Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2020/075

Central and Arctic Region

Research, Monitoring and Hunter Knowledge in Support of the 2017 Assessment of the Eastern Beaufort Sea Beluga Stock

L. A. Harwood[1], X. Zhu[2],, L. Angasuk[3], L. Emaghok[4], S.H. Ferguson[2], C. Gruben[4], P. Gruben, [5], P. Hall[2], Jody Illasiak[6], Joe Illasiak,[6], J. Lennie[7], E. V. Lea[8], L.L. Loseto[2], P. Norton[10], C. Pokiak[7], F. Pokiak[4], H. Rogers[3], K. Snow[8] and W. Storr[9]

Fisheries and Oceans Canada
Yellowknife, NT[1], Winnipeg, MB[2], Inuvik, NT[8]

Hunters and Trappers Committees of Inuvik[3,] Tuktoyaktuk[4], Paulatuk[6], Aklavik[9]

Inuvialuit Game Council[5]
Inuvik, NT, Canada

Fisheries Joint Management Committee[7]
Inuvik, NT, Canada

[10]Victoria, BC

December 2020

Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Harwood, L,A., Zhu, X., Angasuk, L., Emaghok, L., Ferguson, S., Gruben, C., Gruben, P., Hall, P., Illasiak, J., Illasiak, J., Lennie, J., Lea, E.V., Loseto, L. L., Norton, P., Pokiak, C., Pokiak, F., Rogers, H., Snow, K., and Storr, W. 2020. Research, Monitoring and Hunter Knowledge in Support of the 2017 Assessment of the Eastern Beaufort Sea Beluga Stock. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/075. v + 48 p.

Aussi disponible en français :

Harwood, L,A., Zhu, X., Angasuk, L., Emaghok, L., Ferguson, S., Gruben, C., Gruben, P., Hall, P., Illasiak, J., Illasiak, J., Lennie, J., Lea, E.V., Loseto, L. L., Norton, P., Pokiak, C., Pokiak, F., Rogers, H., Snow, K. et Storr, W. 2020. Recherche, surveillance et connaissances des chasseurs à l'appui de l'évaluation de 2017 du stock de bélugas de l'est de la mer de Beaufort. Secr. can. de consult. sci. du MPO, Doc. de rech. 2020/075. v + 53 p.

TABLE OF CONTENTS

ABSTRACT

Here we summarize harvest and biological information for the Eastern Beaufort Sea (EBS) beluga to provide an updated stock assessment that combines science and Indigenous hunter knowledge. The number of EBS beluga whales harvested annually across its range has been variable, declining significantly over the available record in Canada (1980–2015). Including estimated and known loss rates from Canada and Alaska, the average annual removal of EBS beluga 2006–2015 (includes landed and struck but lost) was 145 whales (Standard Deviation 20.7). Catches in Chukotka, Russia, are < 10 belugas per year and we estimate mortality through ice entrapment averaged < 5 belugas per year from 1966 through 2015, but that too is highly variable from year-to-year. Declining interest and dependence on traditional foods and hunting, the high cost of hunting equipment and fuel, and increasingly challenging hunting conditions due to windier weather are described by hunters as the main reasons for the decline of the harvest over time. The decline in struck but lost rates is attributed to the establishment and implementation of beluga hunting by-laws by the local Inuvialuit Hunters and Trappers Committees.

The timing of the beluga harvest did not change statistically over the 1980–2015 series, however there was consensus among hunters that whales appear to be arriving earlier to the Mackenzie Estuary in spring. Incidence and annual variation in harvests in two Amundsen Gulf communities suggest the distribution of EBS beluga in the post-Estuary period varies among years, and that in the post-Estuary period the beluga's range during August and September may be expanding.

The Canadian harvest remains highly biased towards males, > 4 to 1 over the last 16 years. Females in the Mackenzie Delta sample averaged 36.2 growth-layer groups (GLG, corresponds to one year; SD 12.6, range 10–63, n = 246) and males averaged 29.5 GLG (SD 10.1, range 11–67, n = 901). Females in the Amundsen sample averaged 28.8 GLG (SD 17.5, range 5–62, n = 20), and males averaged 26.8 GLG (SD 11.2, range 6–61, n = 105). Using a Gompertz growth model, asymptotic lengths were 377.2 ± 1.97 cm in females (n = 287) and 435.46 ± 1.56 cm in males (n = 1,119).

Temporal trends in mean age and length were evaluated using linear regression, by gender for the Delta and for Amundsen Gulf. There were no significant changes detected in the size of females landed by Delta harvesters over the time series ($n = 794$, $F = 0.20$, $p = 0.66$) but there has been a significant shift to smaller males over time ($n = 2,310$, $F = 77.21$, $p < 0.0001$). There were also statistically significant trends over time to decreasing mean GLG age ($n = 905$, $F = 49.04$, $p < 0.0001$) in males and to increasing mean GLG age in females ($n = 248$, $F = 6.25$, $p = 0.013$). Sample size was too limited to examine for temporal trends in mean size or GLG age of belugas landed in Amundsen Gulf. Hunters provided corroborating reports of a decrease in the size of whales landed in the Delta recent years, and it was suggested by hunters that this is likely the consequence of changes in hunter selectivity in recent years. With increasingly challenging hunting conditions, opportunities for selecting the preferred large males have been noticeably reduced.

Due to the low number of females taken in the harvest, data to determine age of sexual maturity and reproductive rate for this stock are not available. Limited data available suggests that calving interval is similar to that reported for the Eastern Chukchi Sea beluga in Alaska, e.g., once every three years.

The only large-scale aerial survey of EBS beluga was flown in late July 1992, and included coverage of both the Mackenzie Estuary and the offshore Beaufort Sea and western Amundsen Gulf over three consecutive days. Extrapolated counts of surfaced beluga produced an index of stock size of 19,629 (CV = 0.229). Applying a correction factor of 2, to account for beluga below

the surface, this estimate was corrected to 39,258 beluga. This estimate is negatively biased, as the survey study area did not include all of the summer range of EBS beluga, known today from telemetry.

The abundance trend cannot be assessed in the absence of a recent aerial survey. The expert observations and long-term experience of hunters participating in the assessment agreed upon a recovery factor (RF) of 0.75 for the Potential Biological Removal (PBR) calculation. The resulting PBR calculation of 487 includes all anthropogenic losses (e.g., landings, ship strikes and net entanglements), struck and lost whales, and non-reported harvests. The sum of the current Canadian and Alaskan harvests averaging 145 beluga landed and lost total, and adding 10 beluga for the purported Russian take (< 10/y), is less than a third of this PBR estimate at the present time. The stock size estimate used in this calculation is dated and needs to be updated.

BACKGROUND

The Eastern Beaufort Sea (EBS) beluga (*Delphinapterus leucas*) stock winters in the Bering Sea, and migrates along the north coast of Alaska to known summering areas in the Mackenzie Estuary, the offshore Beaufort Sea and Amundsen Gulf (Fraker 1979, Richard et al. 2001; Figure 1). The stock is shared with Alaska and Russia, and is the second largest stock of beluga in the world (NAMMCO 2018). The status of this stock was last assessed as stable or increasing, in Canada by DFO in 2000 (DFO 2000) and in 2004 as not at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2004). It was last assessed by the United States (US) in 2015 (and annually) by National Oceanic and Atmospheric Administration (NOAA) (Muto et al. 2016).

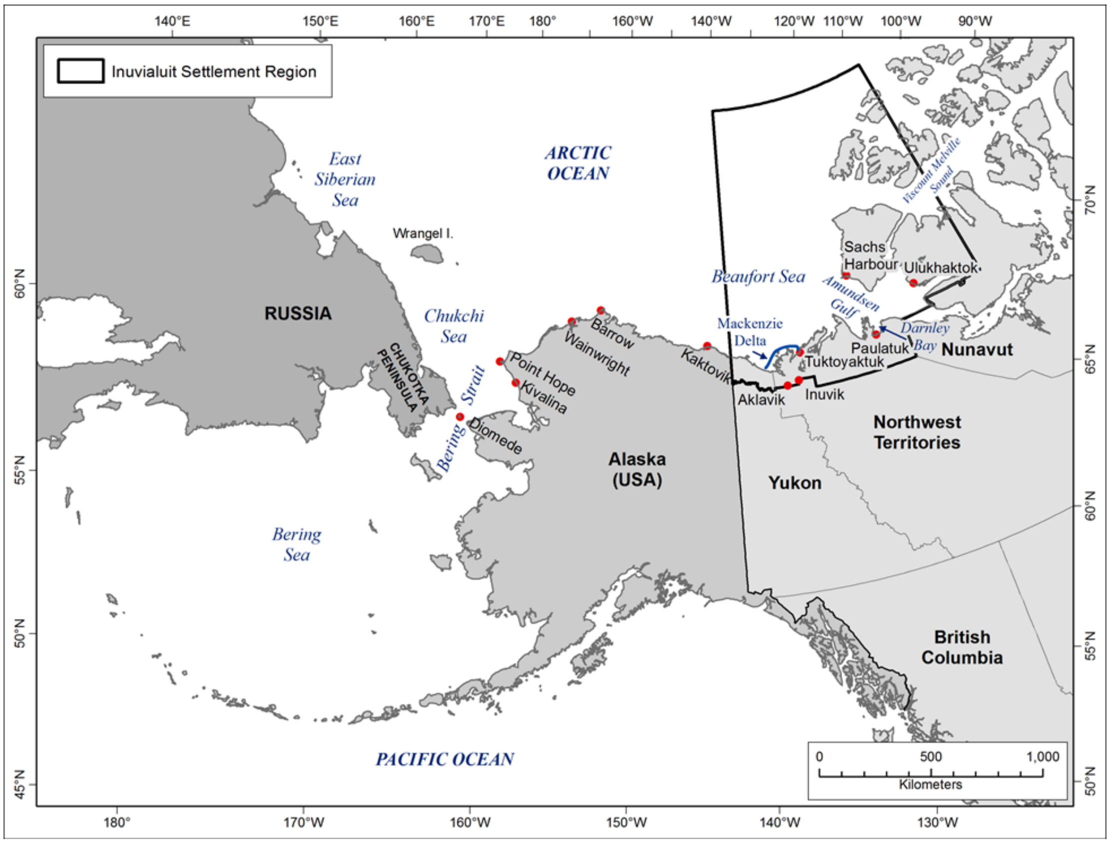

Figure 1. Extent of the known range of the Eastern Beaufort Sea beluga stock, including the Chukotka Peninsula and the boundaries of the Inuvialuit Settlement Region. Inuvialuit and Inupiat communities that harvest from this stock are also shown.

The Inuvialuit of the Western Arctic have a long history of hunting belugas from the EBS stock while in Canadian waters (McGhee 1988, Day 2002, Harwood and Smith 2002), in particular within the Mackenzie Estuary (Figure 2). Beaufort Sea belugas are also hunted by Inupiat from six coastal Alaskan villages (Diomede, Kivalina, Point Hope, Barrow, Wainwright, and Kaktovik) during the spring and fall migrations offshore of Alaska (Lowry et al. 1988, Adams et al. 1993, Frost and Suydam 2010; Figure 1). Residents from the Russian Chukotka region also take beluga from this stock (Figure 1), although the size of this take has not been well documented (Klumov 1939). It was previously described as < 20–30 annually (Belikov 1999), and is now < 10 annually (D. Litovka, Pacific Research Fisheries Center, Chukotka Branch (ChukotTINRO), Anadyr, Chukotka, Russia, 2017, pers. comm.).

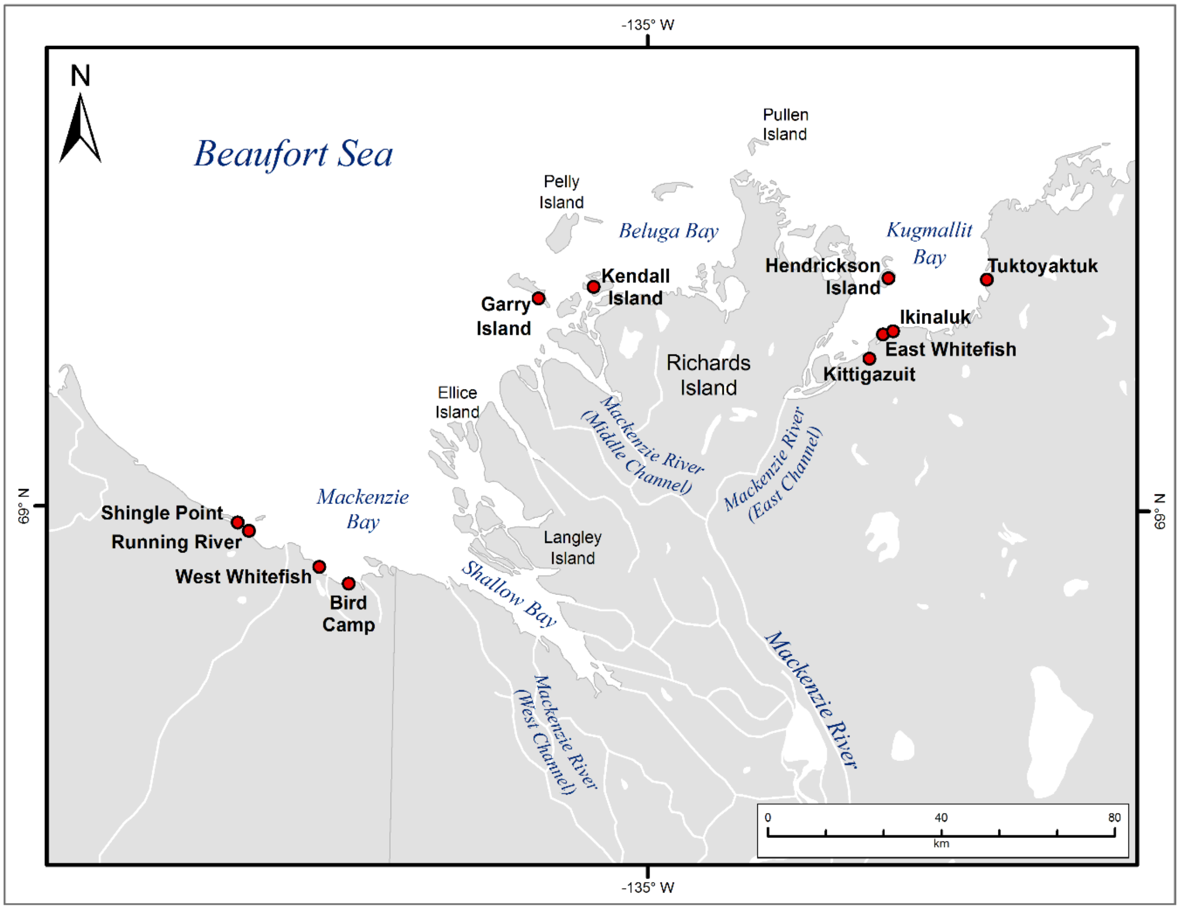

Figure 2. Locations of Inuvialuit beluga whale hunting camps on the shores of the Mackenzie River Delta.

The Inuvialuit and their ancestors have conducted a self-regulated harvest of beluga from this stock for centuries (McGhee 1988, Friesen and Arnold 1995, Cosens et al. 1998). They are holders of local hunting and traditional knowledge regarding the beluga stock and its habitats (Byers and Roberts 1995), and are active stewards of the beluga resource on which they depend, most recently through the co-management process (Fisheries Joint Management Committee [FJMC]) and the Beluga Management Plan (FJMC 2013).

MARINE PROTECTED AREA

Interests in formal, legal protection of beluga and their habitats in the Mackenzie Estuary date back to the Berger Enquiry in the 1970s (Berger 1977). The establishment of the Tarium Niryutait Marine Protected Area (TNMPA) in 2010 (Figure 3) was finally possible through enactment of Canada's *Oceans Act* in 1997. The objective of the TNMPA is to conserve and protect the biological resources within the Mackenzie Estuary, especially beluga, and ensuring a viable healthy population of beluga whales (DFO 2010).The TNMPA is Canada's first Arctic MPA and covers approximately 1,800 km^2 in the Mackenzie Estuary in the Beaufort Sea (Figure 3). It consists of three subareas, Imaryuk Bay (Shallow Bay) in the west, Okeevik in East Mackenzie Bay and Kittigaryuit in Kugmallit Bay (Figure 3).

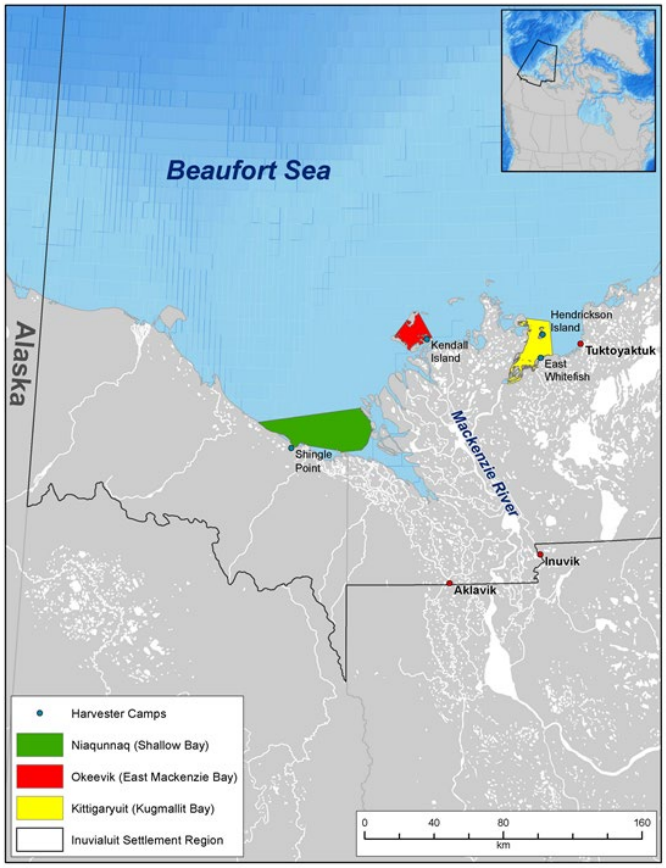

Figure 3. Tarium Niryutait Marine Protected Area (TNMPA), established 2010.

METHODS

SCIENTIFIC KNOWLEDGE

This work summarizes results from published and unpublished sources on the EBS beluga stock, up to 2015. This information includes five decades of harvest data, biological data obtained through harvest-based sampling annually over four decades, systematic aerial survey data spanning four decades, and satellite telemetry from the 1990s (3 years) and 2000s (2 years). All data collected up to and including 2009 are published in the primary literature. Data from harvests and harvested whales from 2010 to 2015 have not yet been published, but are included here, extending the time series by six years. These additional years of data were collected and analysed with the same methods as described and published for earlier years of the same program (Harwood et al. 2002, 2015).

INDIGENOUS KNOWLEDGE

The Inuvialuit of the Western Arctic have a long history of hunting beluga for food (McGhee, 1988, Day, 2002, Harwood and Smith 2002), which includes prior to European contact (ca. 1888), during the commercial whaling period (1888–1907; Bockstoce 1986), and up until the 1950s. Present-day harvesters from the communities of Inuvik, Aklavik and Tuktoyaktuk travel by small boat to seasonal whaling camps clustered on the coast of the Mackenzie River delta (hereafter called 'the Delta'), mainly on the shores of Kugmallit Bay, Kendall Island, and Shallow Bay. Harvesters from Paulatuk, Ulukhaktok (formerly Holman) and Sachs Harbour

(Figure 1) also hunt belugas opportunistically near their communities, usually in late July or early August (Norton and Harwood 1985, Richard et al. 2001).

Here we extend by six years the existing series of hunter-based beluga whale monitoring from the 1970s through 2009 (Fraker 1977, 1978, 1979, Fraker and Fraker 1979, 1981, Hunt 1979, Fraker et al. 1979, Norton 1983, Strong, 1989, 1990, Weaver 1991, Harwood et al. 2002, 2015). Collectively, these annual harvest sampling and monitoring programs have produced the longest and largest database on beluga harvesting in Canada, spanning five decades.

It was critical that Inuvialuit knowledge, observations, and perspectives be included in the EBS beluga stock assessment. Accordingly, it was a priority to hold the Canadian Science Advisory Secretariat (CSAS) regional peer-review within the Inuvialuit Settlement Region (ISR) where Inuvialuit participation could be optimized. One or two beluga Inuvialuit harvesters from each of the FJMC, the Inuvialuit Game Council (IGC), and each of the six Inuvialuit Hunters and Trappers Committees (HTCs) were invited participants to the meeting, 12 of 29 participants in total, to ensure contributions of traditional, local, and ecological Indigenous knowledge to the assessment process. Here an Inuvialuit beluga harvester is defined as someone who hunts beluga to provide for their family and community, and also someone who has knowledge about preparing beluga for consumption.

Each of the HTCs in the ISR selected representatives who were experienced beluga harvesters and would be well-positioned to speak to the topics identified in the Terms of Reference. This would arise through both the sharing of their own knowledge, as well as knowledge transferred from other harvesters in their respective communities. Collectively these local experts represented several centuries' of Indigenous knowledge, observations, and experience in the harvesting and monitoring of EBS beluga. All meeting participants, including the beluga harvesters, received the working paper in advance of the meeting which included highlighted text for seven specific topic areas/questions. Participants from Indigenous organizations, including the beluga harvesters, also received these questions summarized in a questionnaire format, and designed to capture their knowledge gained through beluga harvesting and observations made while spending time in estuarine and coastal waters.

The specific questions that were asked of the Indigenous knowledge holders were:

1. Have you detected specific changes in the distribution of beluga in the Estuary?
2. Have you observed changes in the distribution of beluga in the offshore?
3. Do you have an explanation or interpretation as to the reasons for decline in the harvest over time?
4. Have you seen a shift in the size (length) of whales?
5. Have you seen a shift in the fatness of whales?
6. Have you seen any changes in the overall health of beluga?
7. Are there other observations, knowledge, notes you wish to share?

Maps of the Mackenzie Estuary and ISR marine waters were included with the questionnaires, for reference. During the three hours prior to the meeting, four DFO participants met with the harvesters, either individually or in groups. The purpose of this pre-meeting session was to provide an overview and context of the CSAS process, review the Terms of Reference for the meeting, and discuss the questions identified in the working paper specifically for harvester input. Harvesters were encouraged to submit written responses to the questions on the questionnaire, either at the pre-meeting or during the discussions on each respective topic at the peer-review meeting.

Harvester knowledge was sought and discussed at seven specific topic areas, addressed in the same order as these topics arose in the discussion. Most often responses were provided at the meeting verbally by one or two harvesters, although additional responses were captured in the questionnaire and documented in this report (Appendix 1).

As per CSAS procedures, dissenting opinions on conclusions using either Indigenous or scientific knowledge were raised during the meeting, by the topic-area discipline experts (be it harvester or scientific expertise), and peer review occurred as such during the meeting. Time did not permit all harvesters or all scientists to be queried on all points during the meeting, but there was ample time for tabling and exploration of dissenting opinion or opposing observations to be raised. This is a basic process of peer review, such as it occurred at this meeting, and relates to both scientific or Indigenous knowledge.

Following the meeting, the written responses on the completed questionnaires along with verbal responses and contributions of the harvesters during both the pre-meeting and the assessment were compiled and summarized for inclusion in this research document. These responses were tabulated, checked, reviewed and shared with each of the Indigenous knowledge holders so that they could individually verify their contributions and review those provided by other contributors, to ensure information was accurately captured and represented.

Throughout the assessment, Indigenous and scientific knowledge sources are presented together according to topic, rather than as separate streams, as that approach best supported the flow of the meeting, and the results, interpretations and conclusions of the assessment.

RESULTS AND DISCUSSION

DISTRIBUTION

The EBS beluga stock shares their wintering area with four other stocks of beluga (Eastern Chukchi Sea, Norton Sound, Bristol Bay, eastern Bering Sea; Frost and Suydam 2010), although each uses a stock-specific wintering area in the Bering Sea with varying but generally small degrees of overlap (Citta et al. 2017). EBS belugas migrate along the north coast of Alaska in spring to known summering areas in the Mackenzie Estuary, the offshore Beaufort Sea and Amundsen Gulf (Fraker 1979, Richard et al. 2001; Figure 1). They first arrive in the southeastern Beaufort Sea region in late May or early June, and eventually follow the edge of the landfast ice toward the Mackenzie Estuary in mid to late June (Fraker 1979, Norton and Harwood 1986, Hornby et al. 2014). Once the ice breaks across the Mackenzie Estuary in June or early July, the belugas enter and aggregate in the warm, shallow waters (Fraker et al. 1979, Norton and Harwood 1986). From late July through August, their distribution shifts offshore from the Mackenzie Estuary, to the Beaufort Sea and beyond (Norton and Harwood 1985, Harwood et al. 1996, Richard et al. 2001; Figure 1). Their summer and fall distribution is associated with habitat features including ice cover and bathymetry, with habitat selection driven by size, sex and reproductive status (Loseto et al. 2006). Their return fall migration to the Bering Sea begins in August and continues into September, and in most years, occurs offshore seaward of the continental shelf (Clarke et al. 1993, Moore and DeMaster 1998, Richard et al. 2001, J. Clarke, Leidos, CA., 2017, pers. comm.).

Summer aggregations in the Mackenzie Estuary

Belugas aggregate in the warm, shallow waters of three main bays (Shallow Bay ["West Side"], East Mackenzie Bay ["Central Delta"], and Kugmallit Bay) of the Mackenzie Estuary (referred to herein as "Estuary"; Fraker et al. 1979, Norton and Harwood 1986; Figure 2). Use of the Estuary peaks in early to mid-July, and declines in late July (Fraker and Fraker 1979, Norton and

Harwood 1986, Day 2002, Richard et al. 2001) as they move to the offshore (Norton and Harwood 1985, Harwood et al. 1996, Richard et al. 2001). Some belugas moult while they are in the Estuary (St. Aubin et al. 1990), although the specific locations within the Estuary they prefer for this purpose are not known. It is during the 4–6 week period when they are concentrated in the Estuary that the majority of the annual subsistence harvest takes place, by Inuvialuit harvesters from the Mackenzie Delta communities of Aklavik, Tuktoyaktuk, and Inuvik, NT (Figures 1 and 2).

Belugas were instrumented with satellite-linked transmitters in the Estuary, in July 1993 (n = 4), 1995 (n = 16), 1997 (n = 10), 2004 (n = 9) and 2005 (n = 4). The tagged whales stayed in the Estuary for varying lengths of time. For the 1993, 1995 and 1997 deployments, whales averaged 3 to 5 days in the Estuary following tagging (range 1–10 days; Richard et al. 2001). Satellite tagging results from 1993, 1995, and 1997 (Richard et al. 2001, Loseto et al. 2006) and 2004 and 2005 (Hauser et al. 2014, 2017) described large scale movements and results have not been examined explicitly with the objective of describing small-scale local movements of the belugas within and among the bays of the Estuary. Additionally due to the salt water switch on satellite transmitters (used to notify tag to switch from collecting data to transmitting data), the freshened waters of the Estuary influenced the consistency of uplinks to varying degrees depending on conditions, and therefore limits confidence in the interpretation and application of beluga residence time and beluga migrations in/out of the Estuary (L. Loseto, DFO Science, Winnipeg, MB, pers. comm.).

While they are in the Estuary, the distribution of belugas is highly aggregated (Norton and Harwood 1986). To quantify the extent of clumping, aerial survey counts of beluga from 77 systematic aerial surveys were analyzed using a Geographic Information System (GIS) for the extent and location of aggregation during the month of July, spanning the years 1977–1985, and 1992 (Harwood et al. 2014; Figure 4). The distribution of surfaced belugas was significantly clumped in the Estuary in all three time periods examined (June 26–July 9, July 10–20, July 21–31) and in all three bays of the Estuary. Beluga sighting rates (number of beluga per linear km of survey) varied among bays of the Estuary; however, Shallow Bay had sighting rates that were three (early July) and four (mid-July) times higher than the other bays. The retrospective spatial analyses also revealed belugas were aggregated in seven localized, recurrent geographic areas within the Estuary (termed ‘hot spots’; Figure 4) during the 1977–1985 period (Harwood et al. 2014).

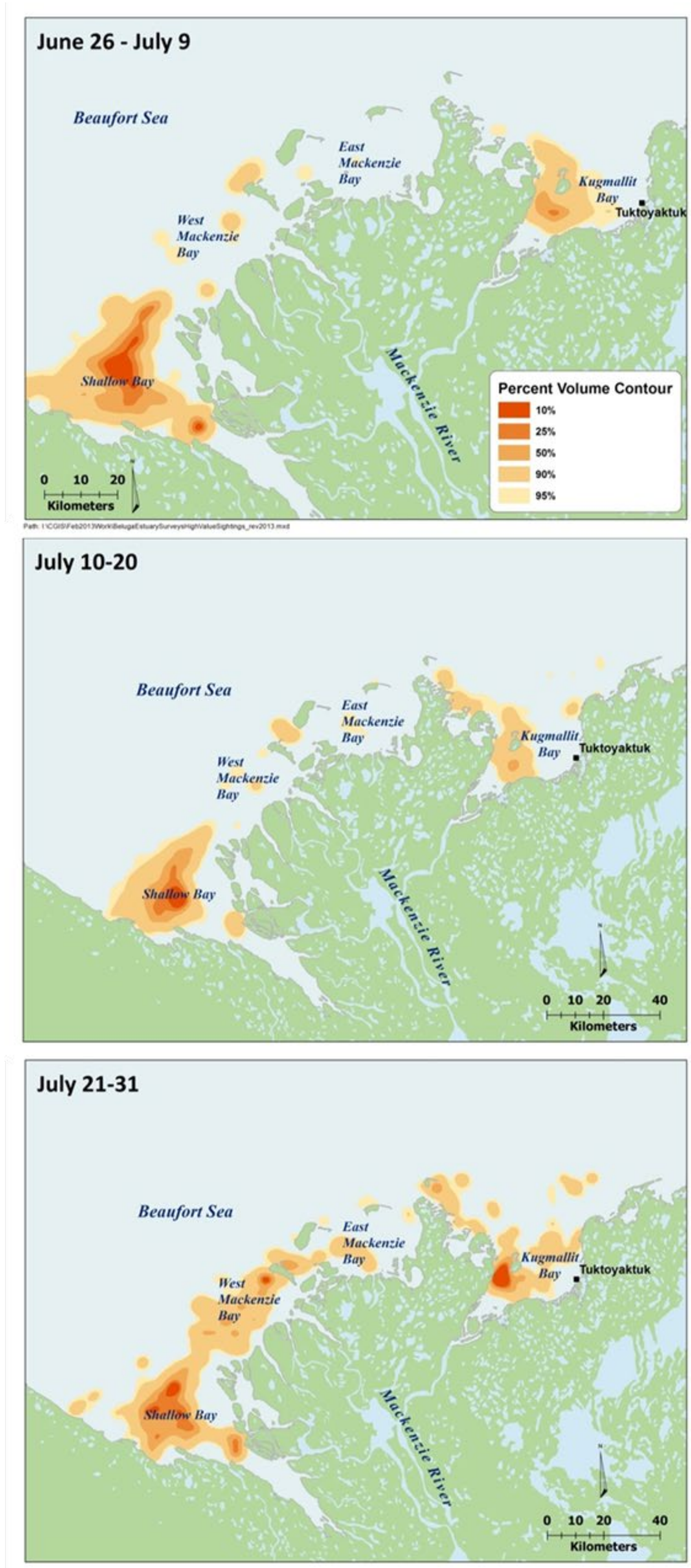

Figure 4. "Hot spot" areas used by belugas in the Mackenzie Estuary during early, mid and late July, 1977–1985 and 1992 pooled (from Harwood et al. 2014).

The tendency for belugas to occupy the same geographic locations within an estuary has been reported for the Cook Inlet beluga (Carter and Nielsen 2011), and St. Lawrence beluga (Mosnier et al. 2010), where scientific knowledge has been used to identify important habitats and examine linkages to environmental variables and change. Changes to the climate, environment, sea ice and pelagic and benthic food webs have been documented for the Pacific Arctic in recent years (e.g., Moore and Stabeno 2015, Wood et al. 2015). However, EBS beluga growth and survivorship trends did not reflect timing of these Pacific Arctic regime shifts (Luque and Ferguson 2009).

Extensive local knowledge based on direct observation is held by beluga harvesters, who have for centuries known of the beluga's tendency to concentrate in certain areas of the Estuary (Nuligak 1966, McGhee 1988, Day 2002). There are no recent aerial surveys to examine contemporary patterns of beluga distribution, hot spot use, or clumping in the Estuary. Hunters did not indicate any obvious changes or shifts in the patterns of distribution in the Estuary (Appendix 1), except one Delta hunter reported females with calves have been staying longer in the shallower waters of the Estuary in recent years and there were reports of changes in distribution in coastal areas near the Estuary as well (Waugh et al. 2018; Appendix 1). Past and recent work using passive acoustic monitoring (PAM) has linked patterns of beluga habitat use with oceanographic parameters, in particular temperature and salinity (Fraker et al. 1979, Scharffenberg 2018, Scharffenberg et al. 2019).

Using published (1980–2009) and unpublished (2010–2015) data on hunter reports of harvested whales, we have examined the timing of the beluga harvest, by calendar day, by bay and by year. This is our only measure in the historic harvesting records of the annual timing and extent of beluga occupancy of the Estuary. We calculated the calendar day of the year when 5%, 50%, and 95% of the annual subsistence harvest had been landed, by year for the three Delta hunting areas and for Paulatuk. Trends over time were evaluated using Mann-Kendall temporal trend tests in XLStat (Figure 5). No significant temporal trends were detected in timing of the harvest in any bay ($p > 0.05$), for the start (first 5% of landings), middle (50%), or end (95%) of harvest, across all years in the database (1980–2015) ($p < 0.05$).

Five of six Delta hunters reported that belugas were arriving to the Mackenzie Estuary earlier in spring in recent years, and two reported they were leaving earlier (Appendix 1). They suggested that this is linked with earlier timing of sea ice clearance in spring. There are also increasing anecdotal observations that they arrive earlier (e.g., see Loseto et al. 2018a), however recent survey coverage to evaluate the timing of beluga arrival is limited, with only three recent years of data (2011–2013; Hornby et al. 2014). Using the start of the harvest as a proxy for arrival of whales, these data suggest that the start of the harvest has not shifted (based on data from 1980–2015). However at the meeting, harvesters offered the explanation that this result reflects that hunters, and monitoring efforts at some locations have not kept pace with the earlier arrival of whales (DFO 2021). For this reason, start of the hunt is no longer a reliable and cost-effective proxy for whale arrival times, so DFO will have to explore aerial surveys along with remotely sensed ice conditions in order to obtain empirical data on beluga arrival times.

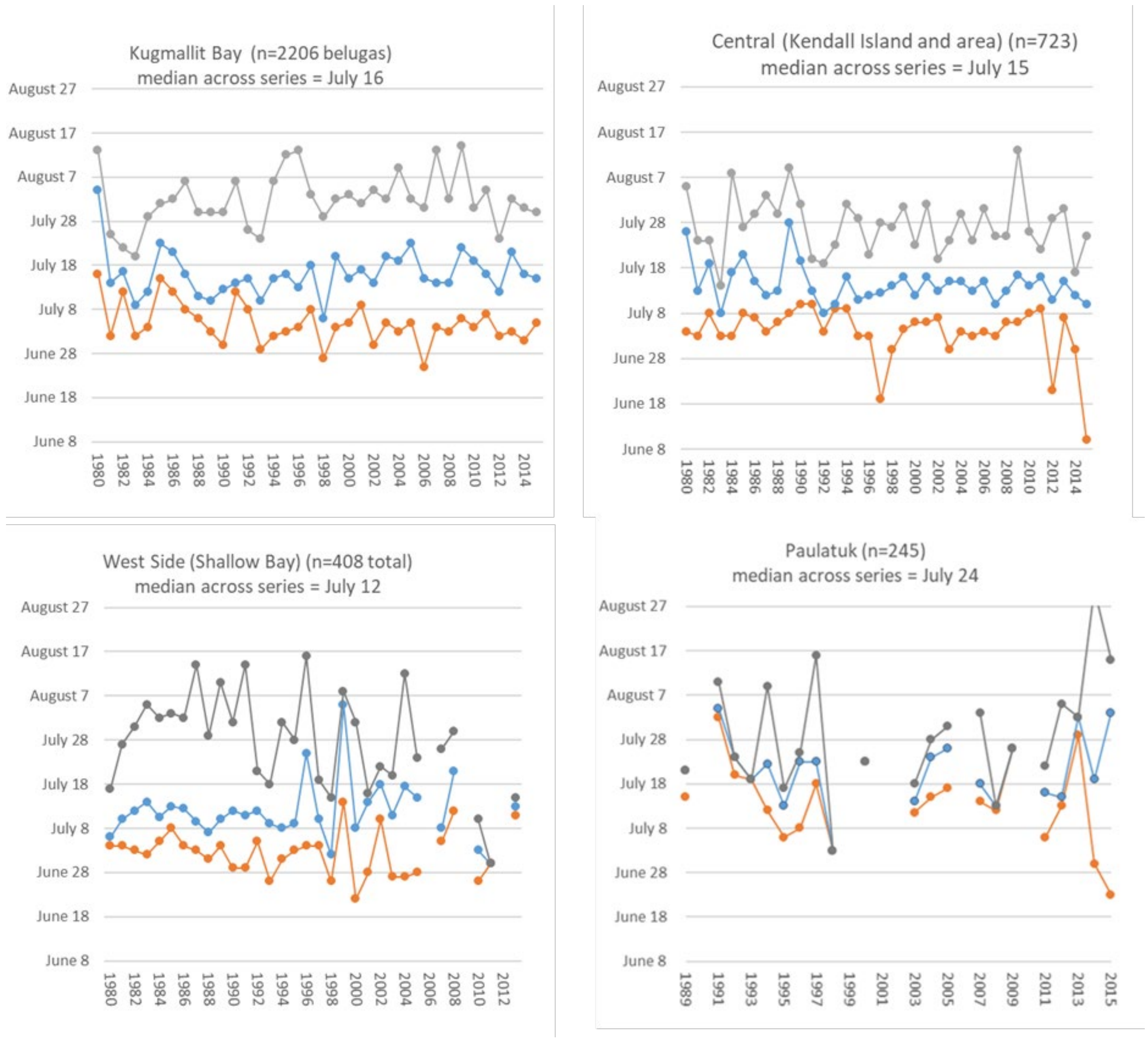

Figure 5. Annual values for day of the year when 5% (orange), 50% (blue) and 95% (gray) of the subsistence beluga harvest was landed, by hunting area and year, 1980–2015 (data from Harwood et al. 2015, FJMC unpublished data).

Distribution offshore including coastal areas outside the Estuary

Aerial surveys flown in the Canadian Beaufort Sea in 1984 revealed that belugas also occurred throughout the offshore (i.e., outside the Mackenzie Estuary), including the Beaufort Sea Shelf concurrently while other portions of the stock were aggregated in the Estuary (Norton and Harwood 1985; Figure 6). The clumped pattern of distribution in the Mackenzie Estuary is in sharp contrast to patterns that are observed in the offshore Beaufort Sea, where sightings of small groups were widespread and consisted almost exclusively of single whales or groups of only 2 or 3 (Norton and Harwood 1985, Harwood et al. 1996, Harwood and Kingsley 2013, Hornby et al. 2017).

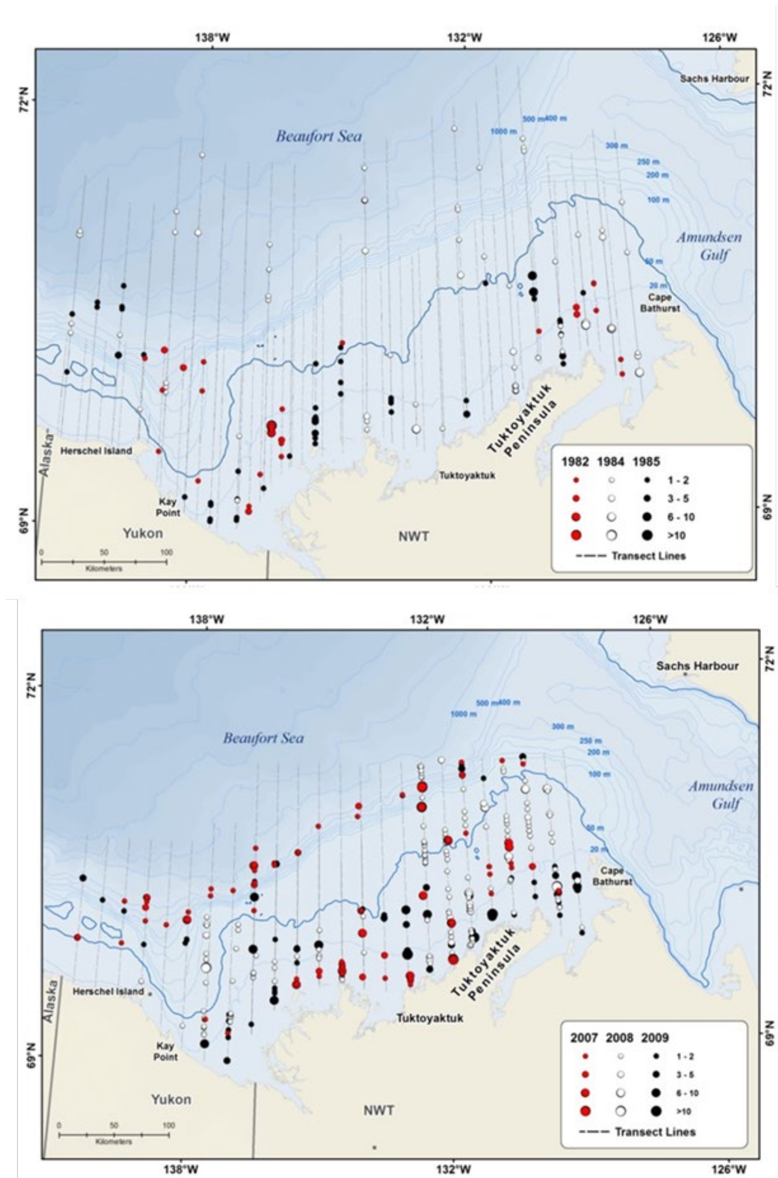

Figure 6. Location of transects and numbers of surfaced belugas sighted in the offshore Beaufort Sea during aerial surveys in late August 1982, 1984 and 1985 (upper) and in 2007–2009 (lower; from Harwood and Kingsley 2013).

Satellite tracking studies in 1993, 1995, and 1997 revealed that EBS belugas use the offshore Beaufort Sea Shelf extensively (Richard et al. 2001). Telemetry data also showed that in late summer, some belugas went far beyond the Canadian Beaufort Sea and the range of the aerial survey effort into habitats such as Amundsen Gulf, M'Clure Strait, Prince of Wales Strait, and Viscount Melville Sound (Norton and Harwood 1985, Harwood et al. 1996, Richard et al. 2001; Figure 7). This provided the first scientific evidence of a change in Estuary to offshore habitat use in late summer. Loseto et al. (2006) demonstrated that beluga in the offshore Beaufort Sea and Amundsen Gulf showed preferences for different sea ice/bathymetry habitats that were defined by size, sex and reproductive status. More recently telemetry data corroborated the earlier patterns observed by Richard et al. (2001), plus a new finding of a single tagged whale travelling north (79 degrees) into the deep Canada Basin in spring 2005 before going to the Beaufort Sea (L. Loseto, DFO Science, Winnipeg, MB, pers. comm.).

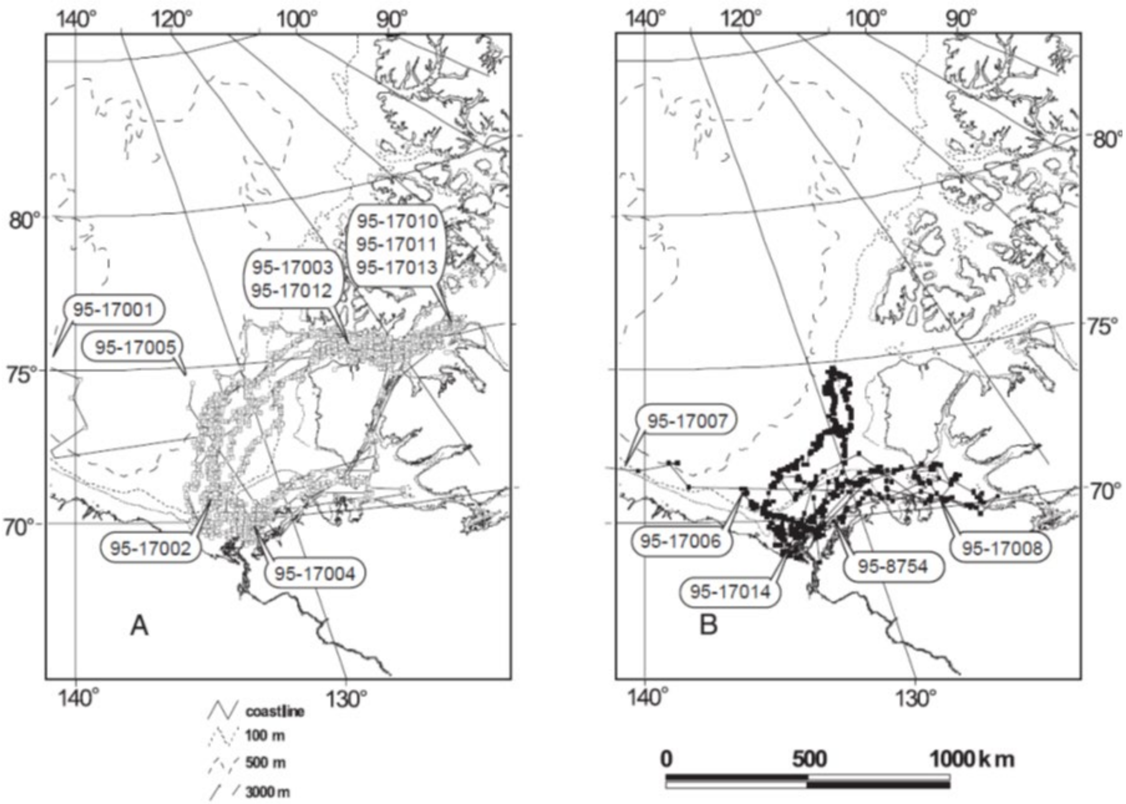

Figure 7. Telemetry movements of male (A) and (B) female beluga whales tagged in the Mackenzie Estuary in early July 1995 (from Richard et al. 2001).

It is during this late summer period (late July to late August) that residents of coastal communities in Amundsen Gulf (Paulatuk, Ulukhaktok, and Sachs Harbour) would from time to time observe belugas near their community, and occasionally harvest them (Table 1). Historically, the number of belugas harvested by these communities was small (i.e., 1–2 per decade), opportunistic or non-existent, at least compared to the Delta communities. Overall, harvesting is more common now in the coastal waters near the Amundsen Gulf communities than in the past, but landings do vary markedly among years (0 to > 30; Appendix 1). Amundsen Gulf hunters report the occurrence of whales near their communities to be increasing overall, in some but not all years (J. Illasiak, Community of Paulatuk, Paulatuk, NWT, pers. comm., Appendix 1). Harvesters have reported that coastal waters close to the Mackenzie Estuary appear to have become more attractive to beluga in late summer in some years (Appendix 1). Hunters from Ulukhaktok and Sachs Harbour also report increased incidence of killer whales (*Orcinus orca*) in recent years, whereas in the past they have not been observed. They suggest that this is likely influencing the distribution and behaviour of belugas (DFO 2021).

One notable occurrence was the unprecedented harvest of 37 beluga whales at Ulukhaktok in July–August 2014, where previously beluga have been taken at a rate of 1–2 per decade (Table 1). Twenty-two stomachs were sampled to assess diet. Stomachs from beluga sampled in the Mackenzie Estuary are almost always empty (Harwood et al. 2000, 2015), however these beluga had been feeding extensively on Sandlance (*Ammodytes* spp.; Loseto et al. 2018b). This was an unexpected finding since Arctic Cod (*Boreogadus saida*) have been long known to be the most common summer prey for beluga based on fatty acid profiling in summer (Loseto et al. 2009) and stomach content analyses in spring (Quakenbush et al. 2015).

Table 1. Number of beluga landed by subsistence harvesters by year, and recorded in FJMC database, Inuvialuit Settlement Region, 1980–2015.

Year	Mackenzie Delta			Amundsen Gulf		Beaufort Sea	
	Inuvik (Kendall Is. and Garry Is.)	Inuvik and Tuktoyaktuk (Kugmallit Bay, East Whitefish, Hendrickson Is.)	Aklavik (Shingle Point, Bird Camp, West Whitefish)	Ulukhaktok	Paulatuk (Darnley Bay)	Sachs Harbour (vicinity)	Aklavik (vicinity of Herschel Is.)
1980	24	37	29[1]	0	0	0	0
1981	22	91	35	0	0	0	0
1982	25	62	20	0	0	0	0
1983	25	48	13	0	0	0	0
1984	30	91	20	0	0	0	0
1985	25	81	12	0	0	0	0
1986	15	94	22	0	0	0	0
1987	13	102	19	0	0	0	0
1988	27	69	18	0	0	0	0
1989	11	88	15	0	4	0	0
1990	14	42	31	0	0	0	0
1991	16	67	17	0	16	0	0
1992	23	63	17	0	18	0	0
1993	24	62	21	0	3	0	0
1994	25	82	26	0	8	0	0
1995	23	67	28	0	11	0	0
1996	17	59	19	0	25	0	0
1997	20	75	12	0	7	0	0
1998	16	55	13	0	2	0	0
1999	20	58	7	0	1	0	0
2000	17	53	3	0	2	0	0
2001	23	55	8	0	0	0	0
2002	21	54	10	0	0	0	0
2003	19	67	5	0	20	0	0
2004	29	70	6	3	25	0	0
2005	23	46	6	1	30	0	0

Year	Mackenzie Delta			Amundsen Gulf		Beaufort Sea	
	Inuvik (Kendall Is. and Garry Is.)	Inuvik and Tuktoyaktuk (Kugmallit Bay, East Whitefish, Hendrickson Is.)	Aklavik (Shingle Point, Bird Camp, West Whitefish)	Ulukhaktok	Paulatuk (Darnley Bay)	Sachs Harbour (vicinity)	Aklavik (vicinity of Herschel Is.)
2006	22	85	4	0	10	0	0
2007	20	38	7	0	17	0	1
2008	22	44	2	0	5	2	0
2009	28	62	5	0	1	0	0
2010	17	51	2	0	0	0	2
2011	25	36	1	0	9	0	0
2012	16	43	1	0	7	2	0
2013	16	59	3	0	11	0	0
2014	11	37	0	37	10	0	0
2015	10	44	0	0	15	0	0

[1]Includes 8 whales taken by Ulukhaktok hunters in the Aklavik hunting area

During late July and August, in addition to the Amundsen Gulf and Viscount Melville Sound forays, belugas regularly enter Liverpool Bay and travel deep into the brackish waters of the Husky Lakes system (Figure 8). Here they are believed to prey on diverse and abundant fish resources (Roux et al. 2015); one beluga removed from the entrapment in December 1996 had a large Lake Trout (*Salvelinus namaycush*) in its stomach (fork length 1 m; DFO unpublished data). Occasionally, some beluga do not leave the Husky Lakes in a timely manner prior to freeze-up and become entrapped (Figure 8).

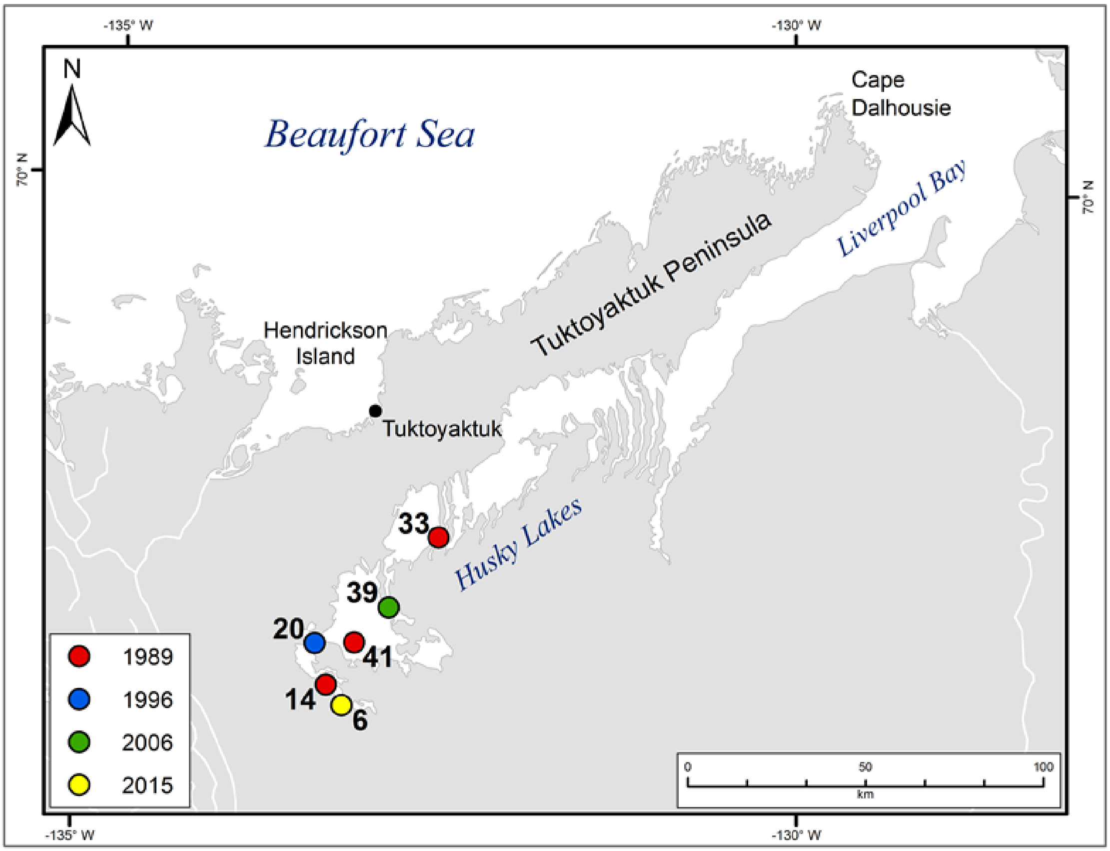

Figure 8. Location and numbers of entrapped belugas in the Husky Lakes (DFO and FJMC unpublished data).

There are no recent offshore aerial surveys to compare to the Harwood et al. (1996) July 1992 beluga survey in order to evaluate changes in offshore distribution in July. However, bowhead whale aerial surveys were flown in the Canadian Beaufort in August in each of 1982, 1984–1986, and 2007–2009 provide an opportunity later in the season to make comparisons among years and decades (Harwood and Kingsley 2013). In the 1980s series, 305 belugas (145 sightings) were observed on-transect during 20,858 km^2 of survey. In the 2000s series, with essentially the same survey area (19,829 km^2), more than three times the number of belugas were sighted on-transect in the same area at the same time of year (1061 belugas; 378 sightings; Figure 9). In both series, belugas were observed mainly in groups of 1 to 3 (49% in 1980s, 43% in 2000s) and groups of 4 to 10 (30% in 1980s; 39% in 2000s). Mean group size was 2.1 (Standard Deviation [SD] 2.1, range 1–15) in the 1980s and 2.6 (SD 3.9, range 1–60) in the 2000s. Both group-size contraharmonic mean and clump factors were larger in the 2000s surveys, consistent with a more clumped distribution in the latter series compared with the former (Harwood and Kingsley 2013).

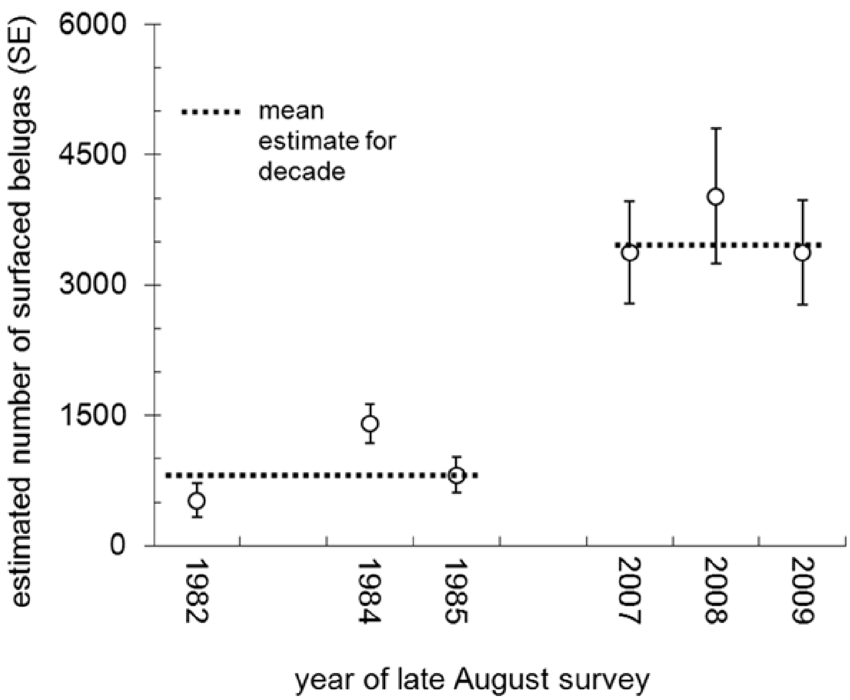

Figure 9. Estimated number of surfaced, visible belugas (and Standard Error) in the southeastern Beaufort Sea, extrapolated for unsurveyed areas but not corrected for subsurface belugas, or belugas outside of the study area at the time of the survey; 1980s vs 2000s (from Harwood and Kingsley 2013).

Population growth, though probably not sufficient to explain the changes observed in relative abundance between decades, could be partly responsible for the apparent increase in beluga use of the Beaufort Sea Shelf in the 2000s vs the 1980s. An alternative explanation is that the Shelf became more attractive to belugas in the 2000s, compared with the 1980s (Harwood and Kingsley 2013). Enhanced pelagic marine productivity is predicted by most climate change models (e.g., Barber et al. 2008, Wood et al. 2015), and belugas observed in the 2000s could have been accessing resources over the Beaufort Sea Shelf to a greater extent, or for longer periods, than was observed in the 1980s. Finally, another mechanism could have been displacement or deterrence of belugas from the Beaufort Sea Shelf in the 1980s given the considerable levels of industry activity there at that time, as has been reported for 2001–2002 in the vicinity of similar, although smaller operations (Miller et al. 2005).

Also a consideration is that the 1980s series of aerial surveys was flown during a period when sea ice concentration in the southeast Beaufort Sea was greater than it was during 80% of the years between 1979 and 2015 (O’Corry Crowe et al. 2016). In contrast, the 2007–2009 series was flown when sea ice concentration was less than 80% of the years from 1979 to 2015 (O’Corry Crowe et al. 2016; Figure 10). Belugas may have remained in Canadian waters longer under the light ice condition scenario, or left earlier under heavy ice conditions in the 1980s. The relationship between beluga movements and sea ice has been examined for this stock using various methods (e.g., genetics, acoustics, aerial surveys; Hauser et al. 2014, 2017, O’Corry Crowe et al. 2016), and so far with no indications of sustained or directional ice-mediated shifts in their habitat use or migration patterns.

Collectively, the available harvester and scientific observations provide some indication that the use of offshore habitats by belugas may be changing with whales arriving earlier in spring, and possibly expanding the extent of summer range (Loseto et al. 2018a).

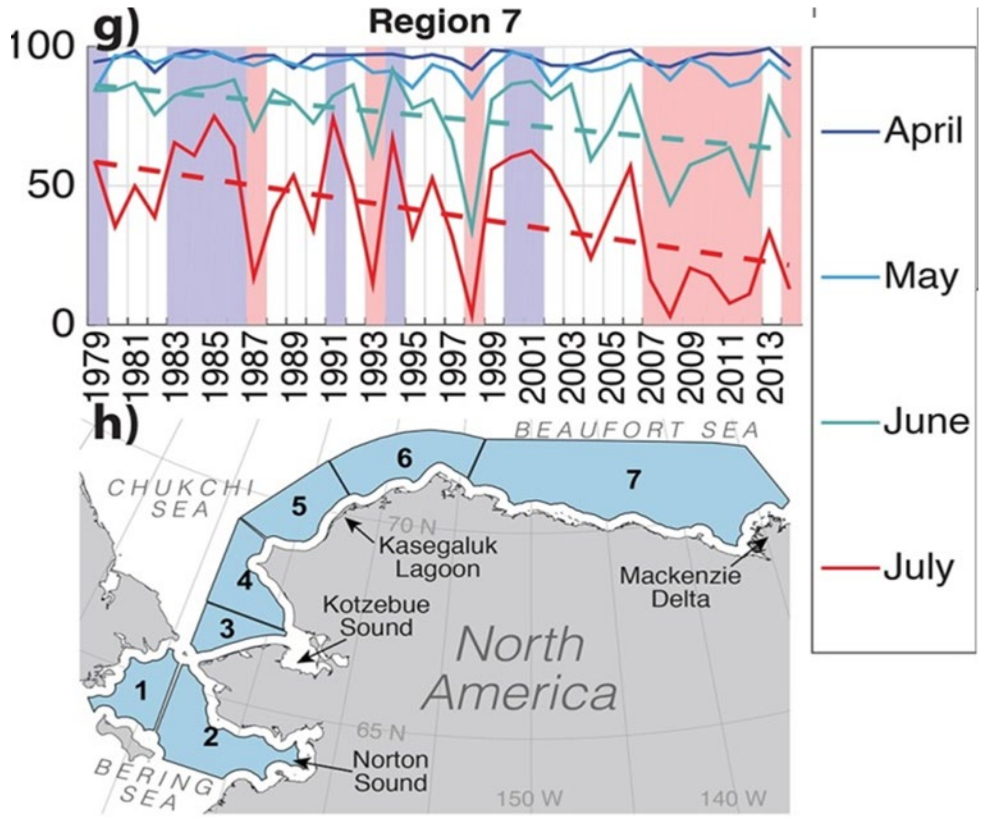

Figure 10. Seasonal and annual sea ice concentrations (upper panel) in the southeastern Beaufort Sea (area shown as region 7, lower panel), 1979–2015 (from O'Corry Crowe, et al. 2016, with data from Cavalieri et al. 1996). Purple blocks = years when ice concentrations were greater than 80% of the years between 1979–2014; pink blocks, years when ice concentration was less than 80% of the years 1979–2014.

ABUNDANCE

The only aerial survey to count beluga over most of the EBS summer area was flown in late July 1992, and included systematic coverage of the Mackenzie Estuary, the offshore Beaufort Sea, and western Amundsen Gulf. It was flown in a short period (3 days), and under favourable survey conditions (Harwood et al. 1996; Figure 11). That survey produced an index of stock size of 19,629 (CV = 0.229), which was ultimately and was reported in the DFO (2000) stock status report. To account for availability bias (beluga whales below the surface at depths that make them unavailable to be seen visually from an aircraft), an availability correction factor (CF) of 2 was recommended for this stock by experts at the Beaufort Beluga Workshop held in 1992 (Duval 1993, cited in Hill and DeMaster 1999). This produced an estimated stock size of 39,258 (i.e., 19,629 × 2), calculated by the National Oceanic and Atmospheric Administration (NOAA) and used annually by NOAA in annual assessments for the status of this stock (Muto et al. 2016).

While a coefficient of variation (CV) for that CF was not available, the survey abundance estimate was considered negatively biased due to (1) the use of a conservative aerial survey availability correction factor of 2 when other studies have used estimates between 2.5 and 3.27 (Frost and Lowry 1995) and (2) the 1992 survey did not encompass the entire summer range of EBS belugas (Richard et al. 2001). There have been no aerial surveys since 1992 with the objective of estimating the size of this stock.

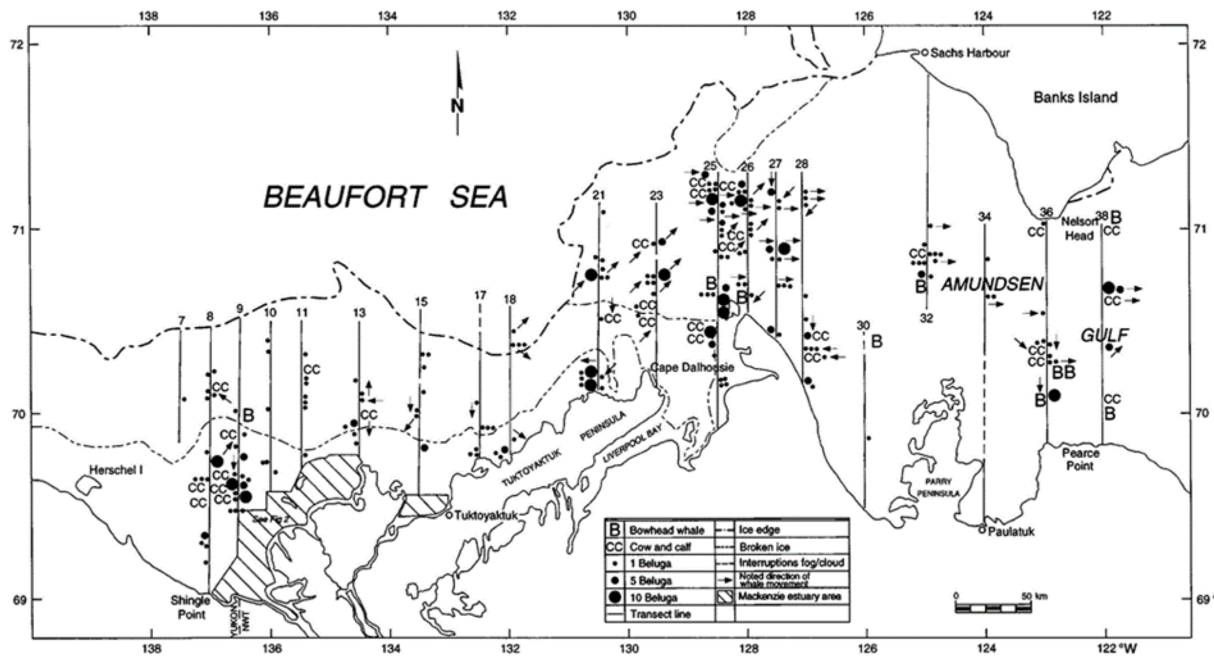

Figure 11. Location and number of transects flown, and surfaced beluga counted on the 23–25 July 1992 aerial survey in the Mackenzie Estuary and the southeast Beaufort Sea and western Amundsen Gulf (from Harwood et al. 1996).

REMOVALS

Subsistence Harvests

While in the Mackenzie Estuary, EBS belugas have long been an important traditional subsistence hunt of the Inuvialuit, the people of the western Canadian Arctic (Nuligak 1966, McGhee 1988, Day 2002). There is little information available about the magnitude of beluga harvests prior to European contact (ca. 1888) or during the commercial whaling period (1888–1907; Bockstoce 1986) and up until the 1950s. Most sources indicate beluga harvests are lower now than they were prior to 1970 (Nuligak 1966, Smith and Taylor 1977, McGhee 1988, Strong 1989, Friesen and Arnold 1995, Day 2002).

Since at least the 1940s (Day 2002) beluga hunters and their families travelled by small boat to seasonal whaling camps clustered on the coast of the Delta, mainly on the shores of Kugmallit Bay, Kendall Island, and Shallow Bay (Figures 1, 2). Beluga hunting occurs mainly during a four-week period in July coincident with when belugas aggregate in the shallow estuarine waters of the Mackenzie River (Fraker et al. 1979, Norton and Harwood 1986, Harwood et al. 2002).

Harvesters from three other Inuvialuit coastal communities also hunt belugas, mainly during the post-estuary period. Paulatuk, NT has had a regular harvest, monitored/sampled since 1989. Harvests at and near Ulukhaktok, NT (formerly Holman) and Sachs Harbour are at present opportunistic (e.g., recent harvests occurred 2004, 2005, 2010), although substantially larger numbers have been taken in some years (Table 1). Whales landed in these outlying locations were understood by hunters as being from the same stock as those taken in the Delta (P. Gruben, Community of Tuktoyaktuk, Tuktoyaktuk, NT, pers. comm.). This was also inferred previously from satellite telemetry results (Richard et al. 2001) and length-at-age curves from the different harvesting regions (Harwood et al. 2015), and now confirmed with molecular methods (Postma 2017).

To calculate the mean decadal harvest, and sex ratio of the harvest, we used published data sources from 1970–2009 (Harwood et al. 2002, 2015), and augmented it with unpublished data from the FJMC monitoring program (2010–2015; Table 2). All data since 1988 were obtained through direct observation and interviews with, and by Inuvialuit beluga hunters, collected as part of the FJMC beluga monitoring program (Strong 1990, Weaver 1991, Harwood et al. 2002, 2015).

Table 2. Known and estimated number of Eastern Beaufort Sea beluga struck, landed, and lost in Canada and Alaska, 1987–2015.

Year	Canada[1,2]			Alaska [3]			Total Estimated Strikes (Canada and Alaska)
	Struck	Landed	Struck but lost/not retrieved [4]	Estimated Struck	Landed	Estimated struck but not retrieved/lost or unreported[3]	
1987	174	144	30	58	50	8	232
1988	139	116	23	78	67	11	217
1989	156	117	39	30	26	4	186
1990	106	87	19	40	34	6	146
1991	144	116	28	50	43	7	194
1992	130	121	9	33	28	5	163
1993	120	110	10	99	85	14	219
1994	149	141	8	72	62	10	221
1995	143	129	14	5	4	1	148
1996	139	120	19	28	24	4	167
1997	123	114	9	50	43	7	173
1998	93	86	7	69	59	10	162
1999	102	86	16	41	35	6	143
2000	84	78	6	77	66	11	161
2001	92	91	1	29	25	4	121
2002	85	83	2	28	24	4	113
2003	123	111	12	50	43	7	173
2004	143	133	10	37	32	5	180
2005	108	106	2	23	20	3	131
2006	126	121	5	6	5	1	132
2007	82	82	0	72	62	10	154
2008	81	75	6	58	50	8	139

Year	Canada[1,2]			Alaska [3]			Total Estimated Strikes (Canada and Alaska)
	Struck	Landed	Struck but lost/not retrieved [4]	Estimated Struck	Landed	Estimated struck but not retrieved/lost or unreported[3]	
2009	102	96	6	15	13	2	117
2010	93	90	3	83	71	12	176
2011	102	98	4	49	42	7	151
2012	75	73	2	107	92	15	182
2013	92	90	2	41	35	6	133
2014	106	104	2	28	24	4	134
2015	83	82	1	50	43	7	133

[1] This includes all harvests reported to government authorities and FJMC; not all were available for sampling/inclusion in Table 1; Community totals derived from DFO/FJMC database of sampled whales.

[2] Data sources: as cited in Harwood et al. 2002, 2015, Frost and Suydam, 2010, Alaska Beluga Whale Committee (ABWC) unpublished data 2010–2015 and FJMC unpublished data 2010–2015.

[3] Added proportion of annual harvest based on Frost and Suydam (2010), stated reporting rates were high (80–87% over the 1987–2006 period), landed harvest increased by 16.5% annually to estimate lost and unreported whales.

[4] Beluga hunting by-laws (local community hunting rules) were developed beginning in 1991, and are available in FJMC (2013).

The mean annual landed harvest from the Mackenzie Delta and Paulatuk harvesting areas (combined) was 134 (SD 16.0) during 1970–1979, 124 (SD 23.3) during 1980–1989, 111 (SD 19.0) during 1990–1999, 98 (SD 19.6) during 2000–2009, and 90 (SD 11.1) during 2010–2015 (Table 3). The number of belugas struck and lost was lowest in the 2010–2015 period (2.5%; struck and lost/divided by total struck x 100) and the 2000s (5.4% of strikes), and was higher in the 1990s (averaged 11.2%), and 1980s (averaged 17.7%), and in the 1970s (estimated 15.9%) (Table 3). Declining interest and dependence on traditional foods and hunting, the high cost of hunting equipment and fuel, and increasingly challenging hunting conditions due to windier weather are described by hunters as the main reasons for the decline of the harvest over time (Appendix 1, Waugh et al. 2019, Worden 2019). The decline in struck but lost rates is attributed to the establishment and implementation of beluga hunting by-laws by the local HTCs (FJMC 1998, 2013). These declines were statistically significant, for both total landings ($R^2 = 0.327$, df = 32, t = -4.232, $p < 0.001$) and struck and lost (not retrieved; $R^2 = 0.563$, df = 32, t = -4.798, $p < 0.0001$) for the Canadian Beaufort Sea (Figure 12).

Table 3. Mean number of Eastern Beaufort Sea beluga whales struck, landed and lost in the Beaufort Sea/Delta region by decade and using data from 1970–2015 in Canada (Harwood et al. 2015, FJMC and DFO unpublished data) and from 1987–2015 for Alaska (Frost and Suydam 2010, ABWC unpublished data). Standard deviation for landed whales is shown in brackets, nd = no data.

Decade	Canada				Alaska			
	Struck	Landed (SD)	Lost	% Lost	Struck	Landed (SD)	Lost	% Lost[1]
1970–1979	164.5	133.7 (16.0)	26.0	15.9	nd	nd	nd	nd
1980–1989[2]	140.7	124.0 (23.3)	19.9	13.8	55.5	47.7 (20.6)	7.9	16.5
1990–1999	125.1	111.0 (19.0)	13.8	11.2	48.6	41.7 (22.6)	6.9	16.5
2000–2009[3]	102.6	97.6 (19.6)	5.0	4.6	39.6	34.0 (20.6)	5.6	16.5
2010–2015	91.8	89.5 (11.1)	2.3	2.5	59.6	51.2 (25.3)	8.4	16.5

[1] Lost whales estimated for Alaska as 16.7% of landed harvest based on Frost and Suydam (2010). Statement reporting rates were high (80–87% over the 1987–2006 period).

[2] Decadal mean for Alaska was based on 1987–1989 data only.

[3] Differs from Harwood et al. (2015) due to updated struck and lost estimates for 2000–2002.

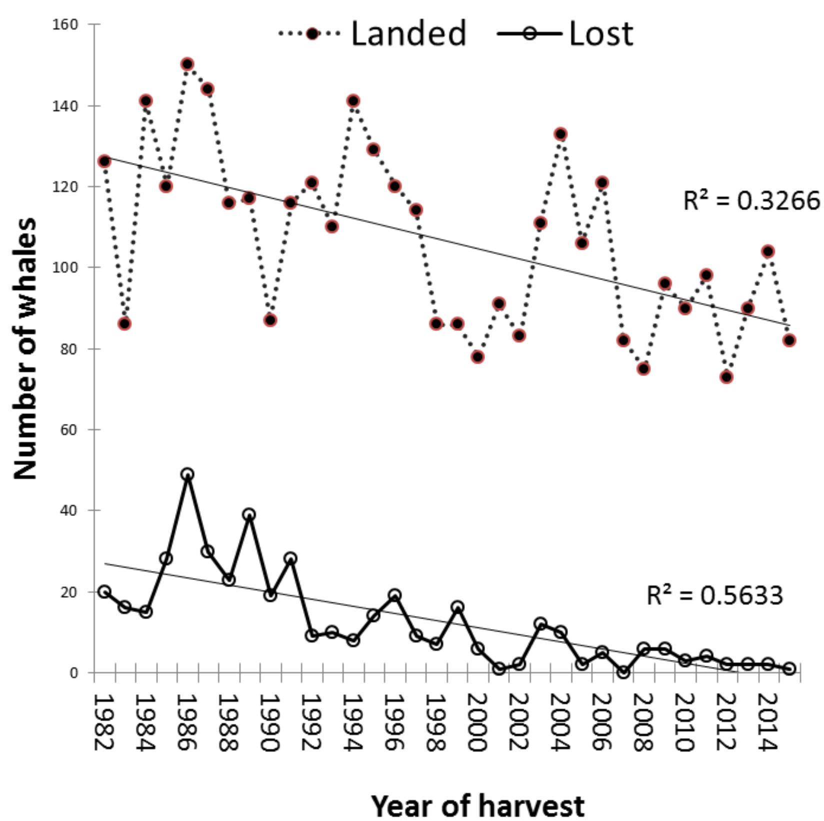

Figure 12. Number of EBS belugas landed, and number struck but lost (not retrieved) in subsistence harvests in Canadian waters, 1982–2015 (data taken from Harwood et al. 2015, FJMC unpublished data).

Gender of harvested whales is determined in the field by the beluga hunter and recorded by the beluga monitor at the whaling camp. The harvest has been strongly biased toward males, and has progressively over time become increasingly biased to males (harvests in Amundsen Gulf were also strongly biased, with harvested males outnumbering females [Table 4]). This bias toward male beluga arises from hunter selection, a local hunting practice aimed at the conservation of reproductive females, formalized in the 1990s under community-specific, local hunting by-laws (FJMC 2013).

Table 4. Gender of landed belugas (where known) and male:female ratios for the subsistence harvest in the Delta and Amundsen Gulf, 1980–2015 (data from Harwood et al. 2002, 2015).

Decade	Delta				Amundsen Gulf			
	Females (F)	Males (M)	Total	M:F Ratio	Females (F)	Males (M)	Total	M:F Ratio
1980–1989	348	696	1044	2.0	8	4	12	0.5
1990–1999	241	733	974	3.0	18	72	90	4.0
2000–2009	176	639	815	3.6	18	82	100	4.6
2010–2015	72	288	360	4.0	13	58	71	4.5

Based on known and estimated harvest removals that were collected from all known sources in Canada and Alaska, and including estimates and records of struck and lost whales in both locations (ABWC unpublished data), the present annual removal for EBS beluga averaged 164 (SD 32.9) per year over the 1987–2015 time series (Table 2). In the most recent 10 years (2006–2015), removals by harvesting in Canada and Alaska including landed and struck but lost averaged 145 belugas (SD 20.7). Harvests in Chukotka, Russia are less than 10 per year in total, some of which may be EBS belugas taken in spring and fall migrations. Takes by residents of the Chukotka Peninsula are not projected to increase (D. Litovka, Pacific Research Fisheries Center, Chukotka Branch (ChukotTINRO), Anadyr, Chukotka, Russia, 2017, pers. comm.).

Ice Entrapments

Six beluga ice entrapments, also known as savssats, are on record in Canada’s Western Arctic, all located within the Husky Lakes (Table 5, Figure 8; Higdon and Ferguson 2012). They have all involved a small number of whales, with a known total of 257 belugas overall drowned, or removed by community hunters, between the years 1966 to 2015 inclusive. These records are not included as harvested animals in the harvested totals, as the whales are generally not considered fit for consumption due to emaciation. Hunters took initiative to remove them for humane reasons (DFO 2021).

Table 5. Estimated number of entrapped beluga whales for known entrapments in the Husky Lakes, 1966–2016 (Hill 1967, Weaver and Richard 1989, DFO unpublished data). When available, mean glg age (standard deviation) and range are provided for males and females. Number of whales removed are not considered harvested whales. Nd = no data, dash (-) = no data collected.

Year	Estimated Number Entrapped	Number Removed	Proportion of males Landed	AGE (glg)					
				MALES			FEMALES		
				n	Mean (SD)	Range	n	Mean (SD)	Range
1966	> 50	0	-	-	-	-	-	-	-
1969	9	0	-	-	-	-	-	-	-
1974	Nd	0	-	-	-	-	-	-	-
1989	125	87	84%	65	30.3 (14.3)	2–58	14	38.14 (16.6)	12–64
1996	21	20	65%	11	22.7 (15)	2–46	6	22.66 (19.7)	2–50
2006	39	37	92%	34	26.4 (7.9)	11–40	3	33 (19.5)	14–53
2007[1]	6	0	-	-	-	-	-	-	-
2015	6	0	-	-	-	-	-	-	-

[1] Whales were discovered in the summer of 2007, but were purportedly trapped during fall 2006.

Potential Biological Removals (PBR)

Using the approach adopted by the DFO National Marine Mammal Peer Review Committee, EBS beluga would be categorized as “data poor” (DFO 2018), requiring the use of Potential Biological Removal (PBR) to calculate the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population:

$$PBR = 0.5 * R_{max} * N_{min} * F_r$$

where:

R_{max} is the maximum rate of increase for the stock (which is unknown, so a default value of 0.04 for cetaceans was used; Hill and DeMaster 1999), N_{min} is the minimum abundance estimate for the stock which was calculated by Wade and Angliss (1997) using the 1992 survey estimate of 32,453 (Harwood et al. 1996). F_r is the recovery factor, here we used $F_r = 0.75$ because the stock is abundant, but with limited data and an unknown trend not considered to be declining (DFO 2018). A recovery factor of 1 was used previously by DFO, and most recently by NOAA (DFO 2000, Mutz et al. 2016), however, it has been more than 10 y since the last aerial survey and stock estimate, and based on expert observations and the long-term experience of hunters, it was agreed that the stock was stable or increasing, and therefore a recovery factor of 0.75 was appropriate for this stock.

The resulting maximum number of EBS beluga that may be removed while still allowing the stock to reach or maintain a sustainable population is 487. The total of current Canadian, Alaskan and Russian harvests (approximately 155 beluga), reported struck and lost whales, potential anthropogenic losses (e.g., ship strikes and net entanglements), and non-reported harvests is considered to be well below the PBR. However, we emphasize that this estimate of PBR is based on an estimate of abundance, which while negatively biased, is out of date.

BIOLOGICAL INDICATORS FOR THE EBS STOCK

A formal harvest monitoring program was conducted from 1973–1975 (Hunt 1979) by the Fisheries and Marine Service of the Government of Canada. An oil and gas industry-sponsored program followed from 1977 through 1982 (Fraker 1977, 1978, Fraker and Fraker 1979, 1981, Norton 1983). A DFO-led program followed from 1981 through 1986 (Strong 1990, Weaver 1991), and finally, FJMC assumed responsibility for the program in 1987 and has continued in that role to the present day (Harwood et al. 2002, 2015, FJMC unpublished data).

In all years, the basic program was conducted at the seasonal whaling camps in the Delta, and in some years, from remote camps used by harvesters from Paulatuk. Data were collected from the hunters on number of whales struck, landed and lost in the harvest, and the size and timing of the harvest. From 1980 onward, the whales were measured, sex determined, and biological samples were taken from almost all of the landed whales. This information was collected to document the size and trend of the harvest, and to assess the health of the beluga stock and the impact of the harvest on that stock. The program has been conducted annually since 1980, and now comprises the longest (30 y) and largest database on harvested beluga in Canada.

Here we summarize the available biological data on EBS beluga, published previously in Weaver (1991) and Harwood et al. (2002, 2015), and include an update through 2010–2015 using more recent and unpublished data from the FJMC beluga monitoring program. All field methods and laboratory analyses are as described in Harwood et al. (2015), unless otherwise noted.

Field measurements of standard length (ASM 1961), blubber thickness at sternum (2000–2015) and gender (1980–2015), plus reproductive tracts (2000–2005) and other ancillary morphometric measures and samples (e.g., fluke widths, colour, stomach contents, unusual observations; Harwood et al. 2015) were taken from beluga in the ISR by dedicated field monitors during the annual beluga monitoring program. In the database, there are 270 records of beluga harvested from Amundsen Gulf (Paulatuk, Ulukhaktok), 8 records from the Beaufort (Herschel Island, Sachs Harbour, 1 from Husky Lakes in summer), 3,167 records from the Delta, and 141 records from 1989, 1996, and 2006 when belugas were trapped in Husky Lakes following freeze up (Table 5).

Table 6. Number of EBS beluga whales that were aged (FJMC and DFO unpublished data). Whales and samples were obtained from hunter-based subsistence harvest monitoring programs and entrapments in the Inuvialuit Settlement Region, 1975–2015.

Year	Mackenzie Delta	Amundsen Gulf	Beaufort Sea	Husky Lakes	Unknown Region	Total
1975	0	0	0	0	0	0
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	0	0	0
1979	0	0	0	0	0	0
1980	0	0	0	0	0	0
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	79	0	79
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1992	0	0	0	0	0	0
1993	64	3	0	0	0	67
1994	2	8	0	0	0	10
1995	98	9	0	0	0	107
1996	78	14	0	17	0	109
1997	43	0	0	0	0	43
1998	39	1	0	0	0	40
1999	66	0	0	0	0	66
2000	43	2	0	0	0	45
2001	72	0	0	0	0	72
2002	79	0	0	0	0	79
2003	65	0	0	0	0	65
2004	36	0	0	0	0	36
2005	33	13	0	0	0	46
2006	35	0	0	37	0	72
2007	56	15	0	0	0	71
2008	61	5	0	0	0	66
2009	19	0	0	0	0	19
2010	19	0	0	0	0	19
2011	51	9	0	0	0	60
2012	59	7	0	0	0	66
2013	64	10	0	0	0	74
2014	40	25	0	0	0	65
2015	53	15	0	0	0	68

Standard Length and Age (GLG)

Standard length has been a regular measurement taken in the annual beluga monitoring program over four decades. It is measured as the straight line distance from the notch in the fluke to the tip of the snout. The counts of Growth Layer Groups (GLGs) in the dentin of marine mammal teeth are widely used as indicators of age because GLGs are deposited annually in beluga. Box plots depicting the distribution of standard length and GLG age of male and female EBS belugas that were sampled from the subsistence harvest and entrapment locations in the Inuvialuit Settlement Region (1975–2015) are presented in Figure 13.

Mean standard length and mean GLG age (+1 SD) of belugas landed in the Delta and in Amundsen Gulf, by gender, were examined across the time series (Figure 14). Females in the Delta averaged 36.2 GLG (SD 12.6, range 10–63, n = 246) and males averaged 29.5 GLG (SD 10.1, range 11–67, n = 901). Females in Amundsen Gulf averaged 28.8 GLG (SD 17.5, range 5–62, n = 20) and males averaged 26.8 GLG (SD 11.2, range 6–61, n = 105).

Temporal trends in mean standard length and GLG age were evaluated using linear regression, by gender. There were no significant changes detected in the size of females landed by Delta harvesters over the time series (Figure 14a; $n = 794$, $F = 0.20$, $p = 0.66$) but there has been a significant shift to smaller males over time (Figure 14b; $n = 2310$, $F = 77.21$, $p < 0.0001$). This was well aligned with hunter’s observations that the size of whales landed in recent years is smaller than 10 to 15 years ago (Appendix 1). Three of six hunters reported that the incidence of 4.6 to 5.2 m (15’–17’) whales landed in the harvest was now unusual (Appendix 1). Others report they did not notice a trend, and said that the changing climate, including windier conditions in recent years are making it more difficult to select large whales (their preference) compared with the past. Another hunter added that people are spending less time at the coast for hunting than in the past (Appendix 1). This shift in hunter selection is thought to be the reason why some hunters report landed whales are smaller than in the past (DFO 2021).

There were statistically significant trends over time to decreasing mean GLG age ($n = 905$, $F = 49.04$, $p < 0.0001$) in males (Figure 14d), and to increasing mean GLG age in females (Figure 14c; $n = 248$, $F = 6.25$, $p = 0.013$).

Sample size was too limited to examine for temporal trends in mean size or GLG age of belugas landed in Amundsen Gulf (Figure 15 a-d). The estimated ages of 9 male belugas landed at Ulukhaktok in 2014, (included data in Figure 15), ranged from 5 GLG to 50 GLG, and for 11 females, from 5 to 56 GLG. None of the belugas landed previously by Ulukhaktok hunters (1980, n = 8; 2004, n = 3; 2005, n = 1) were aged.

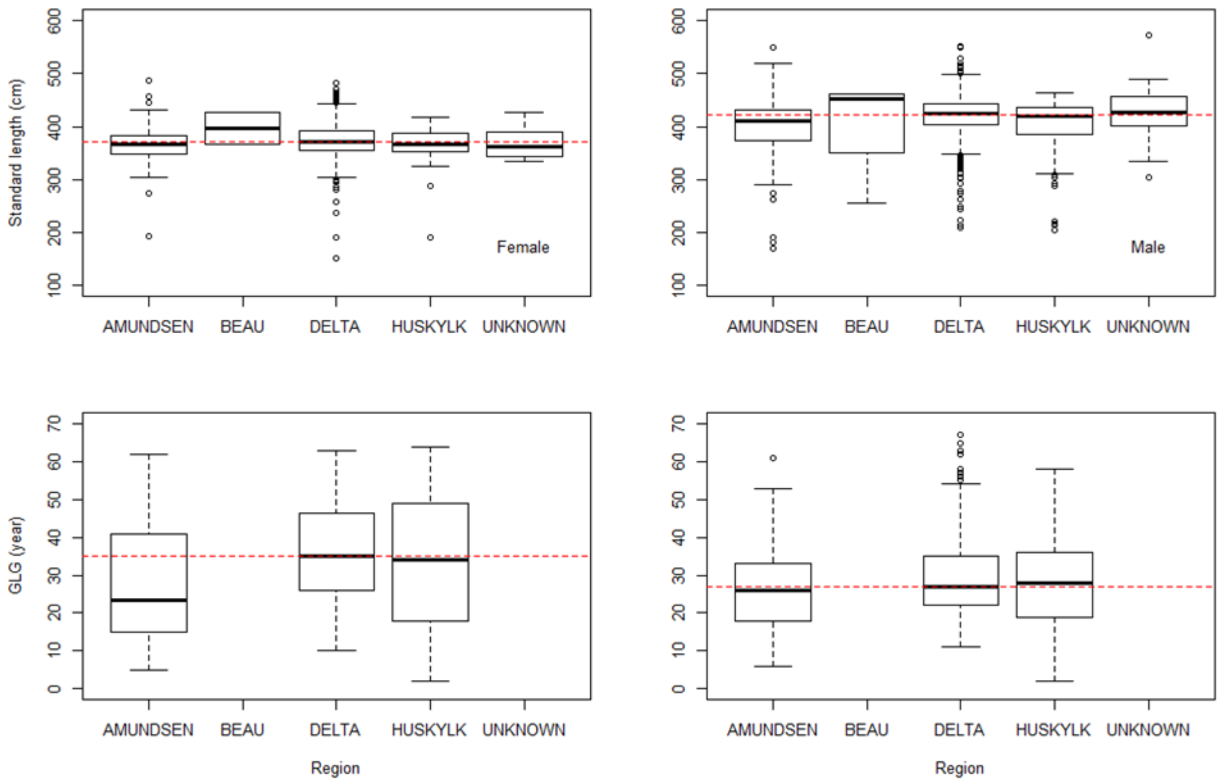

Figure 13. Whisker-box plots of standard length (cm, upper) and age (GLG in year, lower) for female (left panels) and males (right panels) for EBS beluga, by harvesting area and entrapment area. Samples obtained from subsistence harvests from Amundsen Gulf (AMUNDSEN), Beaufort Sea (BEAU), the Mackenzie Delta (DELTA), unknown region (UNKNOWN), and entrapments from Husky Lakes (HUSKYLK). Red dotted line is the mean across each time series. Boxes = 75% of observations for the harvest or entrapment location.

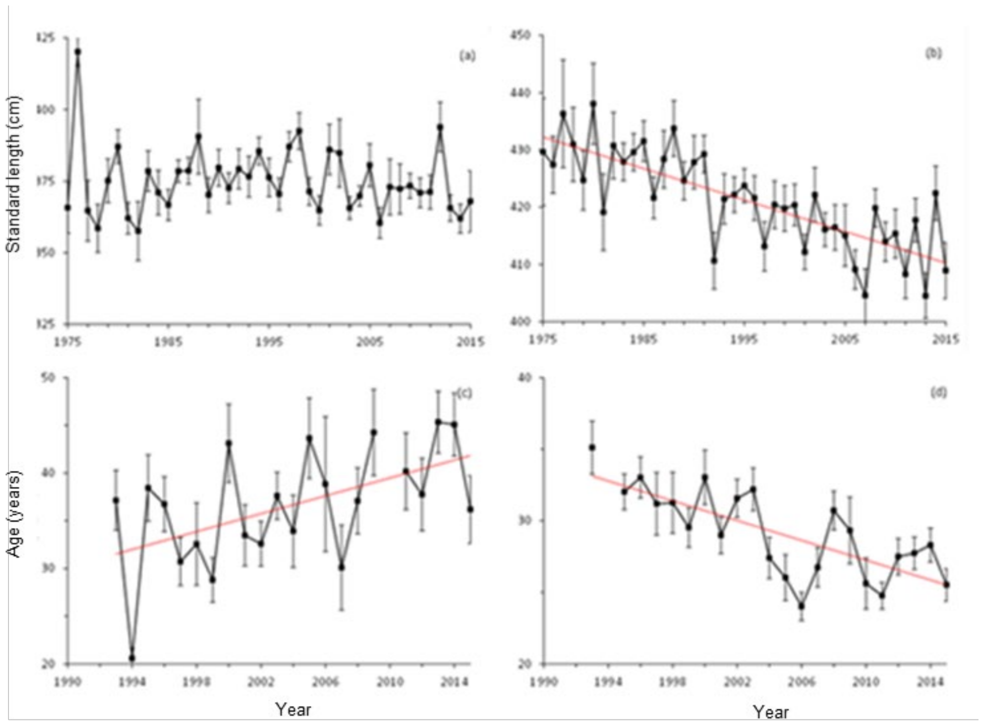

Figure 14. Temporal variation in annual mean (± SE) standard length (cm) (a, b) and GLG age (c, d) for female (left) and male (right) EBS belugas taken in the Mackenzie Delta subsistence harvests, 1992–2015.

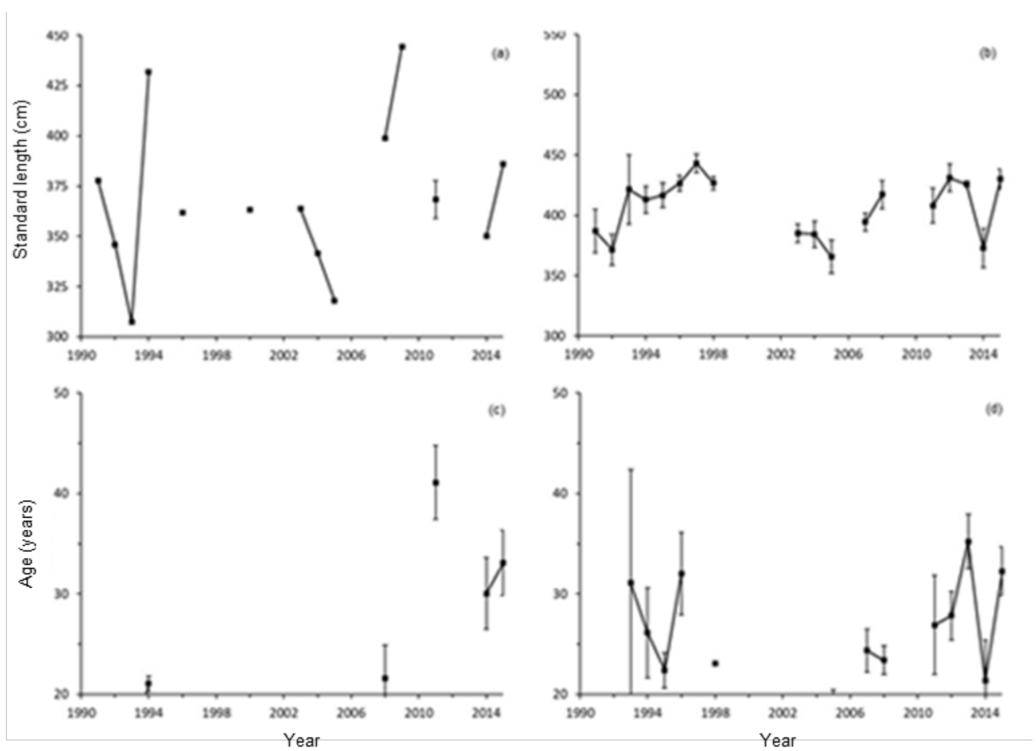

Figure 15. Temporal variation in annual mean (± SE) of standard length (cm) (a, b) and GLG age (c, d) for female (left) and male (right) EBS beluga taken in the Amundsen Gulf subsistence harvests, 1993–2015.

Asymptotic size was determined using a Gompertz growth model (Quinn and Deriso 1999), with 8 parameters including deviance, process error and hierarchical structure parameters for L∞ and K:

$$G4: L_t = L_\infty e^{-\alpha e^{-K_4(t-t_4)}}$$

This produced an asymptotic size of 377.2 cm + 1.97 for females (n = 287) and 435.46 cm + 1.56 for males (n = 1,119), similar to values reported by Luque and Ferguson (2010). Cumulative frequency distributions of standard length and GLG age of beluga landed by Delta and Amundsen Gulf hunters, by sex, are presented in Figures 16 and 17. Compared to belugas landed in the Delta, whales landed in Amundsen Gulf (main hunting location Paulatuk) are younger (Figure 17; Kolmogorov-Smirnov test, females: D = 0.363008, p = 0.0153, n = 266; males, D = 0.184969, p = 0.0032m, n = 1006) but not shorter (females, D = 0.221951, p = 0.3219, n = 266; males, D = 0.131727, p = 0.0765, n = 1,006). This aligns with the Richard et al. (2001) satellite tagging results which show the large males tended to migrate to distant Viscount Melville Sound following the Mackenzie Estuary aggregation period; while females and smaller, younger males moved into Amundsen Gulf for much of August.

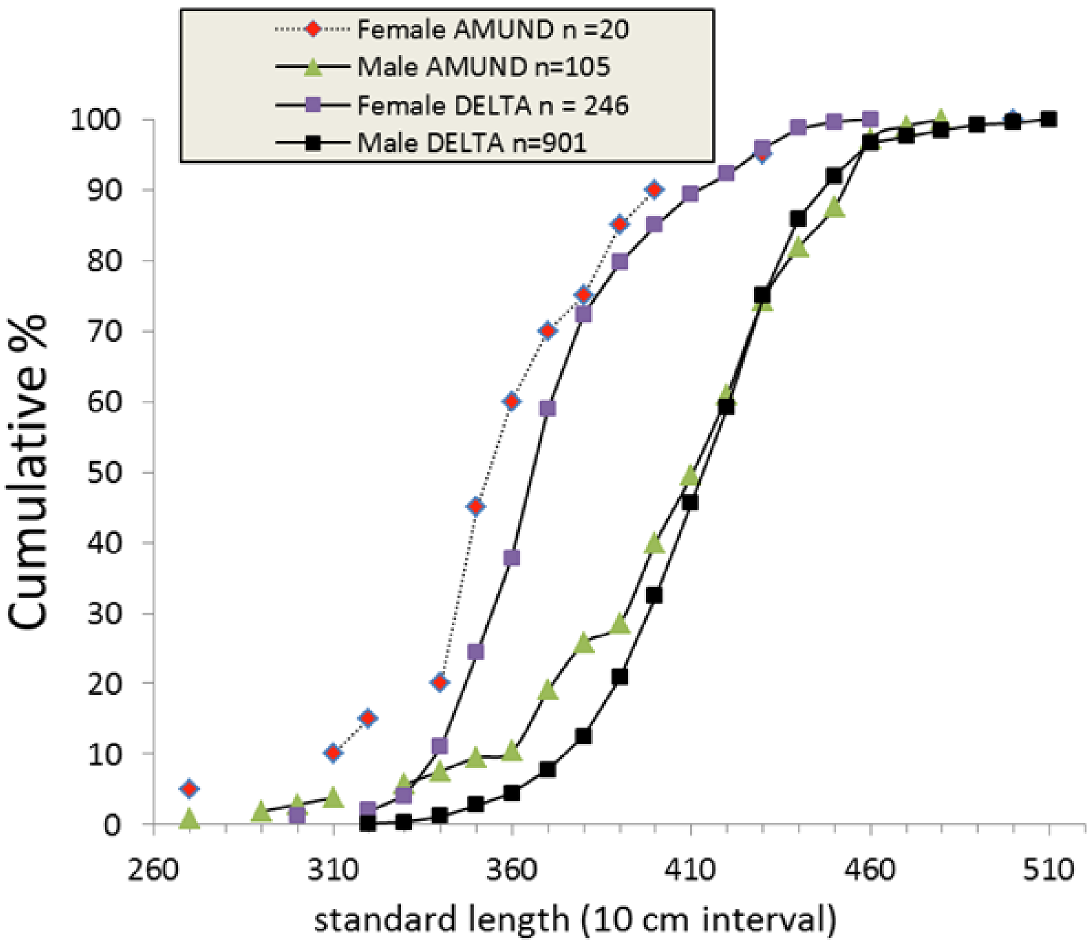

Figure 16. Cumulative frequency distribution of standard length in 10 cm intervals for male and female belugas landed by Delta and Amundsen Gulf hunters, 1993–2015.

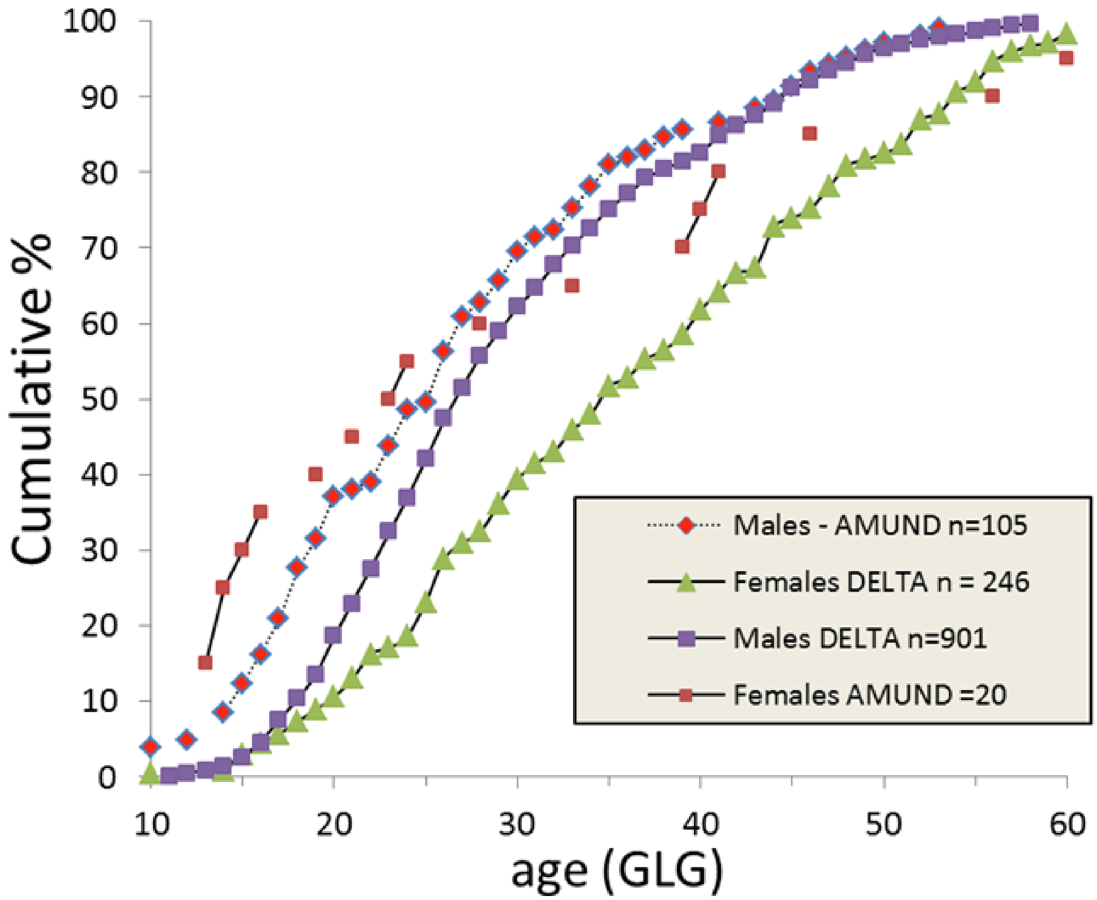

Figure 17. Cumulative frequency distribution of GLGs for male and female belugas landed by Delta and Amundsen Gulf hunters, 1993–2015.

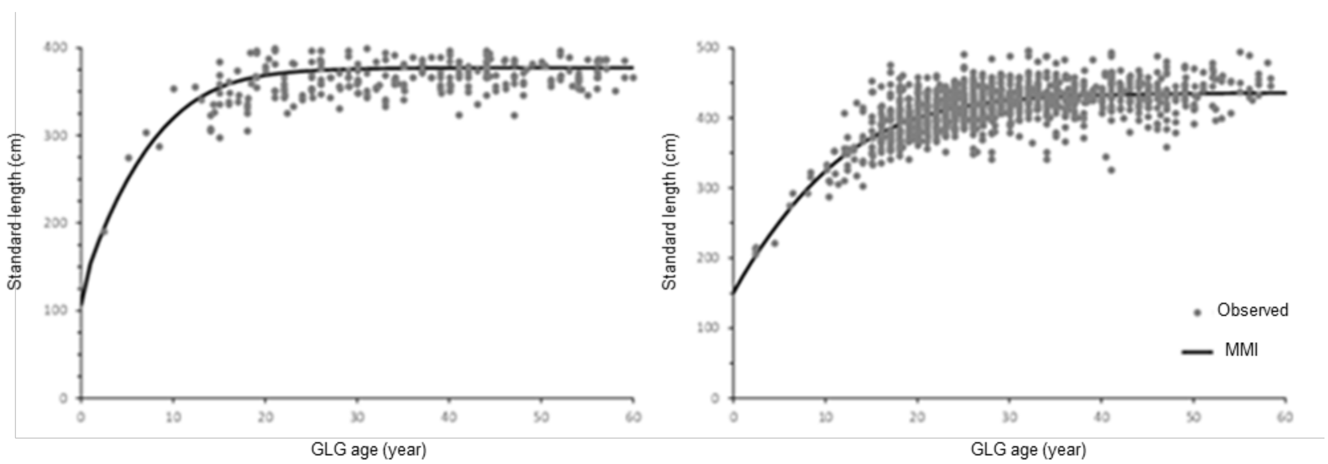

Figure 18. Length vs GLG age for female (left) and male (right) belugas sampled in the Delta and Paulatuk, 1980–2015.

Reproduction

Since the beluga harvest is strongly biased toward males and older animals, obtaining data to establish age of maturity, or assess temporal changes in reproductive rates, is difficult. Therefore, age-specific reproductive rates are not available for this stock, although mortality rates have been reported by Luque and Ferguson (2010).

Harwood et al. (2015) reported on reproductive data from 56 landed females between 2000 and 2005. Of these 56 females, 29 were from the Kendall Island area, and 27 were from Kugmallit Bay. All females sampled were sexually mature, with 53% having corpora lutea (CL), and 100% having regressing CL and corpora albicantia (CA; Figure 19). These mature females ranged in age from 10 to 58 GLGs (n = 51), and in size from 323 cm (41 GLG) to 439 cm (49 GLG). The numbers of visible corpora appeared to decrease in later years of life, although the sample size of females older than 40 GLG was small (n = 10). The same pattern was apparent in CLs, also lower in females over 40 GLG (Figure 20).

The two youngest females in the sample (10 and 17 GLGs) were neither pregnant nor lactating, but ovarian corpora were present in both (Figure 20). The two oldest females in the sample (56 and 58 GLGs) were both lactating. Twenty-three of 56 females (41%) were lactating, 8 of these had also recently ovulated. Twenty-three of 56 (41%) had no evidence of lactation or ovulation, 18 (32%) carried a first-term fetus (i.e., conceived that spring), and 15 (27%) carried a full-term fetus or were postpartum (Figure 20). The pregnancy rate for females with first-term fetuses was calculated as 0.32, indicative of a calving interval of three years. This calving interval agrees well with rates published using larger samples for two beluga stocks that also use the Bering Sea overwintering area (i.e., Kotzebue beluga = 0.34 [Burns and Seaman 1986], Eastern Chukchi beluga = 0.41 [Suydam 2009]).

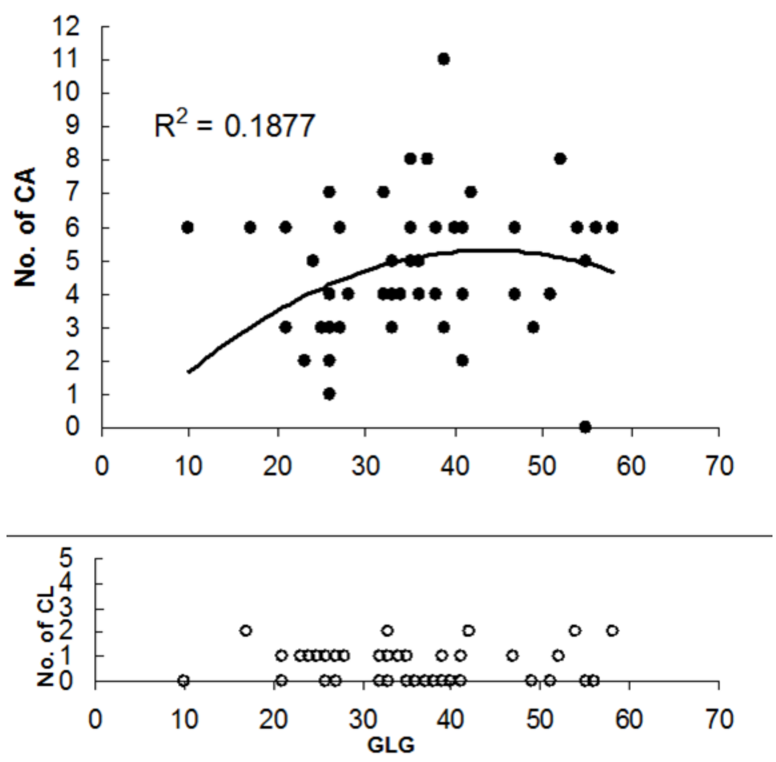

Figure 19. Number of corpora lutea (CL) and corpora albicantia (CA), by GLG age, observed in ovaries of belugas landed in subsistence harvests at Kugmallit Bay and Kendall Island, 2000–2005 (Harwood et al. 2015).

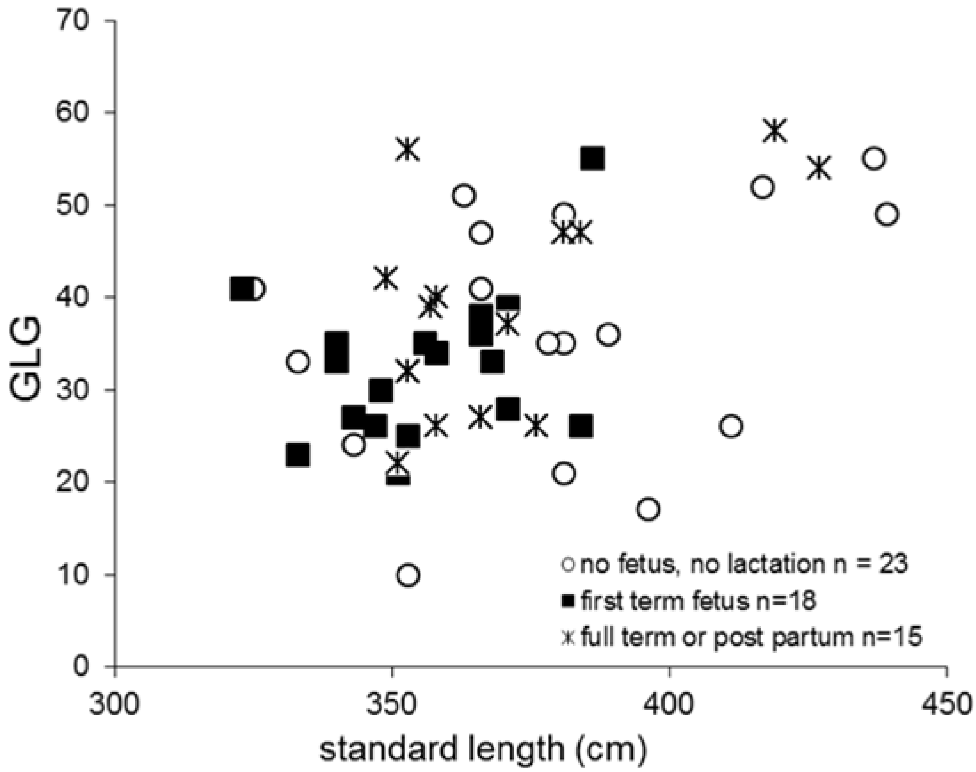

Figure 20. GLG age and standard length (cm) of 56 adult female belugas examined from Kugmallit Bay and Kendall Island subsistence harvests 2000–2005, by reproductive status (Harwood et al. 2015).

STATUS OF STOCK

The present annual rate of removal through harvesting and entrapment combined is small, compared with the estimate of stock size (e.g., < 0.4% of the 1992 estimate). The 12 local hunters who provided Indigenous knowledge, observations and experience based on decades of harvesting consider that stock abundance is stable or increasing. Current abundance and trends in abundance of EBS beluga whales over the past 25 years are not known from aerial survey data, as the last aerial survey was conducted in 1992. As such, under DFOs Precautionary Approach definition which requires only aerial survey data, this population is necessarily designated as “Data Poor”.

Changes in EBS beluga observed in the last two decades include a decline in the size of the harvest and in struck and lost rates, a shift to younger and smaller males being taken in the Delta harvest, a possible expansion of the late summer distribution of belugas offshore following the Estuary occupation period, possible changes in diet (Fortier and Ferguson 2009, Loseto et al., 2015, Loseto et al. 2018b).

The changes we have described may be linked to climate warming influences on hunting conditions, the prey base and/or sea ice. While there is evidence of changes in beluga distribution due to reduced sea ice extent from West Greenland (Heide-Jørgensen et al. 2010) and for the Eastern Chukchi Sea beluga stock (Hauser et al. 2017), it is still less clear if this is the case for EBS beluga (O’Corry Crowe et al. 2016, J. Clarke, Leidos, CA., 2017, pers. comm., 2017). In Amundsen Gulf, harvesting of belugas in locations that were not considered major or regular hunting areas in the recent past (Tables 1, 2) may also be indicative of changes in post-Estuary distribution of belugas. The ecological causes that could be underpinning these changes are currently unknown.

SUMMARY

- The number of EBS beluga whales harvested annually in Canada and Alaska is variable, but has been declining (1980–2015).
- Including estimated and known loss rates, the average annual removal of EBS beluga from 2006 to 2015 was 145 beluga (SD 20.7), considering both Canadian and Alaskan harvests. Catches in Russia are believed to be less than 10 belugas per year from the EBS stock, and removals due to entrapments < 5/y from 1966–2015.
- The Canadian harvest remains highly biased towards males, recently at a ratio of 4.1 to 1. This results from hunter selection in order to conserve females, particularly females with calves. This practice was formalized and fostered with the implementation of community-specific beluga hunting bylaws in the 1990s (FJMC 1998).
- The overall timing of the beluga harvest has not changed during 1980–2015, although there is a general consensus by hunters that whales are arriving to the Mackenzie Estuary earlier in the season.
- Incidence and variation in harvests in two Amundsen Gulf communities indicates that the distribution of EBS beluga after the Estuary concentration period varies among years, and their summer range may be expanding.
- There was a significant decline in the average size and GLG age of male belugas harvested in the Delta since 2007. One explanation for the declining mean size and GLG age of harvested males in recent years was that hunters now encounter more challenging weather and therefore hunting conditions due to the changing climate. This makes hunter selection for large males more difficult.
- There was a four-fold increase in the number of beluga counted during aerial surveys over the eastern Canadian Beaufort Sea shelf in August 2007–2009 compared with August 1982–1985. The reasons why the Beaufort Shelf was more attractive to beluga whales in the later series are not known, but could include a shift in the timing of the beluga’s fall migration, an increase in marine productivity and prey availability, an increase in stock size, deterrence of belugas in the 1980s due to industrial activity over the shelf, or an unknown factor or influence.
- Because of the low number of females taken in the harvest, data to determine age of sexual maturity and reproductive rates for this stock are not available. The limited data available suggests that the reproductive rate is similar to that reported for Eastern Chukchi Sea beluga in Alaska (a calving interval of once every three years).
- The only large-scale survey of EBS beluga whales was flown in late July 1992, and included coverage of both the Mackenzie Estuary and the offshore Beaufort Sea and western Amundsen Gulf. The survey estimated 19,629 (CV = 0.229) beluga at the surface. Assuming an availability correction factor of 2 to account for beluga below the surface at the time of the survey, this estimate was corrected to 39,258. This estimate is negatively biased as the survey study area did not include all of the known summer range of EBS beluga as shown by telemetry.
- Current abundance and trends in abundance of EBS beluga whales over the past 25 years are unknown. As such, under the Precautionary Approach, this population is necessarily designated as “Data Poor” by DFO because there has not been a recent aerial survey.

- Based on decades of harvesting and observer experience, 12 local hunters stated that the stock abundance was considered stable or increasing, but recognized that distribution may be changing.
- Using the Precautionary Approach applied to marine mammal stocks in Canada, a sustainable harvest level was estimated using the PBR method for "data poor" stocks, with a recovery factor of 0.75. This resulted in an estimated PBR of 487 that includes all anthropogenic losses (e.g., ship strikes and net entanglements, struck and loss, and non-reported harvests). The sum of the current Canadian and Alaskan harvest of 145 beluga, and the purported Russian take (< 10/y), is below this level.
- We emphasize that this estimate of PBR is based on an estimate of abundance, which while negatively biased, is out of date.

RECOMMENDATIONS FOR FUTURE RESEARCH AND MONITORING

- Update estimates of abundance and distribution using a broad-scale summer aerial survey that includes both offshore and Mackenzie Estuary areas. Optimum timing and stratification of this survey could be informed through analyses of existing tagging data and possibly a renewed tagging effort.
- Evaluate the timing of beluga arrival to the Mackenzie Estuary, and the relationship of their arrival to spring ice conditions. Retrospective examination of ice and survey records could extend this analysis as far back as the early 1970s.
- Evaluate existing tagging data with the explicit objective of examining spatial and temporal movements of EBS beluga within and among the bays of the Mackenzie Estuary.
- Explore the utility of dive data for calculation of perception and availability correction factors to estimate the proportion of time belugas below the surface in the estuary, with the eventual goal of developing more precise estimates.
- Evaluate distribution of belugas in the Mackenzie Estuary using replicated aerial surveys and the same transects, survey platform, timing, and analytical methods as the estuary surveys from the 1970s and 1980s. Such surveys would provide opportunities to compare:
  - sighting rates (e.g., whales per km flown);
  - patterns of clustering (e.g., standard distances), and;
  - the geographic location of 'hot spots' that were used by beluga formerly, with contemporary locations of 'hot spots'. This would complement concurrent, long-term, and on-going harvest monitoring efforts of the FJMC, DFO, and communities, which have involved standardized sampling of harvested beluga since 1980.
- Examine wind and other habitat variables such as tides for July and possible linkages to timing of hunting and hunting success.
- Examine changes in diet, growth and body condition of beluga relative to environmental change.
- The identification of specific deep-water feeding areas used by EBS beluga during late summer beyond the Mackenzie Estuary emphasizes the need for more research to be conducted on the use of distant habitats, particularly M'Clure Strait and Viscount Melville Sound.
- Use spring harvested beluga samples from Point Hope to augment reproductive information available for the small sample of adult females taken in the Mackenzie Delta. This may

provide information relating to age at first reproduction, calving interval and calf survival, all of these being biological characteristics that could change in response to climate-influenced changes in carrying capacity.

ACKNOWLEDGEMENTS

This Research Document reports on the work of many people, particularly the Inuvialuit beluga whale monitors who conducted field sampling since the 1970s. We gratefully acknowledge the beluga whale hunters and monitors who generously provided access to their landed whales for measuring and sampling. We also acknowledge the HTC from Inuvik, Tuktoyaktuk, Aklavik, and Paulatuk, Ulukhaktok, and Sachs Harbour for administration and support of the monitoring program, for decades. Ms B. E. Stewart, Sila Consultants, Winnipeg, is gratefully acknowledged for her work aging teeth and analysing reproductive tracts. Underpinning the program's success were the support and guidance of FJMC members and staff, most recently Kristin Hynes for assistance with updating the database for 2010–2015. The DFO Oceans Program and Northern Operations contributed extensive in-kind and operational resources and support toward the assessment process, including preparation of this document, attendance of hunters at the CSAS assessment. We gratefully acknowledge Garry Stenson, Veronique Lesage, Jack Lawson, Robert Suydam, Joclyn Paulic and Kathleen Martin for reviewing earlier drafts of this paper. John Alikamik (Ulukhaktok), Norman Anikina (Sachs Harbour), Lawrence Ruben (Paulatuk) and Jordan McLeod (Aklavik) and DFO staff who attended the assessment and contributed knowledge to the assessment and Kathy Frost of ABWC for sharing updates to the Alaskan harvest numbers, and Dennis Litovka, Russia for harvest data from Chukotka. We thank Shannon MacPhee for documenting the meeting proceedings, Mark Ouellette for GIS assistance, and Joclyn Paulic and Lia Kruger for formatting.

REFERENCES CITED

Adams, M., Frost, K.J., and Harwood, L.A. 1993. Alaska and Inuvialuit Beluga Whale Committee (AIBWC) – An initiative in “at home management”. Arctic 46(2): 134–137.

ASM (American Society of Mammalogists). 1961. Standardized methods for measuring and recording data on the smaller cetaceans. J. Mamm. 42(4): 471–476.

Barber, D.G., Lukovich, J.V., Keogak, J., Baryluk, S., Fortier, L., and Henry, G.H.R. 2008. The changing climate of the Arctic. Arctic 61 (Supp. 1): 7–26.

Belikov, S. 1999. The status of the white whale population (*Delphinapterus leucas*) inhabiting the Russian Arctic. International Whaling Commission Scientific Committee Report SC/51/SM21. 19 p.

Berger, Thomas R. 1977. Northern Frontier, Northern Homeland: The Report of the Mackenzie Valley Pipeline Inquiry: Volume 1. Minister of Supply and Services Canada, Ottawa, ON. xxxii + 214 p.

Bockstoce, J.R. 1986. Whales, ice and men. The history of whaling in the Western Arctic. University of Washington Press, Seattle, U.S. 400 p.

Burns, J.J., and Seaman, G.A. 1986. Investigations of belukha whales in coastal waters of western and northern Alaska. II. Biology and ecology. US Department of Commerce, NOAA, OCSEAP Final Report 56: 221–357.

Byers, T., and Roberts, L.W. 1995. Harpoons and ulus: collective wisdom and traditions of Inuvialuit regarding the beluga ("qilalugaq") in the Mackenzie River estuary. Byers Environmental Studies and Sociometrix Inc., Winnipeg, MB. Available: Fisheries Joint Management Committee, Box 2120, Inuvik, NT Canada X0E 0T0. 76 p.

Carter, B.T.G., and Nielsen, E. A. 2011. Exploring ecological changes in Cook Inlet beluga whale habitat through traditional and local ecological knowledge of contributing factors for population decline. Mar. Policy 35(3): 299–308.

Cavalieri, D., Parkinson, C.L., Gloersen, P., and Zwally, H.J. 1996. Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data, Version 1. [NSIDC-0051]. Boulder, Colorado, U.S. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi:10.5067/8GQ8LZQVL0VL.

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

Clarke, J. T., Moore, S. E., and Johnson, M.M. 1993. Observations on beluga fall migration in the Alaskan Beaufort Sea, 1982-87, and northeastern Chukchi Sea, 1982-1991. Report of the International Whaling Commission 43: 386–396.

Cosens, S.E., de March, B.G.E., Innes, S., Mathias, J., and Shortt, T.A. 1998. Report of the Arctic Fisheries Scientific Advisory Committee for 1993/94, 1994/95 and 1995/96. Can. Manuscr. Rep. Fish. Aquat. Sci. 2473: v + 87 p.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2004. COSEWIC assessment and update status report on the beluga whale *Delphinapterus leucas* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 70 pp.

Day, B. 2002. Renewable resources of the Beaufort Sea for our Children: perspectives from an Inuvialuit elder. Arctic 55 (Suppl. 1): 1–3.

DFO. 2000. Eastern Beaufort Sea beluga whales. DFO Science Stock Status Report E5–38.

DFO. 2010. Proceedings of the Central and Arctic Regional Science Advisory Process to Select Indicators for the Tarium Niryutait Marine Protected Area (TNMPA); 30-31 March and 13 April 2010. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2010/038.

DFO. 2018. Harvest advice for eastern and western Hudson Bay Beluga (*Delphinapterus leucas*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/008. (Erratum : September 2020)

DFO. 2021. Proceedings for the Central and Arctic Regional Science Advisory Process to assess the status of the Beaufort Sea beluga stock; January 24–26, 2017. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2021/nnn. In press.

FJMC (Fisheries Joint Management Committee). 1998. Beaufort Sea Beluga Management Plan, 3rd Amended Printing. Fisheries Joint Management Committee, Inuvik, NWT. iv + 28 p.

FJMC. 2013. Beaufort Sea Beluga Management Plan. 4th Amended Printing. Fisheries Joint Management Committee, Inuvik, NWT. 44 p.

Fortier, L., and Ferguson, S.H. 2009. Summer diet of beluga whales inferred by fatty acid analysis of the eastern Beaufort Sea food web. J. Exp. Mar. Biol. Ecol. 34(1): 12–18. doi:10.1016/j.jembe.2009.03.015.

Fraker, M.A. 1977. The 1977 whale monitoring program, Mackenzie Estuary, N.W.T. Report by F.F. Slaney and Company, Limited, Vancouver, BC. Available at: Dept. of Fisheries and Oceans, 301- 5204 50th Avenue, Yellowknife, NT X1A 3Y2. 53 p.

Fraker, M.A. 1978. The 1978 whale monitoring program, Mackenzie Estuary, N.W.T. Report by F.F. Slaney and Company, Limited, Vancouver, BC. Available at: Dept. of Fisheries and Oceans, 301- 5204 50th Avenue, Yellowknife, NT X1A 3Y2. 28 p.

Fraker, M.A. 1979. Spring migration of bowhead (*Balaena mysticetus*) and white whales (*Delphinapterus leucas*) in the Beaufort Sea. Fish. Mar. Ser. Tech. Rpt. No 859. 36 p.

Fraker, M.A., and Fraker, P.N. 1979. The 1979 whale monitoring program, Mackenzie Estuary. Report by LGL Limited, Sidney, BC. Available at: Dept. of Fisheries and Oceans, Box 1871, Inuvik, NT, Canada X0E 0T0. 51 p.

Fraker, M.A., Gordon, C.W., McDonald, J.W., Ford, J. K. B., and Cambers, G. 1979. White whale (*Delphinapterus leucas*) distribution and abundance and the relationship to physical and chemical characteristics of the Mackenzie Estuary. Fish. Mar. Ser. Tech. Rpt. No. 863. 56 p.

Fraker, P.N., and Fraker, M.A. 1981. The 1980 whale monitoring program, Mackenzie Estuary. Report by LGL Limited, Sidney, BC. Available at: Dept. of Fisheries and Oceans, 301- 5204 50th Avenue, Yellowknife, NT X1A 3Y2. 98 p.

Friesen, T.M., and Arnold, C.D. 1995. Zooarchaeology of a focal resource: dietary importance of beluga whales to pre-contact Mackenzie Inuit. Arctic 48(1): 22–30.

Frost, K. J., and Lowry, L.F. 1995. Radio tag based correction factors for use in beluga whale population estimation. Working paper for the Alaska Beluga Whale Committee, Scientific Workshop, 5–7 April 1995, Anchorage, AK. 12 p.

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

Harwood, L.A., and Kingsley, M.C.S. 2013. Trends in offshore distribution and relative abundance of Beaufort Sea beluga, 1982-1985 vs 2007-2009. Arctic 66(3): 247–256.

Harwood, L.A., Kingsley, M.C.S., and Smith, T.G. 2014. An emerging pattern of declining growth rates in belugas of the Beaufort Sea: 1989–2008. Arctic 67(4): 483–492.

Harwood, L.A., Norton, P., Day, B., and Hall, P.A. 2002. The harvest of beluga whales in Canada's Western Arctic: hunter-based monitoring of the size and composition of the catch. Arctic 55(Suppl. 1): 10–20.

Harwood, L.A., and Smith, T.G. 2002. Beaufort Sea Whales: An overview and outlook. Arctic 55 (Suppl. 1): 77–93.

Harwood, L.A., Innes, S., Norton, P., and Kingsley, M.C.S. 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): 2262–2273.

Harwood, L.A., Kingsley, M.C.S., and Pokiak, F. 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. Manu. Rept. Fish. Aquat. Sci. 3059: vi + 32 p.

Hauser, D.D.W., Laidre, K.L., Stern, H.L., Moore, S.E., Suydam, R.S., and Richard, P.R. 2014. Habitat selection by two beluga whale populations in the Chukchi and Beaufort seas. PLoS ONE 12(2): e0172755. doi:10.1371/journal.pone.0172755.

Hauser, D.D.W., Laidre, K.L., Stafford, K., Stern, H., Suydam, R.S., and Richard, P.R. 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): 2206–2217.

Heide-Jørgensen, M.P., Laidre, K. L., Borchers, D., Marquest, T.A., Stern, H., and Simon, M. 2010. The effect of sea-ice loss on beluga whales (*Delphintapterus leucas*) in West Greenland. Polar Res. 29(2): 198–208.

Higdon, J.W., and Ferguson, S.H. 2012. Environmental conditions and beluga whale entrapment events in the Husky Lakes, NWT. Canada/Inuvialuit Fisheries Joint Management Committee Report 2012: 39 p.

Hill, R.M. 1967. Observations on beluga whales trapped by ice in Eskimo Lakes winter 1966-1967. Inuvik Research Laboratory. Unpubl. Report. Available: Canada Dept. of Fisheries and Oceans, Box 1871, Inuvik, NT.

Hill, P.S., and DeMaster, D.P. 1999. Alaska marine mammal stock assessments, 1999. U.S. Dep. Commer., NOAA Tech. Memo. NMFSAFSC-110. 166 p.

Hornby, C., Hoover, C., Joynt, A. Torontow, V., Hynes, K., and Loseto, L. 2014. Arrival and distribution of beluga whales (*Delphinapterus leucas*) along the Mackenzie Shelf : report on spring areal surveys. Can. Data Rep. Fish. Aquat. Sci. 1251. vii + 34 p.

Hornby, C.A., Iacozza, J., Hoover, C., Barber, D. G., and Loseto, L.L. 2017. Beluga whale *Delphinapterus leucas* late summer habitat use and support for foraging areas in the Canadian Beaufort Sea. Mar. Ecol. Prog. Ser. 574: 243–257.

Hunt, W.J. 1979. Domestic whaling in the Mackenzie Estuary, Northwest Territories. Can. Fish. Mar. Ser. Tech. Rep. 769: iv + 14 p.

Klumov, C. K. 1939. Belukha sovetskogo severa (syryevaya baza i promysel) [Belukhas of the soviet North (Raw material base and hunting)]. Moscow, Trudy VNIRO. Vol. XII: 77 p.

Loseto, L.L., Richard, P., Stern, G.A., Orr, J., and Ferguson, S.H. 2006. Segregation of Beaufort Sea beluga whales during the open-water season. Can. J. Zool. 84: 1743–1751. doi:10.1139/z06-160.

Loseto, L.L., Hoover, C., Ostertag, S., Whalen, D., Pearce, T., Paulic, J., and Iacozza, J. 2018a. Beluga whales (*Delphinapterus leucas*), environmental change and marine protected areas in the Western Canadian Arctic. Estuar. Coast. Shelf Sci. 212: 128–137.

Loseto, L.L., Brewster, J.D., Ostertag, S.K., Snow, K., MacPhee, S.A., McNicholl, D.G., Choy, E.S., and Giraldo, G., and Hornby, C.A. 2018b. Diet and feeding observations from an unusual beluga harvest in 2014 near Ulukhaktok, Northwest Territories, Canada. Arct. Sci. 4(3): 421–431. doi:10.1139/as-2017-0046.

Loseto, L.L., Stern, G.A., Connelly, T.L., Deibel, D., Gemmill, B., Prokopowicz, A., Fortier, L., and Ferguson, S.H., 2009. Summer diet of beluga whales inferred by fatty acid analysis of the eastern Beaufort Sea food web. J. Exp. Mar. Bio. Ecol. 374(1) 12–18. doi:10.1016/j.jembe.2009.03.015.

Loseto, L.L., Stern, G.A., and Macdonald, R.W. 2015. Distant drivers or local signals: Where do mercury trends in western Arctic belugas originate? Sci. Total Env. 509: 226–236. doi:10.1016/j.scitotenv.2014.10.110.

Lowry, L. F., Burns, J.J., and Frost, K. J. 1988. Recent harvests of belukha whales in western and northern Alaska and their potential impact on provisional management stocks. Report of the International Whaling Commission 39. 5 p.

Luque, S.P. and Ferguson, S.H. 2009. Ecosystem regime shifts have not affected growth and survivorship of eastern Beaufort Sea belugas. Oecologia 160: 367–378. doi: 10.1007/s00442-009-1300-6.

Luque, S.P. and Ferguson, S.H. 2010. Age structure, growth, mortality, and density of belugas (*Delphinapterus leucas*) in the Canadian Arctic: responses to environment? Polar Biol. 33: 163–178.

McGhee, R. 1988. Beluga hunters. An archaeological reconstruction of the history and culture of the Mackenzie Delta Kittygaryumuit. Newfoundland Social and Economic Series No. 13. Institute of Social and Economic Research, Memorial University of Newfoundland. 124 p.

Miller, G.W., Moulton, V.D., Davis, R.A., Holst, M., Millman, P., MacGillivray, A., and Hannay, D. 2005. Monitoring seismic effects on marine mammals –southeastern Beaufort Sea, 2001–2002. *In* Offshore oil and gas environmental effects monitoring: Approaches and technologies. Edited by S.L. Armsworthy, P.J. Cranford, and K. Lee. Battelle Press, Columbus, OH. pp 511–542.

Moore, S.E., and DeMaster, D.P. 1998. Cetacean habitats in the Alaskan Arctic. J. Northwest Atl. Fish. Sci. 22: 55–69.

Moore, S.E. and Stabeno, P.J. 2015. Synthesis of Arctic Research (SOAR) in marine ecosystems of the Pacific Arctic. Prog. Oceanogr. 136: 1–11.

Mosnier, A., Lesage, V., Gosselin, J-F, Lemieux, Lefebvre S, Hammill MO, Doniol-Valcroze T. 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

Muto, M.M., Helker, V.T., Angliss, R.P., Allen, B.A., Boveng, P.L., Breiwick, J.M., Cameron, M. F.P., Clapham, J., Dahle, S.P., Dahlheim, M.E., Fadely, B.S., Ferguson, M.C., Fritz, L.W., Hobbs, R.C., Ivashchenko, Y.V., Kennedy, A.S., London, J.M., Mizroch, S.A., Ream, R.R., Richmond, E.L., Shelden, K.E.W., Towell, R.G., Wade, P.R., Waite, J.M., and Zerbini, A.N. 2016. Alaska marine mammal stock assessments, 2015. U.S. Dep. Commer., NOAA Tech. Memo. NMF-SAFSC-323. 300 p. doi:10.7289/V5/TM-AFSC-323.

NAMMCO (North Atlantic Marine Mammal Commission) 2018. Report of the NAMMCO Global Review of Monodontids. 13-16 March 2017. North Atlantic Marine Mammal Commission, Hillerød, Denmark. 82 p.

Norton, P. 1983. The 1982 White Whale Monitoring Program, Mackenzie Estuary. Prepared by LGL Ltd., Sidney, B.C., for Esso Resources, Dome Petroleum, and Gulf Canada, Calgary, AB. Available at: Dept. of Fisheries and Oceans, 301- 5204 50th Avenue, Yellowknife, NT X1A 3Y2. 53 p.

Norton, P., and Harwood, L.A. 1985. White whale use of the Southeastern Beaufort Sea, July-September 1984. Can. Tech. Rpt. Fish. Aquat. Sci. 1401: v + 46 p.

Norton, P., and Harwood, L.A. 1986. Distribution, abundance and behaviour of white whales in the Mackenzie Estuary. Environmental Studies Revolving Funds Report No. 036. Ottawa, ON. 73 p.

Nuligak, I. 1966. The autobiography of a Canadian Eskimo. Simon and Schuster of Canada, Toronto, ON. 191 p.

O'Corry-Crowe, G., Mahoney, A., Suydam, R., Quakenbush, L., Whiting, A., Lowry, L., Ferreira, L., Tazruk, J., Saccheus, C., and Harwood, L. 2016. Genetic profiling links changing sea-ice to shifting beluga whale migration patterns. Biol. Lett. 12: 20160404. doi:10.1098/rsbl.2016.0404.

Postma, L. 2017. Genetic diversity, population structure and phylogeography among belugas (*Delphinapterus leucas*) in Canadian waters: broad to fine-scale approaches to inform conservation and management strategies. Thesis (Ph.D.) University of Manitoba, Winnipeg, M.B. xviii + 296.

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

Quinn II, T.J., and Deriso, R.B. 1999. Quantitative fish dynamics. Oxford University Press, New York, NY. 560 p.

Richard, P.R., Martin, A. R., and Orr, J.R. 2001. Summer and autumn movements of belugas of the eastern Beaufort Sea stock. Arctic 54(3): 223–236.

Roux, M.-J., Harwood, L. A., Zhu, X., and Sparling, P. J. 2015. Early summer near-shore fish assemblage and environmental correlates in an Arctic estuary, J. Great Lakes Res. 42(2): 256–266.

Scharffenberg, K., Whalen, D., Marcoux, M., Iacozza, J., Davoren, G., and Loseto, L. 2019. Environmental drivers of beluga whale (*Delphinapterus leucas*) habitat use in the Mackenzie Estuary. Mar. Ecol. Prog. Ser. 626: 209–226.

Scharffenberg, K. 2018. Passive Acoustic Monitoring to Identify Drivers of Beluga Whale Habitat Use in the Mackenzie Estuary. Thesis (M.Sc.) University of Manitoba, Winnipeg, MB. ix + 99 p.

Smith, T.G., and Taylor, D. 1977. Notes on marine mammal, fox and polar bear harvests in the Northwest Territories 1940 to 1972. Fisheries and Marine Service Technical Report 694: 37 p.

St. Aubin, D.J., Smith, T.G., and Geraci, J.R. 1990. Seasonal epidermal moult in beluga whales, *Delphinapterus leucas*. C. J. Zool. 68(2): 359–367.

Strong, T. 1989. Reported harvests of narwhal, beluga, and walrus in the Northwest Territories, 1948-1987. Can. Data Rep. Fish. Aquat. Sci. 734: iv + 14 p.

Strong, T. 1990. The domestic beluga (*Delphinapterus leucas*) fishery in the Mackenzie River Estuary, Northwest Territories, 1981-1986. Can. Data Rep. Fish. Aquat. Sci. 800: iv + 52 p.

Suydam, R. S. 2009. Age, growth, reproduction and movements of beluga whales (*Delphinapterus leucas*) from the eastern Chukchi Sea. Thesis (Ph.D.) University of Washington, Seattle, WA. xi + 152 p.

Wade, P. R., and Angliss, R. 1997. Guidelines for assessing marine mammal stocks: report of the GAMMS workshop April 3-5, 1996, Seattle, Washington. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-12. 93 p.

Waugh, D., Pearce, T., Ostertag, S., Collings, P., Loseto, L. 2018. Inuvialuit Traditional Ecological Knowledge of Beluga Whale (*Delphinapterus leucas*) Under Changing Climatic Conditions in Tuktoyaktuk, NT. Arct. Sci. 4: 242–258.

Weaver, P.A. 1991. The 1987 beluga (*Delphinapterus leucas*) Harvest in the Mackenzie River estuary, NWT. Can. Manu. Rpt. Fish. Aquat. Sci. 2097. 18 p.

Weaver, P.A., and Richard P. R., 1989. Background report: A history of “Svassats”. Internal DFO, Central and Arctic Region, Winnipeg, MB. Available: Freshwater Institute, 501 University Crescent, Winnipeg, MB. R3T 2N6.

Wood, K.R., Bond, N.A., Danielson, S.L., Overland, J.E., Salo, S.A., Stabeno, P.J., and Whitefield, J. 2015. A decade of environmental change in the Pacific Arctic region. Prog. Oceanogr. 136: 12–31.

Worden, E. 2019. "Everything is changing so much": Community Perspectives on the Declining Beluga Whale Harvest in Aklavik, NT. Thesis (M.Sc.). University of Manitoba, Winnipeg, MB. viii + 188.

APPENDIX 1. HARVESTER INPUT

Table A1. Summary of written responses to harvester input requests identified in Working Paper. NR = not reporting on this question.

Hunter number	Harvester	Affiliation/ Community	Hunting Area	Q1: Have you observed changes in the distribution of belugas in the Estuary?	Q2: Have you observed changes in the distribution off belugas in offshore waters?	Q3: What is your explanation for decline in harvest?	Q4: Have you noticed if the size of whales harvested is changing (total length)?	Q5: Have you noticed if the fatness/blubber thickness of harvested whales is changing over time?	Q6: Have you noticed changes in the overall health of belugas harvested or observed over time?	Q7: Are there other observations, knowledge, or notes you want to share?
1	LA	Inuvik	Mackenzie Delta	NR	NR	high cost of fuel and some hunters limited by not owning equipment	belugas are smaller in the past 10–15 years	decrease in blubber thickness observed over past ten years	NR	NR
2	LE	Tuktoyaktuk	Mackenzie Delta	NR	whales appear to be going into very small bays along the coastline	1. declining interest and dependence on traditional foods and hunting; 2. less harvest in present day because dog teams are rare relative to the 1970s when there used to be 60–70 in Tuktoyaktuk; 3. more wind all the time now and season starting earlier with ice moving away so quickly	1. noticed whales are smaller and/or shorter relative to the number of large yellow whales in the past; 2.selectivityof larger whales depends on community and timing, sometimes a preference by elders for younger grey whales	used to see fat whales in the past, appear to not be as good shape in recent years	NR	improvements in monitoring program over time

Hunter number	Harvester	Affiliation/ Community	Hunting Area	Q1: Have you observed changes in the distribution of belugas in the Estuary?	Q2: Have you observed changes in the distribution off belugas in offshore waters?	Q3: What is your explanation for decline in harvest?	Q4: Have you noticed if the size of whales harvested is changing (total length)?	Q5: Have you noticed if the fatness/blubber thickness of harvested whales is changing over time?	Q6: Have you noticed changes in the overall health of belugas harvested or observed over time?	Q7: Are there other observations, knowledge, or notes you want to share?
3	CG	Tuktoyaktuk	Mackenzie Delta	relative to 10–20 years ago little change in distribution in estuary but arrive/leave earlier with earlier ice free summers	in September, belugas seem to spend a lot of time at the bottom of McKinley Bay when there is a lot of Arctic Cisco there and water is very clear	younger generation mostly harvesting other traditional foods that do not take as much time for preparation as belugas	no changes observed in past 10–20 years	variable among years; blubber thickness increases during the summer, whale harvested by brother in September had blubber 5–6" thick and floated once shot	belugas are generally healthy	comment moved to Q2 response.

Hunter number	Harvester	Affiliation/ Community	Hunting Area	Q1: Have you observed changes in the distribution of belugas in the Estuary?	Q2: Have you observed changes in the distribution off belugas in offshore waters?	Q3: What is your explanation for decline in harvest?	Q4: Have you noticed if the size of whales harvested is changing (total length)?	Q5: Have you noticed if the fatness/blubber thickness of harvested whales is changing over time?	Q6: Have you noticed changes in the overall health of belugas harvested or observed over time?	Q7: Are there other observations, knowledge, or notes you want to share?
4	PG	Inuvialuit Game Council	Mackenzie Delta	observed changes over the last two decades; belugas arrive in the estuary when the leads open; with earlier breakups observing belugas in the estuary earlier and leaving earlier	more sighting of belugas along the coastline from end of summer to early fall	1. High cost of hunting equipment and fuel. 2. high winds- likely why Tuktoyaktuk harvested less whales in 2016; 3. hot weather limits harvesting opportunities, with hotter temperatures harvesters are waiting until the weather cools off but when they go to harvest the belugas are not there; 4. less dog teams in the area; 5. harvesters not adapting as quickly as the belugas are with climate change	no trend observed; selective for a particular size when harvesting	blubber thickness varies from year to year, some years lots and other years average but haven't noticed any real thin ones; depends on what they are eating; in recent years blubber was very thick, in 2016 and a couple years before that not as thick	selective when harvesting whales	behavioural changes observed in belugas: learned how to stop and are more aggressive when being chased; in the past would rarely see belugas between Tuktoyaktuk and Hendrickson Island but now it is common

Hunter number	Harvester	Affiliation/ Community	Hunting Area	Q1: Have you observed changes in the distribution of belugas in the Estuary?	Q2: Have you observed changes in the distribution off belugas in offshore waters?	Q3: What is your explanation for decline in harvest?	Q4: Have you noticed if the size of whales harvested is changing (total length)?	Q5: Have you noticed if the fatness/blubber thickness of harvested whales is changing over time?	Q6: Have you noticed changes in the overall health of belugas harvested or observed over time?	Q7: Are there other observations, knowledge, or notes you want to share?
5	JI	Paulatuk	Amundsen Gulf	NR	fluctuates, no trend observed	1. declining interest and dependence on traditional foods and hunting and more store-bought food; 2. high cost of hunting equipment and fuel; 3. changes in beluga distribution, fluctuations in occurrence in Paulatuk area	1. no trend observed in size but fewer large yellow whales are harvested today; 2. with weather conditions in recent years can't be as selective for larger whales as in the past	1. no trend observed but think it is related to food or weather conditions (timing of ice break-up); 2. blubber thickness variable among years	no trends observed; occasionally harvest one thin whale amongst many healthy whales	1. small motors have a direct impact on belugas as they scatter when hunted; 2. never observed a whale or group of whales lingering, always appear to be travelling; 3. very important to continue to monitor and assess beluga whale health and population given the importance of the species to his family's diet
6	JIJr	Paulatuk	Amundsen Gulf	NR	belugas seem to pass by Darnley Bay without stopping or resting; it all depends on the ice conditions; some years they just pass through far offshore; late June 1989 was the only year he observed whales hanging near the beach (Brock River); arriving earlier in 2014 and 2015	1. high cost of hunting equipment and fuel; 2. changes in the distribution of belugas due to ice conditions in the Darnley Bay area; 3. weather plays a big part of the hunt	no trend observed over the years but has observed differences in sizes when the males start to pass through compared to the females	no trend observed; selection for the large fat ones out of a pod but also see some long thin ones in the same group	no trend observed; always select the whales they want to harvest so they are all healthy, other than a skinny one in Paulatuk Harbour in 2003 and another in Billy Creek in 2015	started seeing whales in Darnley Bay in mid-June in 2014 and 2015, this occurred at first break up at the sand bar outside of Paulatuk (earlier than in the past); added to Q2 response also.

Hunter number	Harvester	Affiliation/ Community	Hunting Area	Q1: Have you observed changes in the distribution of belugas in the Estuary?	Q2: Have you observed changes in the distribution off belugas in offshore waters?	Q3: What is your explanation for decline in harvest?	Q4: Have you noticed if the size of whales harvested is changing (total length)?	Q5: Have you noticed if the fatness/blubber thickness of harvested whales is changing over time?	Q6: Have you noticed changes in the overall health of belugas harvested or observed over time?	Q7: Are there other observations, knowledge, or notes you want to share?
7	GI	Fisheries Joint Management Committee	Mackenzie Delta	whales are coming in earlier, leaving later	NR	1. high cost of hunting equipment and fuel; 2. high winds and warmer weather, have to go earlier to avoid rough weather and warm conditions	No trend observed. Notice in old pictures they look bigger but could be due photographer, position of whale.	No trend observed. The whale fatness depends on diet of whales. Fatness was observed to be good after July 15, notice the desired fatness of the whales is good at the end of June. Sometimes it is better to hunt at the end of June to avoid hot weather. Hunting earlier because the fatness is not as thin as used to be. When whales go back to regular diet of herring and cod diet that's when it's good to hunt. When the diet is sandlance and capelin the whales aren't in the best condition. Hunters are mainly hunting earlier due to weather. One year could be different from the next year. The fatness is observed as a yearly thing. FJMC taught Gerry a lot about what to look out for- example Herpes. Difference in knowledge sets 1) observing weather, animals etc. and 2) science research (trend of size of whales etc.).	2016 was the first time a crippled whale was observed	After a big storm with high winds on July 19, 2016, East Whitefish Point became sandy, observed many lampreys brought up onto the beach and caught a lot of herring. Weather: it gets too hot in July to hunt. Hunters will not hunt with hot weather and see their harvest get ruined. If it's not raining it's too hot. Rain cleans the muktuk, but if it continues the whale blubber will stay too moist and not drain and the mipku will not dry properly.

Hunter number	Harvester	Affiliation/ Community	Hunting Area	Q1: Have you observed changes in the distribution of belugas in the Estuary?	Q2: Have you observed changes in the distribution off belugas in offshore waters?	Q3: What is your explanation for decline in harvest?	Q4: Have you noticed if the size of whales harvested is changing (total length)?	Q5: Have you noticed if the fatness/blubber thickness of harvested whales is changing over time?	Q6: Have you noticed changes in the overall health of belugas harvested or observed over time?	Q7: Are there other observations, knowledge, or notes you want to share?
8	CP	Tuktoyaktuk	Mackenzie Delta	arriving into Kugmallit Bay earlier;	NR	1. warmer weather; 2. fuel and equipment costs rising; 3. arriving earlier in the area; 4. knowledge gaps about traditional harvesting practices though he makes an effort to bring kids out; 5. high winds limits harvesting opportunities	NR	1. decrease in blubber thickness observed over past 10-15 years; 2. can be variable and was high in 2016, good for making oil (ooksok); 3. prefer greater blubber thickness and body weight at harvesting time; 4. belugas harvested later in the season have greater body condition	no trends observed, learn more about beluga health from researchers	1. belugas are having their young earlier; 2. more wind in July makes it more difficult for hunting; 3. warmer weather makes it more challenging to prepare muktuk and dry meat safely; 4. similar observations of trends as other harvesters; 5. no ice during summer, whales do not have scars on their backs from ice when travelling in Kugmallit Bay as observed in the past; 6. goal of having whales available for future generations; 7. recommend earlier surveys to see ice break-up

Hunter number	Harvester	Affiliation/ Community	Hunting Area	Q1: Have you observed changes in the distribution of belugas in the Estuary?	Q2: Have you observed changes in the distribution off belugas in offshore waters?	Q3: What is your explanation for decline in harvest?	Q4: Have you noticed if the size of whales harvested is changing (total length)?	Q5: Have you noticed if the fatness/blubber thickness of harvested whales is changing over time?	Q6: Have you noticed changes in the overall health of belugas harvested or observed over time?	Q7: Are there other observations, knowledge, or notes you want to share?
9	HR	Inuvik	Mackenzie Delta	in the Kendall Island area over the past 10-20 years more cows are staying in the shallows longer than usual, possibly because of something in the deeper water closer to the Islands	NR	1. declining interest and dependence on traditional foods and hunting; 2. high cost of hunting equipment and fuel, more people selling their muktuk to offset their expenses; 3. changes in the distribution of belugas; 4. limiting knowledge being passed down between generations	past 10 years the size of the whales in smaller than 20 years ago, used to get an average size of 17 ft. total length	decrease in blubber thickness relative to twenty years ago	observed a few whales that are not healthy over the past 5 years	1. observed that more belugas have scars and more severe in the Kendall Island area ten years ago; 2. would like to see more accurate counts of beluga taken or lost in the harvest 3. In order to collect traditional knowledge on beluga whales, it is best to collect traditional knowledge with the knowledge holder out on the land. Being out on the land rather than in town in a conference setting, is more comfortable for the knowledge holder, free of distractions/influences and opens up the knowledge-holder's mind.

Hunter number	Harvester	Affiliation/ Community	Hunting Area	Q1: Have you observed changes in the distribution of belugas in the Estuary?	Q2: Have you observed changes in the distribution off belugas in offshore waters?	Q3: What is your explanation for decline in harvest?	Q4: Have you noticed if the size of whales harvested is changing (total length)?	Q5: Have you noticed if the fatness/blubber thickness of harvested whales is changing over time?	Q6: Have you noticed changes in the overall health of belugas harvested or observed over time?	Q7: Are there other observations, knowledge, or notes you want to share?
10	WS	Aklavik	Mackenzie Delta	arriving earlier likely because of earlier breakup	NR	1. declining interest and dependence on traditional foods and hunting; 2. high cost of hunting equipment and fuel; 3. weather, frequent high winds; 4. timing of whales being there vs. when hunters are ready, especially earlier in the summer; 5. changes in hunter effort in Aklavik most people spend about a month on the coast, now 'there and back'; 6. shift in hunting locations (i.e., from Bird camp to Shingle Point where it is more difficult to hunt in deeper waters).	1. fewer larger whales, recall many 15 and 16 ft. long whales in the past; 2. people used to target larger whales when they spent more time on the coast, now with time and weather hunters are less selective	NR	no trends observed	NR