not clear how belugas and narwhals will respond to the cumulative, rapid changes now occurring, but there is some evidence that they have some flexibility (belugas perhaps more than narwhals). Therefore, some stocks might manage to deal with changes while others do not (Kovacs and Lydersen, 2008; Laidre et al., 2008; Heide-Jørgensen et al., 2010a; Kovacs et al., 2011).

Belugas—Areas Impacted

- Cook Inlet: Pollution, competition from fisheries, anthropogenic noise, shipping, and construction (Norman et al., 2015).
- St. Lawrence Estuary: St. Lawrence belugas have very high tissue loads of organochlorine compounds and heavy metals (Béland et al., 1993; Martineau et al., 1994; Martineau, 2010) which are likely to interact with competition from fisheries, anthropogenic noise, shipping, construction, and whale-centered tourism.
- White Sea: Industrial pollution, organochlorine compounds and heavy metal contaminants, competition with fisheries, anthropogenic noise, shipping (Glazov et al.[54]).
- Sakhalin Bay–Amur River: Competition with fisheries, anthropogenic noise, shipping, construction (Shpak et al., 2019)

Narwhals—Areas Impacted

- Baffin Bay, Davis Strait: Competition with Greenland halibut and shrimp fisheries (Laidre et al., 2008, 2015); icebreaking and shipping interfere with migration and access to winter habitat.
- Hudson Strait: Likely competition with Greenland halibut and shrimp fisheries, effects of icebreaking and shipping.

Impact Assessment of Different Threats

Ideally, meaningful quantitative analyses of the cumulative impacts of multiple threats should be part of impact assessment, but this is usually not even attempted. Authorization requests from mining interests and oil and gas operators, for example, almost invariably focus on the impacts of their individual projects or activities in isolation, and do not give serious consideration to the cumulative impacts of environmental changes by other projects.

The methodology for quantitative assessment of cumulative impacts is not well developed for any Arctic cetacean species. Therefore, additional scientific effort is needed to develop and make available assessment methods that are understandable, quantitative, meaningful, and repeatable.

In all areas, the impact assessment and approval processes and the response plans for development activities are of concern. The precautionary approach is often used in harvest management (as it should be), but companies planning development activities are generally not held to the same standard of precaution. For example, the beluga and narwhal harvests in Canada and Greenland are closely monitored and managed, yet development projects are rarely halted or even significantly modified when they are known to have, or are likely to have, significant impacts on monodontid stocks.

Recommendations for Monodontid Research and Cooperation

Abundance Estimates

There are several areas where no dedicated surveys of monodontid stocks have been conducted, the available data are outdated, or there is a single estimate and therefore it is not possible to assess trend. Reliable information on abundance is critical to assessment of status. New or improved technology (satellite imagery, drones, genetic mark-recapture, etc.) is available that could be used as an alternative to aerial surveys for collecting data less expensively and with greater safety to humans. However, it is important that new methods be comparable to previous methods so that trend assessment is feasible. Stocks with no abundance estimate or with abundance estimates that were older than 5 years at the time of the GROM workshop are listed below, and these should be assigned a high priority.

Beluga stocks with no survey data:

- Svalbard (planned 2018),
- Barents-Kara-Laptev Seas, and
- Anadyr

Beluga stocks with most recent survey older than 5 years:

- Eastern Beaufort Sea (1992),
- High Arctic-Baffin Bay (1996),
- Eastern Bering Sea (2000; surveyed June 2017, see Update under stock review),
- Sakhalin Bay–Amur (2010),
- Ulbansky (2010),
- Tugursky (2010),
- Udskaya (2010), and
- Shelikov (2010).

Narwhal stocks with no survey data:

- Northeast Greenland (partial survey after the workshop in 2017 and in 2018; results in stock review above), and
- Svalbard-Russian Arctic (partial survey in Norwegian waters 2015).

Narwhal stocks with most recent survey older than 5 years:

- Inglefield Bredning (2007), and
- Northern Hudson Bay (2011; surveyed 2018, results unavailable).

Stock Identity

The ability to assign individual whales to the correct stock is a high priority. It is especially important for narwhals in areas where they are hunted, but it is important for numerous beluga stocks whether they are hunted or not, including Svalbard, Barents-Kara-Laptev Seas, eastern Hudson Bay, White Sea, and western Hudson Bay. Collection of tissue samples from areas where narwhals and belugas are harvested is important, but it will also be important to obtain samples (e.g., via remote biopsy, opportunistic access to stranded or bycaught individuals) from across the range of both species.

Movements and Distribution: Satellite Tracking

Shifts in the movements and distribution of belugas and narwhals have been observed over the last 20 years, and there is a need for additional satellite-linked tagging and tracking. This should be done in areas where no data are available on movements and also in areas like James Bay where previous tagging was limited. Information obtained from satellite tracking can be used in many ways, such as investigating the effects of industrial activities or shipping on whale movements and providing a basis for designing aerial surveys for abundance estimation.

Telemetry data can also be used to identify important areas and times to conduct surveys, determine where and when different stocks overlap spatially, and help prevent overestimation of abundance due to "double counting." Importantly, dive data from satellite tags are used in developing correction factors to account for availability bias in data from aerial surveys; these factors have a large influence on abundance estimates and are best developed from tags deployed during the survey period and in the surveyed area. Movement data from satellite tracking also provide a valuable supplement to genetic analyses for defining stocks. This is particularly important for narwhals as movement data are used to assign takes during fall, winter, and spring hunts to the appropriate summer aggregations.

Satellite tagging is particularly needed in the following areas:

Belugas

- James Bay (especially the west coast),
- Eastern Hudson Bay,
- Belcher Islands,
- Cumberland Sound,
- Okhotsk Sea, and
- Russian Arctic.

Narwhals

- East Baffin Island,
- Jones Sound and Smith Sound, and
- East Greenland, Svalbard, Franz Josef Land, northern Russia.

Responses to Disturbance

Considering the increase in human activities in the Arctic, there is a need for controlled studies on the behavioral and physiological responses of monodontids to disturbance, particularly in relation to ship traffic, icebreaking, oil and gas activities, and human-generated noise generally. Studies should include, for example, investigating the movements, heart rate, stress hormone levels, and sleep/rest rhythm of tagged animals in the presence and in the absence of potentially disturbing stimuli. Baffin Bay was identified as a particularly important area for such studies although it was recognized that findings from robust studies of monodontids regardless of the study site could have considerable value.

Although controlled experiments with wild monodontids concerning their responses to various types of vessel traffic, seismic surveys, and icebreaking activities are lacking, the observational evidence that is available suggests that both species are very sensitive to anthropogenic sounds and that those sounds can disrupt normal behavior, cause the animals to move away from preferred habitat, and increase the risk of ice entrapment in some areas (NAMMCO[29]). Therefore, it is recommended that seismic surveys and icebreaking activities be avoided, at least in areas and during times when the whales are likely to be most vulnerable (e.g., when they are migrating toward wintering areas and while they are in wintering areas where there is limited access to open water; breeding or calving areas and seasons; etc).

Health Assessment

Health assessment studies can provide useful information to managers on the status of beluga and narwhal populations and basic biological data for researchers studying the impacts of threats. Such studies can also provide valuable information on the benefits and risks of consuming the whales' skin, meat, and organs to the human communities that rely on these animals for food. Although no health assessment projects are currently under way on narwhals, several such projects on belugas are ongoing in Alaska, notably in Bristol Bay (Norman et al., 2012; Castellote et al., 2014), Point Lay (eastern Chukchi), and Cook Inlet, in the Inuvialuit region of Canada (Loseto et al., 2015), and in the Russian Far East, specifically on the Sakhalin-Amur stock.

Local Knowledge

Knowledge held by local people, subsistence hunters in particular, is an important source of information on monodontids, especially in locations where little scientific field research on belugas and narwhals has been or is being carried out. Such knowledge has been used to inform stock delineation and will continue to do so, and it can also provide valuable information on population trends, impacts of disturbance, and environmental changes, both short-term and long-term and both natural and human-caused. In Canada, the Species at Risk Act recognizes Aboriginal Traditional Knowledge (ATK) as central to the process of assessing risks and assigning species and populations to different levels of concern. ATK and Indigenous Peoples also play an important role in the development and implementation of protection and recovery measures.

Cumulative Impacts and Management Advice

The importance of integrating consideration of cumulative impacts into management advice is widely recognized, but such integration is rarely achieved. In the case of monodontids, management advice has historically focused on hunting, although it is increasingly recognized that these whales face multiple threats and that various threats in addition to hunting must be considered and addressed. Restrictions on hunting are often necessary to enable populations to recover and to prevent them from decreasing, but other human activities that are known or suspected to have serious impacts on monodontid populations are rarely subject to meaningful restrictions. This situation needs to change. A precautionary approach should be applied equally to the management of harvesting, industrial and commercial activities, tourism, and scientific exploration.

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Literature Cited

Ahonen, H., K. M. Stafford, L. de Steur, C. Lydersen, Ø. Wiig, and K. M. Kovacs. 2017. The underwater soundscape in western Fram Strait: Breeding ground of Spitsbergen's endangered bowhead whales. Mar. Pol. Bull. 123(1–2):97–112 (doi: https://doi.org/10.1016/j.marpolbul.2017.09.019).

Alekseev, A. Y., O. V. Shpak, L. S. Adamenko, D. M. Glazov, I. V. Galkina, M. Y. Schelkanov, and A. M. Shestopalov. 2017. Serological detection of causative agents of infectious and invasive diseases in the beluga whale *Delphinapterus leucas* (Pallas, 1776)(Cetacea: Monodontidae) from Sakhalinsky Bay. Russ. J. Mar. Biol. 43(6):485–490 (doi: https://doi.org/10.1134/S1063074017060037).

Allen, A., and R. P. Angliss. 2015. Alaska marine mammal stock assessments, 2014. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-301, 304 p. (doi: https://doi.org/10.7289/V5NS0RTS).

Andersen, G., K. M. Kovacs, C. Lydersen, J. Skaare, I. Gjertz, and B. Jenssen. 2001. Concentrations and patterns of organochlorine contaminants in white whales (*Delphinapterus leucas*) from Svalbard, Norway. Sci. Total Environ. 264(3):267–281 (doi: https://doi.org/10.1016/S0048-9697(00)00765-8Get).

__________, S. Føreid, J. U. Skåre, B. M. Jenssen, C. Lydersen, and K. M. Kovacs. 2006. Levels of toxaphene congeners in white whales (*Delphinapterus leucas*) from Svalbard, Norway. Sci. Total Environ. 357(1–3):128–137 (doi: https://doi.org/10.1016/j.scitotenv.2005.05.014).

Andrianov, V., V. Bel'kovich, and L. Lukin. 2009. White whale (*Delphinapterus leucas*) distribution in Onega Bay of the White Sea in the summer. Oceanology 49(1):73–82.

Bailleul, F., V. Lesage, M. Power, D. W. Doidge, and M. O. Hammill. 2012. Differences in diving and movement patterns of two groups of beluga whales in a changing Arctic environment reveal discrete populations. Endang. Species Res. 17(1):27–41 (doi: https://doi.org/10.3354/esr00420).

Becker, P. R., M. M. Krahn, E. A. Mackey, R. Demiralp, M. M. Schantz, M. S. Epstein, M. K. Donais, B. J. Porter, D. C. Muir, and S. A. Wise. 2000. Concentrations of polychlorinated biphenyls (PCB's), chlorinated pesticides, and heavy metals and other elements in tissues of belugas, *Delphinapterus leucas*, from Cook Inlet. Mar. Fish. Rev. 62(3):81–98.

Béland, P., S. DeGuise, C. Girard, A. Lagacé, D. Martineau, R. Michaud, D. C. Muir, R. J. Norstrom, E. Pelletier, and S. Ray. 1993. Toxic compounds and health and reproductive effects in St. Lawrence beluga whales. J. Great Lakes Res. 19(4):766–775 (doi: https:// doi.org/10.1016/SO380-1330(93)71264-2).

Belikov, S. E., and A. N. Boltunov. 2002. Distribution and migrations of cetaceans in the Russian Arctic according to observations from aerial ice reconnaissance. NAMMCO Sci. Publ. 4:69–86 (doi: https://doi.org/10.7557/3.2838).

Bettridge S., R. L. Brownell, Jr., M. A. Garcia, R. C. Hobbs, C. L. McCarty, R. D. Methot, Jr., D. L. Palka, P. E. Rosel, K. S. Swails, and B. L. Taylor. 2016. Status review of the Sakhalin Bay–Amur River beluga whale (*Delphinapterus leucas*) under the Marine Mammal Protection Act. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-51, 34 p. (avail. at https://www.fisheries.noaa.gov/resource/document/status-review-sakhalin-bay-amur-river-beluga-whale-delphinapterus-leucas).

Boertmann, D., and R. D. Nielsen. 2010. Geese, seabirds and mammals in North and Northeast Greenland. Aerial surveys in summer 2009. NERI Tech. Rep. 773, 66 p. (avail. at http://www.dmu.dk/Pub/FR773.pdf).

__________, K. Olsen, and R. D. Nielsen. 2009. Seabirds and marine mammals in northeast Greenland. Aerial surveys in spring and summer 2008. NERI Tech. Rep. 721, 50 p. (avail. at http://www.dmu.dk/Pub/FR721.pdf).

Boltunov, A. N., and S. E. Belikov. 2002. Belugas (*Delphinapterus leucas*) of the Barents, Kara and Laptev seas. NAMMCO Sci. Publ. 4:149–168 (doi: https://doi.org/10.7557/3.2842).

Born, E. W., M. P. Heide-Jørgensen, F. Larsen, and A. R. Martin. 1994. Abundance and stock composition of narwhals (*Monodon monoceros*) in Inglefield Bredning (NW Greenland). Meddelelser om Grønland. Bioscience 39:51–68.

Boulva, J. 1981. Catch statistics of beluga (*Delphinapterus leucas*) in northern Quebec: 1974 to 1976, final; 1977 to 1978, preliminary. Rep. Int. Whal. Comm. 31:531–538.

Brennin, R., B. W. Murray, B. N. White, J. W. Clayton, M. K. Friesen, and L. D. Maiers.

1997. Population genetic structure of beluga whales (*Delphinapterus leucas*): mitochondrial DNA sequence variation within and among North American populations. Can. J. Zool. 75(5):795–802 (doi: https://doi.org/10.1139/z97-101).

Brown Gladden, J. G., M. M. Ferguson, and J. W. Clayton. 1997. Matriarchal genetic population structure of North American beluga whales *Delphinapterus leucas* (Cetacea: Monodontidae). Mol. Ecol. 6(11): 1,033–1,046 (doi: https://doi.org/10.1046/j.1365-294X.1997.00275.x).

__________, __________, M. K. Friesen, and J. W. Clayton. 1999. Population structure of North American beluga whales (*Delphinapterus leucas*) based on nuclear DNA microsatellite variation and contrasted with the population structure revealed by mitochondrial DNA variation. Mol. Ecol. 8(3):347–363 (doi: https://doi.org/10.1046/j.1365-294X.1998.00559.x).

Burek, K. A., F. Gulland, and T. M. O'Hara. 2008. Effects of climate change on Arctic marine mammal health. Ecol. Appl. 18(sp2): S126–S134 (doi: https://doi.org/10.1890/06-0553.1).

Burek-Huntington, K. A., J. L. Dushane, C. E. C. Goertz, L. N. Measures, C. H. Romero, and S. A. Raverty. 2015. Morbidity and mortality in stranded Cook Inlet beluga whales *Delphinapterus leucas*. Dis. Aquat. Organ. 114(1):45–60 (doi: https://doi.org/10.3354/dao02839).

Caron, L., T. Smith, and J. R. Geraci. 1990. Philopatry and site tenacity of belugas, *Delphinapterus leucas*, hunted by the Inuit at the Nastapoka estuary, eastern Hudson Bay. *In* T. G. Smith, D. J. St. Aubin, and J. R. Geraci (Editors), Advances in research on the beluga whale, *Delphinapterus leucas*, p. 69–79. Can. Bull. Fish. Aquatic Sci.

Castellote, M., T. A. Mooney, L. Quakenbush, R. Hobbs, C. Goertz, and E. Gaglione. 2014. Baseline hearing abilities and variability in wild beluga whales (*Delphinapterus leucas*). J. Exp. Biol. 217(10):1,682–1,691 (doi: https://doi.org/10.1242/jeb.093252).

__________, R. J. Small, M. O. Lammers, J. J. Jenniges, J. Mondragon, and S. Atkinson. 2016. Dual instrument passive acoustic monitoring of belugas in Cook Inlet, Alaska. J. Acoust. Soc. Am. 139(5):2,697–2,707 (doi: https://doi.org/10.1121/1.4947427).

Citta, J. J., L. T. Quakenbush, K. J. Frost, L. Lowry, R. C. Hobbs, and H. Aderman. 2016. Movements of beluga whales (*Delphinapterus leucas*) in Bristol Bay, Alaska. Mar. Mammal Sci. 32(4):1,272–1,298 (doi: https://doi.org/10.1111/mms.12337).

__________, P. Richard, L. F. Lowry, G. O'Corry-Crowe, M. Marcoux, R. Suydam, L. T. Quakenbush, R. C. Hobbs, D. I. Litovka, K. J. Frost, T. Gray, J. Orr, B. Tinker, H. Aderman, and M. L. Druckenmiller. 2017. Satellite telemetry reveals population specific winter ranges of beluga whales in the Bering Sea. Mar. Mammal Sci. 33(1):236–250 (doi: https://doi.org/10.1111/mms.12357).

__________, G. O'Corry-Crowe, L. T. Quakenbush, A. L. Bryan, T. Ferrer, M. J. Olson, R. C. Hobbs, and B. Potgieter. 2018. Assessing the abundance of Bristol Bay belugas with genetic mark-recapture methods. Mar. Mammal Sci. 34(3):666–686 (doi: https://doi.org/10.1111/mms.12472).

Colbeck, G. J., P. Duchesne, L. D. Postma, V. Lesage, M. O. Hammill, and J. Turgeon. 2013. Groups of related belugas (*Delphinapterus leucas*) travel together during their seasonal migrations in and around Hudson Bay. Proc. Royal Soc. B: Biol. Sci. 280(1752):20122552 (doi: http://dx.doi.org/10.1098/rspb.2012.2552).

Conservation of Arctic Flora and Fauna (CAFF). 2017. State of the Arctic marine biodiversity: Key findings and advice for monitoring. Conserv. Arctic Flora Fauna Int. Secretariat, Akureyi, Iceland.

Cosens, S. E., and L. P. Dueck. 1993. Icebreaker noise in Lancaster Sound, NWT, Canada: Implications for marine mammal behaviour. Mar. Mammal Sci. 9(3):285–300 (doi: https://http://doi.org/10.1111/j.1748-7692.1993.tb00456.x).

Dahl, T. M., C. Lydersen, K. M. Kovacs, S. Falk-Petersen, J. Sargent, I. Gjertz, and B. Gulliksen. 2000. Fatty acid composition of the blubber in white whales (*Delphinapterus leucas*). Polar Biol. 23(6):401–409 (doi: http://dx.doi.org/10.1007/s003000050461).

Dawson, J., L. Pizzolato, S. E. L. Howell, L. Copland, and M. E. Johnston. 2018. Temporal and spatial patterns of ship traffic in the Canadian Arctic from 1990 to 2015. Arctic 71(1):15–26 (doi: https://doi.org/10.14430/arctic4698).

De Guise, S., A. Lagacé, and P. Béland. 1994. Tumors in St. Lawrence beluga whales (*Delphinapterus leucas*). Vet. Pathol. 31(4):444–449 (doi: http://dx.doi.org/10.1177/030098589403100406).

__________, __________, __________, C. Girard, and R. Higgins. 1995. Non-neoplastic lesions in beluga whales (*Delphinapterus leucas*) and other marine mammals from the St. Lawrence estuary. J. Comp. Pathol. 112(3):257–271 (doi: https://doi.org/10.1016/S0021-9975(05)80079-9).

De March, B., L. D. Maiers, and M. K. Friesen. 2002. An overview of genetic relationships of Canadian and adjacent populations of belugas (*Delphinapterus leucas*) with emphasis on Baffin Bay and Canadian eastern Arctic populations. NAAMCO Sci. Publ. 4:17–38. (doi: https://doi.org/10.7557/3.2835).

__________, G. Stern, and S. Innes. 2004. The combined use of organochlorine contaminant profiles and molecular genetics for stock discrimination of white whales (*Delphinapterus leucas*) hunted in three communities on southeast Baffin Island. J. Cetacean Res. Manage. 6(3):241–250.

De March, B. G. E., and L. D. Postma. 2003. Molecular genetic stock discrimination of belugas (*Delphinapterus leucas*) hunted in eastern Hudson Bay, Northern Quebec, Hudson Strait, and Sanikiluaq (Belcher Islands), Canada, and comparisons to adjacent populations. Arctic 56(2):111–124 (https://www.jstor.org/stable/40513046).

Degerbøl, M., and N. Nielsen. 1930. Biologiske Iagttagelser over og Maalinger af Hvidhvalen (*Delphinapterus leucas* (Pall.)) og dens Fostre (Biological observations on and illustrations of the white whale (*Delphinapterus leucas* (Pall.)) and its foetuses) [In Danish]. Meddelelser om Grønland. Bioscience 77(3):119–144.

Dietz, R., M. P. Heide-Jørgensen, P. R. Richard, and M. Acquarone. 2001. Summer and fall movements of narwhals (*Monodon monoceros*) from northeastern Baffin Island towards northern Davis Strait. Arctic 54(3):244–261 (https://www.jstor.org/stable/40512344).

__________, __________, P. Richard, J. Orr, K. Laidre, and H. C. Schmidt. 2008. Movements of narwhals (*Monodon monoceros*) from Admiralty Inlet monitored by satellite telemetry. Polar Biol. 31(11):1,295–1,306 (doi: http://dx.doi.org/10.1007/s00300-008-0466-4).

Doidge, D., and K. Finley. 1994. Status of the Baffin Bay population of beluga, *Delphinapterus leucas*. Can. Field Nat. 107(4): 533–546.

Erbe, C., and D. M. Farmer. 1998. Masked hearing thresholds of a beluga whale (*Delphinapterus leucas*) in icebreaker noise. Deep Sea Res. Part II: Topical Stud. Oceanogr. 45(7):1,373–1,388 (doi: https://doi.org/10.1016/S0967-0645(98)00027-7).

__________ and __________. 2000. Zones of impact around icebreakers affecting beluga whales in the Beaufort Sea. J. Acoust. Soc. Am. 108(3):1,332–1,340 (doi: https://doi.org/10.1121/1.1288938).

Finley, K., G. W. Miller, M. Allard, R. Davis, and C. R. Evans. 1982. The belugas (*Delphinapterus leucas*) of northern Quebec: Distribution, abundance, stock identity, catch history and management. Can. Tech. Rep. Fish. Aquatic Sci. 1123:1–57.

Finley, K. J., G. W. Miller, R. A. Davis, and C. R. Greene. 1990. Reactions of belugas, *Delphinapterus leucas*, and narwhals, *Monodon monoceros*, to ice-breaking ships in the Canadian High Arctic. Can. Bull. Fish. Aquatic Sci. 224:97–117.

Frost, K. J., and R. S. Suydam. 2010. Subsistence harvest of beluga or white whales (*Delphinapterus leucas*) in northern and western Alaska, 1987–2006. J. Cetacean Res. Manage. 11(3):293–299.

__________, L. F. Lowry, and R. R. Nelson. 1985. Radiotagging studies of belukha whales (*Delphinapterus leucas*) in Bristol Bay, Alaska. Mar. Mammal Sci. 1(3):191–202 (doi: https://doi.org/10.1111/j.1748-7692.1985.tb00008.x).

_________, _________, and G. Carroll. 1993. Beluga whale and spotted seal use of a coastal lagoon system in the northeastern Chukchi Sea. Arctic 46(1):8–16 (https://www.jstor.org/stable/40511357).

Garde, E., R. G. Hansen, and M. P. Heide-Jørgensen. 2019. Reconstructing catch statistics for narwhals in Greenland 1862 to 2017. Mar. Fish. Rev. 81(3–4):105–115 (doi: https://doi.org/10.7755/MFR.81.3-4.6).

Gervaise, C., Y. Simard, N. Roy, B. Kinda, and N. Ménard. 2012. Shipping noise in whale habitat: characteristics, sources, budget, and impact on belugas in Saguenay–St. Lawrence Marine Park hub. J. Acoust. Soc. Am. 132(1):76–89 (doi: https://doi.org/10.1121/1.4728190).

Gjertz, I., and Ø. Wiig. 1994. Distribution and catch of white whales *(Delphinapterus leucas*) at Svalbard. Meddelelser om Grønland. Bioscience 39:93–97

Goertz, C. E. C., R. Walton, N. Rouse, J. Belovarac, K. Burek Huntington, V. Gill, R. C. Hobbs, C. Xavier, N. Garrett, and P. Tuomi. 2013. *Vibrio parahaemolyticus*, a climate change indicator in Alaska marine mammals. *In* F. J. Mueter, D. M. S. Dickson, H. P. Huntington, J. R. Irvine, E. A. Logerwell, S. A. MacLean, L. T. Quakenbush, and C. Rosa

(Editors), Responses of Arctic marine ecosystems to climate change, p. 41–52. Alaska Sea Grant, Univ. Alaska Fairbanks. (doi: https://doi.org/10.4027/ramecc.2013.03).

Goetz, K. T., D. J. Rugh, A. J. Read, and R. C. Hobbs. 2007. Habitat use in a marine ecosystem: beluga whales *Delphinapterus leucas* in Cook Inlet, Alaska. Mar. Ecol. Prog. Ser. 330:247–256 (doi: https://doi.org/10.3354/meps330247).

__________, R. A. Montgomery, J. M. Ver Hoef, R. C. Hobbs, and D. S. Johnson. 2012. Identifying essential summer habitat of the endangered beluga whale *Delphinapterus leucas* in Cook Inlet, Alaska. Endang. Species Res. 16(2):135–147 (doi: https://doi.org/10.3354/esr00394).

Grebmeier, J. M., J. E. Overland, S. E. Moore, E. V. Farley, E. C. Carmack, L. W. Cooper, K. E. Frey, J. H. Helle, F. A. McLaughlin, and S. L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. Science 311(5766):1461 (doi: https://doi.org/10.1126/science.1121365).

Hammill, M. O. 2013. Effects of climate warming on Arctic marine mammals in Hudson Bay: Living on the edge? *In* F. Mueter, D. M. S. Dickson, H. Huntington, J. R. Irvine, E. A. Logerwell, S. A. MacLean, L. Quakenbush, and C. Rosa (Editors), Responses of Arctic marine ecosystems to climate change, p. 21–38. Alaska Sea Grant, University of Alaska Fairbanks.

__________, V. Lesage, J. F. Gosselin, H. Bourdages, B. G. E. de March, and M. C. S. Kingsley. 2004. Evidence for a decline in northern Quebec (Nunavik) Belugas. Arctic 57(2):183–195 (www.jstor.org/stable/40512618).

__________, A. Mosnier, J. F. Gosselin, C. J. D. Matthews, M. Marcoux, and S. H. Ferguson. 2017. Management approaches, abundance indices and total allowable harvest levels of belugas in Hudson Bay. Canadian Science Advisory Secretariat.

Hansen, R. G., T. K. Boye, R. S. Larsen, N. H. Nielsen, O. Tervo, R. D. Nielsen, M. H. Rasmussen, M. H. S. Sinding, and M. P. Heide-Jørgensen. 2019. Abundance of whales in west and east Greenland in summer 2015. NAMMCO Sci. Publ. 11:1–17. (doi: https://doi.org/10.7557/3.4689).

Harwood, L. A., and M. C. S. Kingsley. 2013. Trends in the offshore distribution and relative abundance of Beaufort Sea belugas, 1982–85 vs 2007–09. Arctic:247–256.

__________, S. Innes, P. Norton, and M. C. S. Kingsley. 1996. Distribution and abundance of beluga whales in the Mackenzie estuary, southeast Beaufort Sea, and west Amundsen Gulf during late July 1992. Can. J. Fish. Aquat. Sci. 53(10):2,262–2,273 (doi: https://doi.org/10.1139/f96-180).

__________, P. Norton, B. Day, and P. A. Hall. 2002. The harvest of beluga whales in Canada's western Arctic: Hunter-based monitoring of the size and composition of the catch. Arctic 55(1):10–20 (https://www.jstor.org/stable/40512915).

__________, J. Iacozza, J. C. Auld, P. Norton, and L. Loseto. 2014a. Belugas in the Mackenzie River estuary, NT, Canada: Habitat use and hot spots in the Tarium Niryutait Marine Protected Area. Ocean Coastal Manage. 100:128–138 (doi: https://doi.org/10.1016/j.ocecoaman.2014.08.004).

__________, M. C. S. Kingsley, and T. G. Smith. 2014b. An emerging pattern of declining growth rates in belugas of the Beaufort Sea: 1989–2008. Arctic 67(4):483–492 (https://www.jstor.org/stable/24363811).

__________, M. C. S. Kingsley, and F. Pokiak. 2015. Monitoring beluga harvests in the Mackenzie Delta and near Paulatuk, NT, Canada: harvest efficiency and trend, size and sex of landed whales, and reproduction, 1970–2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 3059:vi + 32.

Hauser, D. D. W., K. L. Laidre, R. S. Suydam, and P. R. Richard. 2014. Population-specific home ranges and migration timing of Pacific Arctic beluga whales (*Delphinapterus leucas*). Polar Biol. 37(8):1,171–1,183 (doi: https://doi.org/10.1007/s00300-014-1510-1).

__________, __________, K. M. Stafford, H. L. Stern, R. S. Suydam, and P. R. Richard. 2017. Decadal shifts in autumn migration timing by Pacific Arctic beluga whales are related to delayed annual sea ice formation. Global Change Biol. 23(6):2,206–2,217 (doi: http://dx.doi.org/10.1371/journal.pone.0172755).

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

__________. 2004. Aerial digital photographic surveys of narhwals, *Mondon monoceros*, in Northwest Greenland. Mar. Mammal Sci. 20(2):246–261 (doi: https://doi.org/10.1111/j.1748-7692.2004.tb01154.x).

__________ and K. L. Laidre. 2004. Declining extent of open-water refugia for top predators in Baffin Bay and adjacent waters. AMBIO: J. Human Environ. 33(8):487–494 (https://doi.org/10.1579/0044-7447-33.8.487).

__________ R. Dietz, K. L. Laidre, and P. Richard. 2002. Autumn movements, home ranges, and winter density of narwhals (*Monodon monoceros*) tagged in Tremblay Sound, Baffin Island. Polar Biol. 25(5):331–341 (doi: https://doi.org/10.1007/s00300-001-0347-6).

__________, R. Dietz, K. L. Laidre, P. Richard, J. Orr, and H. C. Schmidt. 2003a. The migratory behaviour of narwhals (*Monodon monoceros*). Can. J. Zool. 81(8):1,298–1,305 (doi: https://doi.org/10.1139/z03-117).

__________, P. Richard, R. Dietz, K. L. Laidre, J. Orr, and H. C. Schmidt. 2003b. An estimate of the fraction of belugas (*Delphinapterus leucas*) in the Canadian High Arctic that winter in West Greenland. Polar Biol. 26(5):318–326 (doi: https://doi.org/10.1007/s00300-003-0488-x).

__________, K. L. Laidre, D. Borchers, T. A. Marques, H. Stern, and M. Simon. 2010a. The effect of sea-ice loss on beluga whales (*Delphinapterus leucas*) in West Greenland. Polar Res. 29(2):198–208 (doi: https://doi.org/10.1111/j.1751-8369.2009.00142.x).

__________, __________, D. L. Borchers, M. L. Burt, T. A. Marques, R. G. Hansen, M. Rasmussen, and S. Fossette. 2010b. Abundance of narwhals (*Monodon monoceros*) on the hunting grounds in Greenland. J. Mammalogy 91(5):1,135–1,151 (doi: https://doi.org/10.1644/09-MAMM-A-198.1).

__________, R. G. Hansen, K. Westdal, R. R. Reeves, and A. Mosbech. 2013a. Narwhals and seismic exploration: Is seismic noise increasing the risk of ice entrapments? Biol. Conserv. 158:50–54 (doi: https://doi.org/10.1016/j.biocon.2012.08.005).

__________, P. R. Richard, R. Dietz, and K. L. Laidre. 2013b. A metapopulation model for Canadian and West Greenland narwhals. Anim. Conserv. 16(3):331–343 (doi: https://doi.org/10.1111/acv.12000).

__________, M. H. S. Sinding, N. H. Nielsen, A. Rosing-Asvid, and R. G. Hansen. 2016. Large numbers of marine mammals winter in the North Water polynya. Polar Biol. 39(9):1,605–1,614 (doi: https://doi.org/10.1007/s00300-015-1885-7).

Hobbs, R. C. 2013. Detecting changes in population trends for Cook Inlet beluga whales (*Delphinapterus leucas*) using alternative schedules for aerial surveys. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-252, 25 p. (avail. at http://www.afsc.noaa.gov/Publications/)

__________, J. M. Waite, and D. J. Rugh. 2000. Beluga, *Delphinapterus leucas*, group sizes in Cook Inlet, Alaska, based on observer counts and aerial video. Mar. Fish. Rev. 62(3):46–59 (http://spo.nwr.noaa.gov/mfr623/mfr6236.pdf).

__________, K. L. Laidre, D. J. Vos, B. A. Mahoney, and M. Eagleton. 2005. Movements and area use of belugas, *Delphinapterus leucas*, in a subArctic Alaskan estuary. Arctic 58(4):331–340 (https://www.jstor.org/stable/40513100).

__________, K. E. W. Shelden, D. J. Rugh, C. L. Sims, and J. M. Waite. 2015a. Estimated abundance and trend in aerial counts of beluga whales, *Delphinapterus leucas*, in Cook Inlet, Alaska, 1994–2012. Mar. Fish. Rev. 77(1):11–32 (doi: https://doi.org/10.7755/MFR.77.1.2).

__________, P. R. Wade, and K. E. W. Shelden. 2015b. Viability of a small, geographically-isolated population of beluga whales, *Delphinapterus leucas*: Effects of hunting, predation, and mortality events in Cook Inlet, Alaska. Mar. Fish. Rev. 77(2):59–88 (doi: https://doi.org/10.7755/MFR.77.2.4).

Innes, S., and R. E. A. Stewart. 2002. Population size and yield of Baffin Bay beluga (*Delphinapterus leucas*) stocks. NAMMCO Scientific Publications 4: Belugas in the North Atlantic and Russian Arctic (doi: https://doi.org/10.7557/3.2846).

IWC. 1993. Report of the Scientific Committee. Rep. Int. Whal. Comm.

__________. 2000. Report of the Scientific Committee. J. Cetacean Res. Manage. (Suppl.) 2:243–251.

Jansen, T., S. Post, T. Kristiansen, G. J. Óskarsson, J. Boje, B. R. MacKenzie, M. Broberg, and H. Siegstad. 2016. Ocean warming expands habitat of a rich natural resource and benefits a national economy. Ecol. Appl. 26(7):2,021–2,032 (doi: https://doi.org/10.1002/eap.1384).

Kelley, T. C., R. E. A. Stewart, D. J. Yurkowski, A. Ryan, and S. H. Ferguson. 2015. Mating ecology of beluga (*Delphinapterus leucas*) and narwhal (*Monodon monoceros*) as estimated by reproductive tract metrics. Mar. Mammal Sci. 31(2):479–500 (doi: https://http://doi.org/10.1111/mms.12165).

Kingsley, M. C. S. 2000. Numbers and distribution of beluga whales, *Delphinapterus leucas*, in James Bay, eastern Hudson Bay, and Ungava Bay in Canada during the summer of

1993. Fish. Bull. 98(4):736–736 (doi: https://doi.org/10.3184/003685008X324010).
Kovacs, K. M., and C. Lydersen. 2008. Climate change impacts on seals and whales in the North Atlantic Arctic and adjacent shelf seas. Sci. Prog. 91(2):117–150 (doi: https://doi.org/10.3184/003685008X324010).
__________, C. Lydersen, J. E. Overland, and S. E. Moore. 2011. Impacts of changing sea-ice conditions on Arctic marine mammals. Mar. Biodiv. 41(1):181–194 (doi: https://doi.org/10.1007/s12526-010-0061-0).
Kuznetsova, D. M., D. M. Glazov, O. V. Shpak, and V. V. Rozhnov. 2016. Winter distribution and migrations of beluga whales (*Delphinapterus leucas*) in the White Sea based on satellite tracking data. Biol. Bull. 43(8):914–917 (doi: https://doi.org/10.1134/S1062359016080124).
Laidre, K. L., and M. P. Heide-Jørgensen. 2005. Arctic sea ice trends and narwhal vulnerability. Biol. Conserv. 121(4):509–517 (doi: https://doi.org/10.1016/j.biocon.2004.06.003).
__________, K. E. W. Shelden, D. J. Rugh, and B. A. Mahoney. 2000. Beluga, *Delphinapterus leucas*, distribution and survey effort in the Gulf of Alaska. Mar. Fish. Rev. 62(3):27–36 (https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/MFR/mfr623/mfr6234.pdf).
__________, I. Stirling, L. F. Lowry, Ø. Wiig, M. P. Heide-Jørgensen, and S. H. Ferguson. 2008. Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change. Ecol. Appl. 18(sp2):S97–S125.
__________, H. Stern, K. M. Kovacs, L. Lowry, S. E. Moore, E. V. Regehr, S. H. Ferguson, Ø. Wiig, P. Boveng, R. P. Angliss, E. W. Born, D. Litovka, L. Quakenbush, C. Lydersen, D. Vongraven, and F. Ugarte. 2015. Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century. Conserv. Biol. 29(3):724–737 (doi: https://doi.org/10.1111/cobi.12474).
Lair, S., L. N. Measures, and D. Martineau. 2016. Pathologic findings and trends in mortality in the beluga (*Delphinapterus leucas*) population of the St Lawrence Estuary, Quebec, Canada, from 1983 to 2012. Vet. Pathol. 53(1):22–36 (doi: https://doi.org/10.1177/0300985815604726).
Lammers, M. O., M. Castellote, R. J. Small, S. Atkinson, J. Jenniges, A. Rosinski, J. N. Oswald, and C. Garner. 2013. Passive acoustic monitoring of Cook Inlet beluga whales (*Delphinapterus leucas*). J. Acoust. Soc. Am. 134(3):2,497–2,504 (doi: https://http://doi.org/10.1121/1.4816575).
Lesage, V., C. Barrette, M. C. S. Kingsley, and B. Sjare. 1999. The effect of vessel noise on the vocal behavior of belugas in the St. Lawrence River Estuary, Canada. Mar. Mammal Sci. 15(1):65–84 (doi: https://http://doi.org/10.1111/j.1748-7692.1999.tb00782.x).
__________, L. N. Measures, A. Mosnier, S. Lair, R. Michaud, and P. Béland. 2014. Mortality patterns in St. Lawrence Estuary beluga (*Delphinapterus leucas*), inferred from the carcass recovery data, 1983–2012. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/118, iv + 23 p.
Lewis, A. E., M. O. Hammill, M. Power, D. W. Doidge, and V. Lesage. 2009. Movement and aggregation of eastern Hudson Bay beluga whales (*Delphinapterus leucas*): A comparison of patterns found through satellite telemetry and Nunavik traditional ecological knowledge. Arctic 62(1):13–24 (https://www.jstor.org/stable/40513261).
Litovka, D., P. Y. Andronov, and R. L. Batanov. 2013. Seasonal distribution of beluga whales *Delphinapterus leucas* depending on prey concentrations in coastal waters of the north-western Bering Sea. Research of water biological resources of Kamchatka and North-West Pacific. KamchatNIRO 27:50–71.
Litovka, D. I. 2002. Distribution of the beluga *Delphinapterus leucas* in the Anadyr Estuary in 2000. Russ. J. Mar. Biol. 28(4):263–266 (doi: https://doi.org/10.1023/A:1020277211821).
Loseto, L. L., G. A. Stern, and R. W. Macdonald. 2015. Distant drivers or local signals: Where do mercury trends in western Arctic belugas originate? Sci. Total Environ. 509–510:226–236 (doi: https://doi.org/10.1016/j.scitotenv.2014.10.110).
Lowry, L. F., K. J. Frost, A. Zerbini, D. Demaster, and R. R. Reeves. 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.
__________, M. C. S. Kingsley, D. D. W. Hauser, J. Clarke, and R. Suydam. 2017a. Aerial survey estimates of abundance of the eastern Chukchi Sea stock of beluga whales (*Delphinapterus leucas*) in 2012. Arctic 70(3):273–286 (doi: https://doi.org/10.14430/arctic4667).
__________, A. Zerbini, K. J. Frost, D. P. DeMaster, and R. C. Hobbs. 2017b. Development of an abundance estimate for the eastern Bering Sea stock of beluga whales (*Delphinapterus leucas*). J. Cetacean Res. Manage. 16:39–47.
__________, J. J. Citta, G. M. O'Corry-Crowe, L. Quakenbush, K. J. Frost, R. Suydam, and R. C. Hobbs. 2019. Distribution, abundance, harvest, and status of western Alaska beluga whale stocks. Mar. Fish. Rev. 81(3–4):54–71 (doi: https://doi.org/10.7755/MFR.81.3-4.2).
Lydersen, C., A. R. Martin, K. M. Kovacs, and I. Gjertz. 2001. Summer and autumn movements of white whales *Delphinapterus leucas* in Svalbard, Norway. Mar. Ecol. Prog. Ser. 219:265–274 (doi: https://doi.org/10.3354/meps219265).
__________, O. A. Nøst, P. Lovell, B. J. McConnell, T. Gammelsrød, C. Hunter, M. A. Fedak, and K. M. Kovacs. 2002. Salinity and temperature structure of a freezing Arctic fjord—monitored by white whales (*Delphinapterus leucas*). Geophysical Res. Letters 29(23):34-31–34-34 (doi: https://doi.org/10.1029/2002GL015462).
__________, A. R. Martin, I. Gjertz, and K. M. Kovacs. 2007. Satellite tracking and diving behaviour of sub-adult narwhals (*Monodon monoceros*) in Svalbard, Norway. Polar Biol. 30(4):437–442 (doi: https://http://doi.org/10.1007/s00300-006-0200-z).
Mahoney, B. A., and K. E. W. Shelden. 2000. Harvest history of belugas, *Delphinapterus leucas*, in Cook Inlet, Alaska. Mar. Fish. Rev. 62(3):124–133 (http://spo.nwr.noaa.gov/mfr623/mfr62311.pdf).
Martineau, D. 2010. Contaminants and health of beluga whales of the St. Lawrence Estuary. Ecology and Animal, Ecosystem Health and Sustainable Agriculture, p. 138–148. The Baltic University Programme, Uppsala University.
__________, A. Lagacé, P. Béland, R. Higgins, D. Armstrong, and L. R. Shugart. 1988. Pathology of stranded beluga whales (*Delphinapterus leucas*) from the St. Lawrence Estuary, Quebec, Canada. J. Comp. Pathol. 98(3):287–310 (doi: https://doi.org/10.1016/0021-9975(88)90038-2).
__________, S. De Guise, M. Fournier, L. Shugart, C. Girard, A. Lagacé, and P. Béland. 1994. Pathology and toxicology of beluga whales from the St. Lawrence Estuary, Quebec, Canada. Past, present and future. Sci. Total Environ. 154(2):201–215 (doi: https://doi.org/10.1016/0048-9697(94)90088-4).
__________, S. Lair, S. De Guise, T. P. Lipscomb, and P. Béland. 1999. Cancer in beluga whales from the St Lawrence Estuary, Quebec, Canada: a potential biomarker of environmental contamination. J. Cetacean Res. Manage. 1:249–265.
__________, K. Lemberger, A. Dallaire, P. Labelle, P. Lipscomb Thomas, P. Michel, and I. Mikaelian. 2002. Cancer in wildlife, a case study: beluga from the St. Lawrence estuary, Québec, Canada. Environ. Health Perspec. 110(3):285–292 (doi: https://doi.org/10.1289/ehp.02110285).
Matishov, G. G., and G. N. Ognetov. 2006. The white whale *Delphinapterus leucas* of the Russia Arctic seas: biology, ecology, protection and exploitation of resources. Apatity: Kola Sci. Center of RAS:295
McQuinn, I. H., V. Lesage, D. Carrier, G. Larrivée, Y. Samson, S. Chartrand, R. Michaud, and J. Theriault. 2011. A threatened beluga (*Delphinapterus leucas*) population in the traffic lane: Vessel-generated noise characteristics of the Saguenay-St. Lawrence Marine Park, Canada. J. Acoust. Soc. Am. 130(6):3,661–3,673 (doi: https://doi.org/10.1121/1.3658449).
Meschersky, I. G., M. V. Kholodova, and E. Y. Zvychaynaya. 2008. Molecular genetic study of the beluga (*Delphinapterus leucas*: Cetacea, Monodontidae) summering in the southern Sea of Okhotsk as compared to North American populations. Russ. J. Genetics 44(9):1,105–1,110 (doi: https://doi.org/10.1134/S1022795408090147).
__________, O. V. Shpak, D. I. Litovka, D. M. Glazov, E. A. Borisova, and V. V. Rozhnov. 2013. A genetic analysis of the beluga whale *Delphinapterus leucas* (Cetacea: Monodontidae) from summer aggregations in the Russian Far East. Russ. J. Mar. Biol. 39(2):125–135 (doi: https://doi.org/10.1134/S1063074013020065).
__________, A. D. Chernetsky, V. V. Krasnova, B. A. Solovyev, D. A. Udovik, O. V. Shpak, D. M. Glazov, and V. V. Rozhnov. 2018. Mitochondrial lineages of the beluga whale *Delphinapterus leucas* in the Russian Arctic. Biol. Bull. 45(2):147–154 (doi: https://doi.org/10.1134/S1062359018020073).
Miller, A. W., and G. M. Ruiz. 2014. Arctic shipping and marine invaders. Nature Climate Change 4(6):413 (doi: https://doi.org/10.1038/nclimate2244).
Miller, G., V. Moulton, R. Davis, M. Holst, P. Millman, A. MacGillivray, and D. Hannay. 2005. Monitoring seismic effects on marine mammals—southeastern Beaufort Sea, 2001–2002. *In* S. L. Armsworthy, P. J. Cranford, and K. Lee (Editors), Offshore oil and gas envi-

ronmental effects monitoring/approaches and technologies p. 511–542. Battelle Press, Columbus, OH.

Mitchell, E. D., and R. R. Reeves. 1981. Catch history and cumulative catch estimates of initial population size of cetaceans in the eastern Canadian Arctic. Rep. Int. Whal. Comm. 31:645–682.

Møller, J. 1928. Grønlandske Erhverv I Godthaab. Træk af Kolonien Godthaabs Historie: 1728–1928.

__________. 1964. Hvidfiskefangst ved Kakuk. Lærebog I fangst for Syd- og Nordgrønland. Den kongelige grønlandske Handel, p. 23–26.

Moore, S. E., K. E. Shelden, L. K. Litzky, B. A. Mahoney, and D. J. Rugh. 2000. Beluga, *Delphinapterus leucas*, habitat associations in Cook Inlet, Alaska. Mar. Fish. Rev. 62(3):60–80 (http://spo.nwr.noaa.gov/mfr623/mfr6237.pdf).

__________, K. M. Stafford, H. Melling, C. Berchok, O. Wiig, K. M. Kovacs, C. Lydersen, and J. Richter-Menge. 2012. Comparing marine mammal acoustic habitats in Atlantic and Pacific sectors of the High Arctic: year-long records from Fram Strait and the Chukchi Plateau. Polar Biol. 35(3):475–480 (doi: http://dx.doi.org/10.1007/s00300-011-1086-y).

Mosnier, A., T. Doniol-Valcroze, J. F. Gosselin, V. Lesage, L. N. Measures, and M. O. Hammill. 2015. Insights into processes of population decline using an integrated population model: The case of the St. Lawrence estuary beluga (*Delphinapterus leucas*). Ecol. Modelling 314:15–31 (doi: https://doi.org/10.1016/j.ecolmodel.2015.07.006).

Muto, M. M., V. T. Helker, R. P. Angliss, B. A. Allen, P. L. Boveng, J. M. Breiwick, M. F. Cameron, P. J. Clapham, S. P. Dahle, M. E. Dahlheim, B. S. Fadely, M. C. Ferguson, L. W. Fritz, R. C. Hobbs, Y. V. Ivashchenko, A. S. Kennedy, J. M. London, S. A. Mizorch, R. R. Ream, E. L. Richmond, K. E. W. Shelden, R. G. Towell, P. R. Wade, J. M. Waite, and A. N. Zerbini. 2016. Alaska Marine Mammal Stock Assessments, 2015. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-323, 300 p. (doi: https://doi.org/10.7289/V5/TM-AFSC-323).

Nelson, M. A., L. T. Quakenbush, B. A. Mahoney, B. D. Taras, and M. J. Wooller. 2018. Fifty years of Cook Inlet beluga whale feeding ecology from isotopes in bone and teeth. Endang. Species Res. 36:77–87 (doi: https://doi.org/10.3354/esr00890).

NOAA. 2008. Taking of the Cook Inlet, Alaska beluga whale stock by Alaska Natives. 73 Fed. Regist. 60976 (22 Oct. 2008), p. 60,976–90,986 (avail. online at https://www.govinfo.gov/content/pkg/FR-2008-10-15/pdf/E8-24511.pdf).

Norman, S. A., C. E. C. Goertz, K. A. Burek, L. T. Quakenbush, L. A. Cornick, T. A. Romano, T. Spoon, W. Miller, L. A. Beckett, and R. C. Hobbs. 2012. Seasonal hematology and serum chemistry of wild beluga whales (*Delphinapterus leucas*) in Bristol Bay, Alaska, USA. J. Wildl. Diseases 48(1):21–32 (doi: https://doi.org/10.7589/0090-3558-48.1.21).

__________, R. C. Hobbs, S. Wuertz, A. Melli, L. A. Beckett, N. Chouicha, A. Kundu, and W. A. Miller. 2013. Fecal pathogen pollution: sources and patterns in water and sediment samples from the upper Cook Inlet, Alaska ecosystem. Environ. Sci.: Processes & Impacts 15(5):1,041–1,051 (doi: https://doi.org/10.1039/C3EM30930D).

__________, __________, C. E. Goertz, K. A. Burek-Huntington, K. E. W. Shelden, W. A. Smith, and L. A. Beckett. 2015. Potential natural and anthropogenic impediments to the conservation and recovery of Cook Inlet beluga whales, *Delphinapterus leucas*. Mar. Fish. Rev. 77(2):89–105 (doi: https://doi.org/10.7755/MFR.77.2.5).

__________, __________, L. A. Beckett, S. J. Trumble, and W. A. Smith. 2019. Relationship between per capita births of Cook Inlet belugas and summer salmon runs: age-structured population modeling. Ecosphere 11(1):e02955. 10.1002/ecs2.2955.

Norton, P., and L. A. Harwood. 1985. White whale use of the southeastern Beaufort Sea, July–September 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1401, 46 p.

O'Corry-Crowe, G., W. Lucey, F. I. Archer, and B. Mahoney. 2015. The genetic ecology and population origins of the beluga whales, *Delphinapterus leucas*, of Yakutat Bay. Mar. Fish. Rev. 77(1):47–59 (doi: https://doi.org/10.7755/MFR.77.1.5).

__________, R. Mahoney Andrew, R. Suydam, L. Quakenbush, A. Whiting, L. Lowry, and L. Harwood. 2016. Genetic profiling links changing sea-ice to shifting beluga whale migration patterns. Biol. Lett. 12(11):20160404 (doi: https://doi.org/10.1098/rsbl.2016.0404).

__________, C. Lydersen, M. P. Heide-Jørgensen, L. Hansen, L. M. Mukhametov, O. Dove, and K. M. Kovacs. 2010. Population genetic structure and evolutionary history of North Atlantic beluga whales (*Delphinapterus leucas*) from West Greenland, Svalbard and the White Sea. Polar Biol. 33(9):1,179–1,194 (doi: https://doi.org/10.1007/s00300-010-0807-y).

__________., R. S. Suydam, A. Rosenberg, K. J. Frost, and A. E. Dizon. 1997. Phylogeography, population structure and dispersal patterns of the beluga whale *Delphinapterus leucas* in the western Nearctic revealed by mitochondrial DNA. Mol. Ecol. 6(10):955–970 (doi: https://http://doi.org/10.1046/j.1365-294X.1997.00267.x).

__________, A. E. Dizon, R. S. Suydam, and L. F. Lowry. 2002. Molecular genetic studies of population structure and movement patterns in a migratory species: The beluga whale, *Delphinapterus leucas*, in the western Arctic. *In* C. J. Pfeiffer (Editor), Molecular and cell biology of marine mammals, p. 53–64. Krieger Publ. Co., Malabar, Fla.

Palsbøll, P., M. P. Heide-Jørgensen, and R. Dietz. 1997. Genetic studies of narwhals, *Monodon monoceros*, from West and East Greenland. Heredity 78:284–292 (doi: https://doi.org/10.1038/hdy.1997.43).

Prasolova, E. A., R. A. Belikov, A. A. Ryabov, and D. I. Litovka. 2014. Results on photo identification for beluga whale *Delphinapterus leucas* in the Anadyr estuary of the Bering Sea. Izv. TINRO 179:120–128 [In Russ.].

Quakenbush, L., R. S. Suydam, A. L. Bryan, L. F. Lowry, K. J. Frost, and B. A. Mahoney. 2015. Diet of beluga whales (*Delphinapterus leucas*) in Alaska from stomach contents, March–November. Mar. Fish. Rev. 77(1):70–84 (doi: https://doi.org/10.7755/MFR.77.1.7).

Reeves, R. R., and S. K. Katona. 1980. Extralimital records of white whales (*Delphinapterus leucas*) in eastern North American waters. Can. Field-Nat. 94(3):239–247.

__________ and E. Mitchell. 1984. Catch history and initial population of white whales (*Delphinapterus leucas*) in the river and Gulf of St. Lawrence, eastern Canada. Naturaliste Canadien 111(1):63–121.

__________ and __________. 1987a. Catch history, former abundance, and distribution of white whales in Hudson Strait and Ungava Bay. Naturaliste Canadien 114(1):1–65.

__________ and __________. 1987b. History of white whale (*Delphinapterus leucas*) exploitation in eastern Hudson Bay and James Bay. Can. Spec. Pub.. Fish. Aquat Sci. 95:1–45.

__________ and __________. 1989. Status of white whales, *Delphinapterus leucas*, in Ungava Bay and eastern Hudson Bay. Can. Field-Nat. Ottawa Ont. 103(2):220–239.

__________ and M. P. Heide-Jørgensen. 1994. Commercial aspects of the exploitation of narwhals (*Monodon monoceros*) in Greenland, with emphasis on tusk exports. Meddelelser om Gronland. Bioscience 39:119–134

_________ and D. S. Lee. 2020. Shifting priorities for narwhal conservation: from trade to rapid environmental change. TRAFFIC Bulletin 32(1):20–31.

__________, P. J. Ewins, S. Agbayani, M. P. Heide-Jørgensen, K. M. Kovacs, C. Lydersen, R. Suydam, W. Elliott, G. Polet, Y. van Dijk, and R. Blijleven. 2014. Distribution of endemic cetaceans in relation to hydrocarbon development and commercial shipping in a warming Arctic. Mar. Policy 44:375–389 (https://doi.org/10.1016/j.marpol.2013.10.005).

Rice, D. W. 1998. Marine mammals of the world: systematics and distribution. Society for Marine Mammology, Lawrence, Kansas.

Richard, P. R. 1991a. Abundance and distribution of narwhals (*Monodon monoceros*) in northern Hudson Bay. Can. J. Fish. Aquatic Sci. 48(2):276–283 (doi: https://doi.org/10.1139/f91-038).

__________. 1991b. Status of the belugas, *Delphinapterus leucas*, of southeast Baffin Island, Northwest Territories. Can. Field-Natur. 105(2):206–214.

__________. 1994. Status of the beluga, *Delphinapterus leucas*, in western and southern Hudson Bay. Can. Field-Natur. 107(4):524–532.

__________ and J. R. Orr. 1986. A review of the status and harvest of white whales (*Delphinapterus leucas*) in the Cumberland Sound area, Baffin Island. Fish. Oceans, Can., 25 p.

__________, __________, and D. G. Barber. 1990. The distribution and abundance of belugas, *Delphinapterus leucas*, in eastern Canadian subarctic waters: a review and update. Can. Bull. Fish. Aquatic Sci. 224:23–38.

__________, M. P. Heide-Jørgensen, and D. St. Aubin. 1998a. Fall movements of belugas (*Delphinapterus leucas*) with satellite-linked transmitters in Lancaster Sound, Jones Sound, and Northern Baffin Bay. Arctic:5–16 (https://www.jstor.org/stable/40511798).

__________, J. R. Orr, R. Dietz, and L. Dueck. 1998b. Sightings of belugas and other marine mammals in the North Water, late March 1993. Arctic:1–4 (https://www.jstor.org/stable/40511797).

__________, A. R. Martin, and J. R. Orr. 2001. Summer and autumn movements of belu-

gas of the eastern Beaufort Sea Stock. Arctic 54(3):207–222 (https://www.jstor.org/stable/40512342).
__________, J. L. Laake, R. C. Hobbs, M. P. Heide-Jørgensen, N. C. Asselin, and H. Cleator. 2010. Baffin Bay narwhal population distribution and numbers: aerial surveys in the Canadian High Arctic, 2002–04. Arctic 65:85–99 (https://www.jstor.org/stable/40513372).
Rose, G. A., and S. Rowe. 2015. Northern cod comeback. Can. J. Fish. Aquatic Sci. 72(12):1,789–1,798 (doi: https://doi.org/10.1139/cjfas-2015-0346).
Rugh, D. J., K. E. Shelden, and B. A. Mahoney. 2000. Distribution of belugas, *Delphinapterus leucas*, in Cook Inlet, Alaska, during June/July 1993–2000. Mar. Fish. Rev. 62(3):6–21 (http://spo.nwr.noaa.gov/mfr623/mfr6232.pdf).
__________, __________, C. L. Sims, B. A. Mahoney, B. K. Smith, L. K. Litzky, and R. C. Hobbs. 2005. Aerial surveys of beluga in Cook Inlet, Alaska, June 2001, 2002, 2003, and 2004. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-149, 71 p.
__________, __________, and R. C. Hobbs. 2010. Range contraction in a beluga whale population. Endang. Species Res. 12(1):69–75.
Sergeant, D. E. 1973. Biology of white whales (*Delphinapterus leucas*) in western Hudson Bay. J. Fish. Res. Board Can. 30(8):1,065–1,090.
__________ and P. F. Brodie. 1975. Identity, abundance, and present status of populations of white whales, *Delphinapterus leucas*, in North America. J. Fish. Res. Board Can. 32(7):1,047–1,054.
Shelden, K. E. W., K. T. Goetz, D. J. Rugh, D. G. Calkins, B. A. Mahoney, and R. C. Hobbs. 2015. Spatio-temporal changes in beluga whale, *Delphinapterus leucas*, distribution: results from aerial surveys (1977–2014), opportunistic sightings (1975–2014), and satellite tagging (1999–2003) in Cook Inlet, Alaska. Mar. Fish. Rev. 77(2):1–32 (doi: https://doi.org/10.7755/MFR.77.2.1).
Shpak, O. V., and D. M. Glazov. 2013. Review of the recent scientific data on the Okhotsk Sea white whale (*Delphinapterus leucas*) population structure and its application to management. J Cetacean Res. Manage. SC/65a/SM23, 19 p.
__________, I. G. Mershersky, D. M. Glazov, D. Litovka, and D. M. Kuvnetsova. 2019. Structure and assessment of beluga whale, *Delphinapterus leucas*, populations in the Russian Far East. Mar. Fish. Rev. 81(3–4):72–86 (https://doi.org/10.7755/MFR.81.3-4.3).
Small, R. J., B. Brost, M. Hooten, M. Castellote, and J. Mondragon. 2017. Potential for spatial displacement of Cook Inlet beluga whales by anthropogenic noise in critical habitat. Endang. Species Res. 32:43–57 (doi: https://doi.org/10.3354/esr00786).
Smith, T. G., and M. O. Hammill. 1986. Population estimates of white whale, *Delphinapterus leucas*, in James Bay, eastern Hudson Bay, and Ungava Bay. Can. J. Fish. Aquatic Sci. 43(10):1,982–1,987 (doi: https://doi.org/10.1139/f86-243).
__________ and A. R. Martin. 1994. Distribution and movements of belugas, *Delphinapterus leucas*, in the Canadian High Arctic. Can. J. Fish. Aquatic Sci. 51(7):1,653–1,663 (doi: https://doi.org/10.1139/f94-166).
Solovyev, B. A., O. V. Shpak, D. M. Glazov, V. V. Rozhnov, and D. M. Kuznetsova. 2015. Summer distribution of beluga whales (*Delphinapterus leucas*) in the Sea of Okhotsk. Russ. J. Theriol 14(2):201–215.
Stafford, K. M., S. E. Moore, C. L. Berchok, Ø. Wiig, C. Lydersen, E. Hansen, D. Kalmbach, and K. M. Kovacs. 2012. Spitsbergen's endangered bowhead whales sing through the polar night. Endang. Species Res. 18(2):95–103 (doi: https://doi.org/10.3354/esr00444).
__________, M. C. Ferguson, D. D. W. Hauser, S. R. Okkonen, C. L. Berchok, J. J. Citta, J. T. Clarke, E. C. Garland, J. Jones, and R. S. Suydam. 2018. Beluga whales in the western Beaufort Sea: current state of knowledge on timing, distribution, habitat use and environmental drivers. Deep Sea Res. Part II: Topical Stud. Oceanogr. 152:182–194 (doi: https://doi.org/10.1016/j.dsr2.2016.11.017).
Storrie, L., C. Lydersen, M. Andersen, R. B. Wynn, and K. M. Kovacs. 2018. Determining the species assemblage and habitat use of cetaceans in the Svalbard Archipelago, based on observations from 2002 to 2014. Polar Res. 37(1):1463065 (doi: https://doi.org/10.1080/17518369.2018.1463065).
Turgeon, J., P. Duchesne, G. J. Colbeck, L. D. Postma, and M. O. Hammill. 2012. Spatiotemporal segregation among summer stocks of beluga (*Delphinapterus leucas*) despite nuclear gene flow: implication for the endangered belugas in eastern Hudson Bay (Canada). Conserv. Genetics 13(2):419–433 (doi: https://doi.org/10.1007/s10592-011-0294-x).
Vacquié-Garcia, J., C. Lydersen, T. A. Marques, J. Aars, H. Ahonen, M. Skern-Mauritzen, N. Øien, and K. M. Kovacs. 2017. Late summer distribution and abundance of ice-associated whales in the Norwegian High Arctic. Endang. Species Res. 32:59–70 (doi: https://doi.org/10.3354/esr00791).
Villanger, G. D., C. Lydersen, K. M. Kovacs, E. Lie, J. U. Skaare, and B. M. Jenssen. 2011. Disruptive effects of persistent organohalogen contaminants on thyroid function in white whales (*Delphinapterus leucas*) from Svalbard. Sci. Total Environ. 409(13):2,511–2,524 (https://doi.org/10.1016/j.scitotenv.2011.03.014).
Vos, D. J., and K. E. W. Shelden. 2005. Unusual mortality in the depleted Cook Inlet beluga (*Delphinapterus leucas*) population. Northwestern Naturalist 86(2):59–65 (https://www.jstor.org/stable/4095766).
Wade, P. R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Mar. Mammal Sci. 14(1):1–37 (doi: https://doi.org/10.1111/j.1748-7692. 1998.tb00688.x).
Ware, C., J. Berge, A. Jelmert, S. M. Olsen, L. Pellissier, M. Wisz, D. Kriticos, G. Semenov, S. Kwaśniewski, and I. G. Alsos. 2016. Biological introduction risks from shipping in a warming Arctic. J. Appl. Ecol. 53(2):340–349 (doi: https://doi.org/10.1111/1365-2664.12566).
Watt, C. A., M. P. Heide-Jørgensen, and S. H. Ferguson. 2013. How adaptable are narwhal? A comparison of foraging patterns among the world's three narwhal populations. Ecosphere 4(6):art71 (doi:https://doi.org/10.1890/ES13-00137.1).
__________, T. Doniol-Valcroze, L. Witting, R. C. Hobbs, R. G. Hansen, D. S. Lee, M. Marcoux, V. Lesage, E. Garde, S. H. Ferguson, and M. P. Heide-Jørgensen. 2019. Hunt allocation modeling for migrating animals: the case of Baffin Bay narwhal, *Monodon monoceros*. Mar. Fish. Rev. 81(3–4):125–136 (doi: https://doi.org/10.7755/MFR.81.3-4.8).
Westdal, K. H., P. R. Richard, and J. R. Orr. 2010. Migration route and seasonal home range of the northern Hudson Bay narwhal (*Monodon monoceros*). *In* S. H. Ferguson, L. L. Loseto, and M. L. Mallory (Editors), A little less Arctic: top predators in the world's largest northern inland sea, Hudson Bay, p. 71–92. Springer Netherlands, Dordrecht. (doi: https://doi.org/10.1007/978-90-481-9121-5_4).
Winge, H. 1902. Grønlands pattedyr. Meddelelser om Grønland 21(2):319–521.
Witting, L., T. Doniol-Valcroze, R. C. Hobbs, S. Ditlevsen, and M. Heide-Jørgensen. 2019. Meta-population modelling of narwhals in East Canada and West Greenland. Mar. Fish. Rev. 81(3–4):116–124 (doi: https://doi.org/10.7755/MFR.81.3-4.7).
Wolkers, H., B. Van Bavel, A. E. Derocher, Ø. Wiig, K. M. Kovacs, C. Lydersen, and G. Lindström. 2004. Congener-specific accumulation and food chain transfer of polybrominated diphenyl ethers in two Arctic food chains. Environ. Sci. Tech 38(6):1,667–1,674 (doi: https://doi.org/10.1021/es030448a).
__________, C. Lydersen, K. M. Kovacs, I. Burkow, and B. van Bavel. 2006. Accumulation, metabolism, and food-chain transfer of chlorinated and brominated contaminants in subadult white whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) from Svalbard, Norway. Arch. Environ. Contam. Toxicol. 50(1):69 (doi: http://dx.doi.org/10.1007/s00244-004-0257-z).
Yesson, C., J. Fisher, T. Gorham, C. J. Turner, N. Hammeken Arboe, M. E. Blicher, K. M. Kemp, and K. Handling (Editor: Michel). 2016. The impact of trawling on the epibenthic megafauna of the west Greenland shelf. ICES J. Mar. Sci. 74(3):866–876 (doi: https://doi.org/10.1093/icesjms/fsw206).
Yurkowski, D. J., M. Auger-Méthé, M. L. Mallory, S. N. P. Wong, G. Gilchrist, A. E. Derocher, E. Richardson, N. J. Lunn, N. E. Hussey, and M. Marcoux. 2019. Abundance and species diversity hotspots of tracked marine predators across the North American Arctic. Divers. Distrib. 25(3):328–345 (doi: https://doi.org/10.1111/ddi.12860).