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ARTICLE

"That's how we know they're healthy": the inclusion of traditional ecological knowledge in beluga health monitoring in the Inuvialuit Settlement Region[1]

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Abstract: Belugas (*Delphinapterus leucas*) from the Eastern Beaufort Sea (EBS) population are harvested annually in the Inuvialuit Settlement Region (ISR) during their seasonal migration past coastal communities and harvest camps. The beluga harvest monitoring program is a flagship program of the ISR's Fish and Marine Mammal Community Monitoring Program, and it has provided critical information about beluga health and observed changes in the EBS population. This study aimed to develop a suite of local indicators of beluga health that bridged traditional ecological knowledge (TEK) about beluga condition, illness, and disease, with western science through the co-production of knowledge. Community members from Inuvik, Paulatuk, and Tuktoyaktuk with beluga harvesting and preparation experience were engaged to characterize beluga health from an Inuvialuit perspective. Inuvialuit knowledge about the environment and beluga health, values about hunting beluga, and Inuvialuit cosmology — the foundation of the knowledge system — were documented through semi-structured questionnaires ($n = 66$), semi-structured interviews ($n = 78$), and focus group meetings ($n = 3$). This research furthers our understanding of how Inuvialuit view beluga health from the physical and behavioural characteristics of belugas, values, and appropriate behaviours by harvesters and how observations made about beluga can be explained. To support the co-production of knowledge, a suite of local indicators was developed that bridged TEK about beluga condition, illness, and disease with western science.

Key words: co-production, Arctic, subsistence hunting, Beaufort Sea, climate change.

Résumé : Les populations de bélugas (*Delphinapteras leucas*) de l'est de la mer de Beaufort (EMB) sont récoltées annuellement dans la région désignée des Inuvialuit (RDI) pendant leur

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migration saisonnière les menant à passer près des communautés côtières et des camps de récolte. Le programme de surveillance de la récolte de béluga est un programme phare du programme communautaire de surveillance des poissons et des mammifères marins de la RDI et il a fourni des informations essentielles sur la santé des bélugas et les changements constatés au niveau de la population de l'EMB. Cette étude avait pour but de développer une série d'indicateurs locaux sur la santé des bélugas afin d'établir un rapprochement entre les connaissances écologiques traditionnelles (CÉT) sur la condition et les maladies des bélugas et la science occidentale, et ce, par la coproduction des connaissances. À l'aide de leur expérience en chasse et en préparation, les membres des communautés Inuvik, Paulatuk et Tuktoyaktuk ont été mis à contribution afin de décrire la santé des bélugas sous une perspective Inuvialuit. Les connaissances Inuvialuit à propos de l'environnement et de la santé des bélugas, des valeurs entourant la chasse au béluga et de la cosmologie Inuvialuit — la base du système des connaissances Inuvialuit — ont été documentées à l'aide de questionnaires semi-structurés ($n = 66$), d'entrevues semi-structurées ($n = 78$) et de réunions de groupe de discussion ($n = 3$). Cette recherche fait évoluer notre compréhension à savoir comment les Inuvialuit voient la santé des bélugas en se basant sur les caractéristiques physiques et comportementales des bélugas, les valeurs et comportements appropriés des chasseurs et comment on peut expliquer les observations faites en lien avec les bélugas. Pour soutenir la coproduction de connaissances, une série d'indicateurs locaux a été développée afin de concilier les CÉT sur la condition et les maladies des bélugas et la science occidentale. [Traduit par la Rédaction]

Mots-clés : coproduction, Arctique, chasse de subsistance, la mer de Beaufort, changement climatique.

Introduction

Beluga whales, *qilalukkat* (*Delphinapterus leucas*), are an endemic arctic species with a nearly circumpolar distribution. The Eastern Beaufort Sea (EBS) beluga population is a significant resource for both Inuvialuit in the Canadian Western Arctic and Inupiat in Alaska, USA. The EBS beluga population is one of the world's largest, with an abundance estimate of 39 258 animals based on 1992 aerial survey data (Hill and DeMaster 1999). The EBS belugas winter in the Bering Sea and migrate to the Beaufort Sea to summer and return west for the fall (Richard et al. 2001). The EBS beluga whales and other marine mammals in the Arctic are experiencing reduction in sea ice due to climate warming (Laidre et al. 2008) and are exposed to anthropogenic activities such as oil and gas development as well as anticipated increased shipping (Reeves et al. 2014) and contaminants originating from southern latitudes such as methylmercury (Loseto et al. 2015) and organic contaminants (e.g., legacy Noël et al. 2018; Smythe et al. 2018). Although belugas are not considered to be sensitive to climate warming compared to other arctic marine species (Laidre et al. 2008), the EBS beluga population has been identified as a potential indicator of environmental change in the arctic marine ecosystem (Harwood et al. 2014).

Environmental change has the potential to affect blubber thickness and growth rates in EBS beluga (Harwood et al. 2015; Choy et al. 2017) and decrease Inuvialuit access to belugas due to unpredictable and unfavorable weather conditions (Wesche and Chan 2010; Waugh et al. 2018). Food depletion and stress cause immune suppression in terrestrial mammals, and it is likely that marine mammals are similarly affected (Burek et al. 2008). Changes in immune function may also increase the prevalence of diseased animals in a population due to increased susceptibility to endemic or common pathogens (Burek et al. 2008). Research in the Inuvialuit Settlement Region (ISR) suggests that EBS belugas are responding contaminant exposure at molecular (Noël et al. 2014; Ostertag et al. 2014; Ostertag and Chan 2018), biochemical (Desforges et al. 2013; Ostertag et al. 2014), and cellular levels (Frouin et al. 2012), which were not linked to physiological changes but could reflect a source of stress for this population.

An indicator approach to assessing ecosystem health was adopted in the Tarium Niryutait Marine Protected Area (TNMPA), which is made up of three separate areas at the edge of the Mackenzie River Delta and is recognized as an important summering and subsistence harvesting area for the EBS beluga (Loseto et al. 2010). The indicator approach suggested for the TNMPA supports the development of a health assessment model that describes population health in context with stressors (Loseto et al. 2010). Indicators are typically selected based on their relevance to people and the environment, the availability of reliable and long-term measurements, and clear relationships between the indicator and the force of change in question (Loseto et al. 2010). Health indicators for beluga whales were identified to assess whether the conservation objectives for the TNMPA were being met and include demographic rates, nutrition/condition, interannual stability of diet, body burden of contaminants, and incidence of disease/parasites (Loseto et al. 2010).

Inuvialuit and their ancestors managed and sustainably harvested belugas for centuries using traditional knowledge and practices (Fisheries Joint Management Committee 2013). Inuvialuit have a long history of harvesting beluga whales and have developed a deep understanding of beluga migration and habitat use, how belugas respond to boat activity and noise, how belugas can be used, harvesting techniques, and the distribution of labour (Hart and Amos 2004; Inuuvik Community Corporation et al. 2006; Waugh et al. 2018). In addition, Inuvialuit knowledge of belugas encompasses traditional conservation methods, traditional whaling customs, beliefs, and celebrations (Hart and Amos 2004; Inuuvik Community Corporation et al. 2006; Waugh et al. 2018). The knowledge held by Inuvialuit about the environment may be referred to as traditional knowledge (TK), traditional ecological knowledge (TEK), indigenous knowledge, or *Inuit Qaujimajatuqangit*. These definitions differ and we have chosen to use the term traditional ecological knowledge, or "TEK" for our study as it refers to "all types of knowledge about the environment derived from the experience and traditions of a particular group of people" (Usher 2000, p. 185), and it is consistent with the territorial definition of TK, which is "the knowledge and values, which have been acquired through experience, observation, from the land or from spiritual teachings, and handed down from one generation to another" (Government of the Northwest Territories 2005).

The Inuvialuit Final Agreement (IFA) states that "the relevant knowledge and experience of both Inuvialuit and the scientific communities should be employed in order to achieve conservation" (IFA 1984: article 14.5). In addition, TK is recognized in the Northwest Territories as "a valid and essential source of information about the natural environment and its resources" (Government of the Northwest Territories 2005). The Fisheries Joint Management Committee (FJMC) includes two Inuvialuit members and annually conducts a community tour in June to ensure that TK is included in their decision-making process (Manseau et al. 2005). Although the FJMC vision supports the "use of sound scientific and traditional knowledge of the renewable freshwater and marine resources of the ISR and their ecosystems" (Fisheries Joint Management Committee 2017), beluga health research in the ISR has been primarily based on "Western science" (e.g., Frouin et al. 2012; Desforges et al. 2013; Harwood et al. 2014; Noël et al. 2014; Ostertag et al. 2014; Choy et al. 2017; Ostertag and Chan 2018), which is based on empirical observation, rationality, and logic as opposed to the "lived experience" (Fernandez-Armesto 1999; as reported in Usher 2000). Instead, western scientific indicators of beluga health are used to monitor changes in beluga health (Loseto et al. 2010), and TEK and local observations are not recorded in beluga harvest monitoring (Loseto et al. 2010; Fisheries Joint Management Committee 2013).

Knowledge co-production has been defined as the "collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem" (Armitage et al. 2011).

Researchers have the opportunity to establish relationships with indigenous people to co-produce knowledge, which allows knowledge to be brought into use and supports indigenous community-based natural resource management (Davidson-Hunt and O'Flaherty 2007). Beluga co-management in the ISR is built on a strong institutional network that includes local Hunters and Trappers Committees, the FJMC, regional Joint Secretariat, and both local and regional DFO offices (Armitage et al. 2011). This network reflects a commitment to knowledge co-production and adaptive management for decision-making in future beluga whale entrapments (Armitage et al. 2011) and also extends to the FJMC's Fish and Marine Mammal Community Monitoring Program (FMMCMP). The long history of community-based research in the ISR offers an excellent opportunity to expand knowledge co-production to support beluga monitoring during a period of environmental change. The co-production of knowledge is particularly valuable in beluga monitoring as TEK is focused on how things work and western science is interested in why things work this way (Kofinas 2002).

Environmental change has the potential to adversely affect EBS beluga health through changes in contaminant exposure, body condition, host–pathogen relationships, or increased human interactions (Burek et al. 2008). In this study, we attempt to co-produce knowledge with Inuvialuit to support holistic monitoring of beluga health in the ISR. We engaged the communities of Inuvik, Paulatuk, and Tuktoyaktuk to characterize beluga health from an Inuvialuit perspective, develop *local indicators of beluga health* to support the inclusion of TEK and local observations in beluga health monitoring and identify the values and cultural-based cosmology of beluga that could influence the FMMCMP. This work contributes to a greater understanding of beluga health and supports adaptive co-management of this important resource in a changing environment.

Background

Inuvialuit use of belugas

Inuvialuit have depended on belugas for hundreds of years (McGhee 1988) and continue to harvest belugas throughout the ISR, NT. The skin with blubber (*maktak*), the blubber (*uqsuq*), and the dried meat (*mipku*) of beluga whales are primarily consumed by Inuvialuit (Waugh et al. 2018). Beluga harvesting in Paulatuk began to occur consistently and in large numbers in the 1990s, when the migration of beluga whales changed and beluga whales began to migrate closer to Paulatuk. Today, belugas are harvested opportunistically in late July and early August close to Paulatuk (Harwood et al. 2015). Precontact Mackenzie Inuit hunted beluga whales in Kugmallit Bay for centuries (McGhee 1988). Inuvialuit hunters from Tuktoyaktuk and Inuvik continue to harvest belugas in Kugmallit Bay (Harwood et al. 2015). Hunters from Tuktoyaktuk bring animals to Hendrickson Island for butchering following the hunt, before returning to Tuktoyaktuk for processing. Inuvialuit from Inuvik travel to seasonal whaling camps at Kendall Island and neighbouring islands and East Whitefish in Kugmallit Bay (Harwood et al. 2015). Inuvialuit from Inuvik harvest belugas in the shallow waters surrounding the harvest camps and belugas are typically butchered and prepared at seasonal whaling camps (Harwood et al. 2015).

Co-management of beluga

In the ISR, the goals of the Beluga Management Plan reflect the socio-cultural significance of beluga to Inuvialuit and have evolved to maintain a thriving population of beluga, provide for the sustainable harvest of beluga by Inuvialuit and to create economic opportunities for Inuvialuit through nondisruptive activities (Fisheries Joint Management Committee 2013). The FJMC was established under the IFA to co-manage the fisheries and beluga populations. Research and monitoring of EBS beluga whales date back to the early

1970s (Harwood et al. 2014, 2015), and since the 1980s data collections were standardized and collected through partnerships and co-management arrangements with Inuvialuit, as prescribed in the IFA (IFA 1984). The FJMC redesigned the DFO's beluga monitoring program in 2010 to create a community-based approach to monitoring fish and marine mammals in the ISR (Fisheries Joint Management Committee 2013). The FMMCMP is a flagship program of the FJMC in which harvest monitors document beluga harvesting activities and provide data needed to assess the health of the EBS beluga population (Manseau et al. 2005). Beluga entrapments in the Husky Lakes (a series of brackish lakes in the ISR) illustrate how co-management under the IFA has allowed Inuvialuit to basically control the beluga management process and begin to take proactive measures about future beluga entrapments in which knowledge co-production is the critical mechanism (Armitage et al. 2011).

TEK about beluga health

Although Inuvialuit knowledge about beluga whales has been documented, limited information about beluga health has been reported in previous TEK studies in the ISR and elsewhere. Inuvialuit harvesters in Tuktoyaktuk reported that blubber thickness had declined in beluga over time; however, other health-related observations were not recorded (Waugh et al. 2018). A brief mention about beluga health was also reported in the Inuvik Community Corporation's TEK study in which Inuvialuit hunters reported that belugas appeared to be healthy and well, although the whales harvested in 2005 were thinner than usual (Inuuvik Community Corporation et al. 2006). In Nunavut and Nunavik, Inuit reported that belugas exhibit seasonal variation in blubber thickness (Kilabuk 1998; Bre ton-Honeyman et al. 2016) and specifically in Kimmirut, Inuit indicated that beluga health had not changed in recent decades, although some belugas have been found to be sick, skinny, or badly deformed (Kilabuk 1998). In Iqaluit, few sick belugas have been observed and the appearance, taste, texture of *maktak*, and meat have not changed (Kilabuk 1998).

Case study: Inuvik, Paulatuk, and Tuktoyaktuk, NT

Inuvik, Paulatuk, and Tuktoyaktuk are three communities in the ISR (Fig. 1) that vary in terms of population size, proximity to the coast, and reliance on country foods (Table 1). Paulatuk is a small and remote community located in Darnley Bay and only accessible by air (Arnold et al. 2011). In recent history, Inuvialuit families began to settle in the Paulatuk area in the early 1920s; however, ancient Inuit house ruins dates back at least 800 years (Arnold et al. 2011). Tuktoyaktuk is the most northerly community on mainland Canada and is located close to the Mackenzie Delta, on the coast of the Beaufort Sea (Arnold et al. 2011). Tuktoyaktuk has been a traditional harvesting area for Inuvialuit for hundreds of years (Arnold et al. 2011). The nearby settlement of Kitigaaryuit was an important summer gathering and whaling location until the early 20th century when infectious disease epidemics led to the abandonment of the site (Arnold et al. 2011). An all-weather road opened in 2017, giving Tuktoyaktuk year-round access to Inuvik and the Dempster Highway to southern communities. Inuvik is located on the East Channel of the Mackenzie River in a traditional Inuvialuit trapping area and was created in the 1950s as a regional government centre (Arnold et al. 2011). In 1981, the ethnic distribution of Inuvik was 33% Inuvialuit, 10% Dene, 10% Metis, and 47% nonaboriginal (Arnold et al. 2011). Hunting, fishing, and consuming country foods continues to be important in all three communities, with 22.5%, 74.5%, and 61.1% of the population consuming country foods in Inuvik, Paulatuk, and Tuktoyaktuk, respectively (NWT Bureau of statistics 2016*a*, 2016*b*, 2016*c*).

Fig. 1. Map of study area including towns and villages (+) and beluga harvest camps (triangles). Map created using ArcGIS® software by Esri. ArcGIS® is the intellectual property of Esri and is used herein under license. Copyright © Esri. All rights reserved.

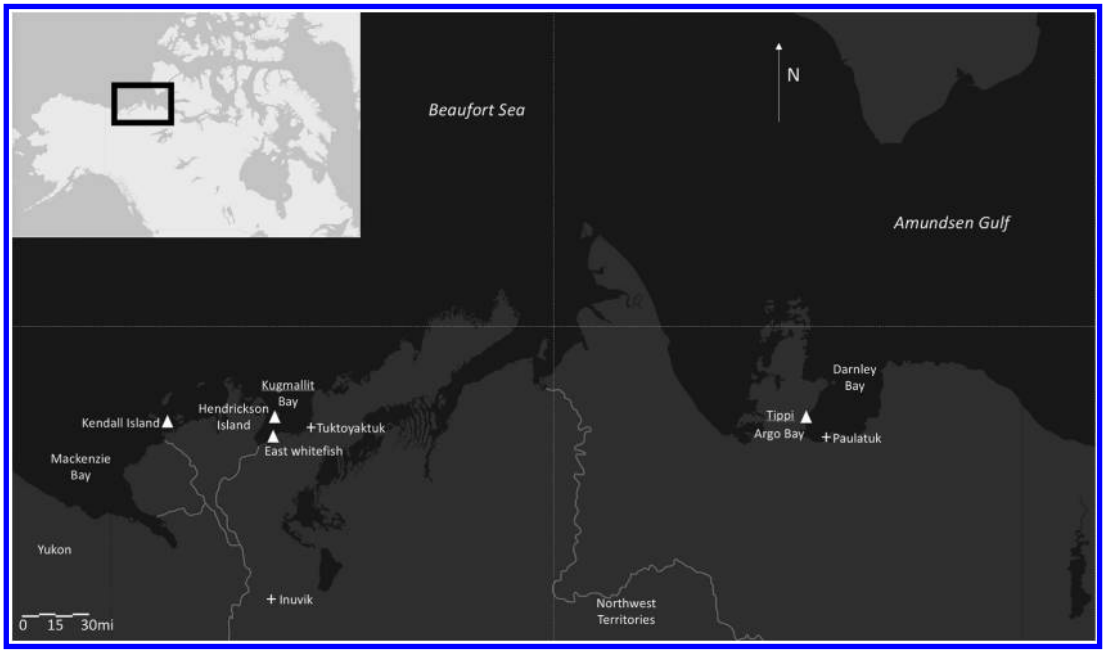


Table 1. Information about the participating communities based on data reported by NWT Bureau of Statistics (2016*a*, 2016*b*, 2016*c*).

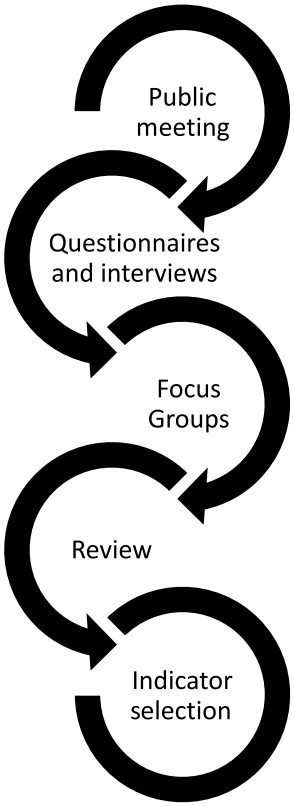
Community	Inuvik	Paulatuk	Tuktoyaktuk
Population (total)	3170	327	996
Population (Aboriginal)	2059	296	880
Aboriginal language speakers (%)	20.6	21.3	24.5
Hunting and fishing (% of population)	44.9	71.7	66
Country food consuming (% of population)	22.5	74.5	61.1

Research approach

This project was initiated to address gaps in effectively including TEK in one of Canada's longest cetacean monitoring program. Prior to this project initiation, S. Ostertag and L. Loseto conducted research in the ISR and developed strong relationships with harvesters and their families. Through consultation with the FJMC, HTCs, and regional leaders in winter 2012/2013, the initial project was designed and funding was sought from the FJMC and the Northern Contaminants Program with the FJMC identified as a research partner and the HTCs identified as research team members. Annual sampling of beluga whales from Hendrickson Island is a priority for the Northern Contaminant Program's (NCP) environmental monitoring program and the integration of community knowledge and perceptions in environmental monitoring and research has been promoted in recent years by the NCP (Northern Contaminants Program 2017*a*, 2017*b*).

Further consultation occurred in June 2013 with the HTCs and Inuvialuit Game Council (IGC) to receive research support and guidance. Public meetings were held in Inuvik,

Fig. 2. The process used to select beluga health indicators involved public meetings, followed by questionnaires and interviews to develop an initial list of potential indicators. The potential indicators were reviewed by Focus Groups (FGs) in Inuvik, Paulatuk, and Tuktoyaktuk and additional knowledge gaps were filled. The final list of indicators was reviewed individually or with pairs of FG participants to determine consensus on useful indicators of beluga health.



Paulatuk, and Tuktoyaktuk at the onset of this project (June 2013) to receive input from community members and further refine the research tools and direction. Public meetings were held frequently (June 2013, November 2013, June 2014, November 2014, and March 2017) in the three communities to receive research direction, provide research updates and discuss next steps. Research updates were communicated to the HTCs, FJMC, and IGC through reports (annual or bi-annual) and presentations (annual or bi-annual) during the study period (2013–2017). Feedback from the FJMC, HTCs, IGC, and participants was incorporated into the study design and recommendations for monitoring. Community-based research assistants (RAs) were employed to assist with public meetings, administer interviews and questionnaires, transcribe interviews, and co-present results during presentations in the community and at conferences.

Methods

Data collection

Beluga health was characterized and beluga health indicators selected through public meetings, questionnaires, interviews, focus groups, and key informant interviews (Fig. 2). Questionnaires and interview questions were developed based on the outcomes from public

Table 2. Description of study participants from Inuvik, Paulatuk, and Tuktoyaktuk in 2014 and 2015.

Data collection		2014	2015
Questionnaires	Total number of questions on questionnaire	15 + 6 follow-up	14 + 3 follow-up questions
	Number of completed questionnaires	33	33
	Participation rate for questionnaire	87%	79%
	Years of beluga hunting experience (median and minimum to maximum)	12 (1.0–65)	20 (3.0–40)
Interviews	Total participants (*n*)	78	
	Elders (*n*)	Paulatuk: 2 (2 male) Inuvik: 9 (3 female and 6 male) Tuktoyaktuk: 10 (7 female and 3 male)	
	Adults (*n*)	Paulatuk: 11 (8 male and 3 female) Inuvik: 15 (5 female and 10 male) Tuktoyaktuk: 24 (11 female and 13 male)	
	Youth (*n*)	Paulatuk: 1 male Inuvik: 1 female Tuktoyaktuk: 3 (2 female and 1 male)	
	Length of interview (total and minimum to maximum minutes)	521 (2.5–41)	
Focus Group	Total participants (*n*)	Paulatuk: 10 Inuvik: 8 Tuktoyaktuk: 9	
Data validation interviews	Key informants (*n*)	Paulatuk: 8 Inuvik: 8 Tuktoyaktuk: 6	

Note: Elders were individuals older than 60 yr of age and youth were 25 yr of age or less.

meetings held in Paulatuk, Tuktoyaktuk, and Inuvik in June 2013. In these meetings, breakout groups were led by individual facilitators (community RAs or DFO/FJMC staff) to record specific observations made about harvested whales during hunting, butchering, preparing, and other times when beluga observed (e.g., travel and camping). These lists of observations were used to generate semi-structured questionnaires about harvested whales and to develop interview questions to record past and present observations about beluga health.

Semi-structured questionnaires were used to record observations about harvested belugas in 2014 and 2015 at Hendrickson Island, East Whitefish, and Darnley Bay. A combination of open-ended and multiple-choice questions was used to record harvesters' observations about beluga health, behaviour, and habitat use following the beluga harvest. Questionnaires have been identified as one of many methods for documenting TEK (Huntington 2000). Interview questions were developed and administered in summer and fall 2014 to record observations and knowledge about beluga health based on the lifetime experience of the participant. Semi-structured interviews (Huntington 1998) were used during and after the harvest season were used to record observations about previously harvested belugas. The strength of questionnaires is that they provide consistency and allow comparisons to be made between respondents and over time; however, semi-directed interviews provide a greater depth and breadth of knowledge and may reveal unanticipated information (Huntington 2000).

Research participants

Questionnaires were completed voluntarily by harvesters ($n = 66$) whose beluga hunting experience ranged from 1 to 65 years (median = 20 years, $n = 51$). Semi-structured interviews were conducted in 2014 with 78 community members from Inuvik, Paulatuk, and Tuktoyaktuk (Table 2). Participants from different age groups (youth: 18–25, adults: 26–59, elders: 60+) and sexes were recruited to ensure that different perspectives and

experience levels were documented. The role of individuals in beluga hunting, butchering, and preparation is influenced by gender, age, and experience levels. Men typically harvest whales, whereas women and children usually prepare beluga *mipku*, *maktak*, and *uqsuq*. Whale monitors were selected because of their extensive experience as harvesters and their unique perspective about the monitoring program. Participant recruitment and interviewing strategies differed by community. In Paulatuk, the Paulatuk Hunters and Trappers Committee identified beluga harvesters and invited them to be interviewed. Interviews were conducted by a community-based RA with individuals and one couple. In Tuktoyaktuk, participants were selected based on records from the beluga monitoring program and knowledge about the harvesters held by S. Ostertag and an Elder-Advisor in the community. A community-based RA conducted interviews with individuals in Tuktoyaktuk in summer and fall 2014. In Inuvik, harvesters and women engaged in beluga harvesting were identified based on the monitoring program records and knowledge held by K. Snow. Interviews took place with individuals and pairs at the Inuvik Community Corporation boardroom by S. Ostertag, L. Loseto, and K. Snow and additional interviews were conducted in participants' homes by K. Snow and S. Ostertag. Interviewers in Inuvik initially administered interviews in pairs to develop consistent interviewing techniques before interviewing participants individually. In Paulatuk and Tuktoyaktuk, the RAs were given the interview guide and brief training prior to interviewing the participants. Participants reviewed and signed the informed consent form prior to starting the interview, and the interview was recorded electronically when permitted. Participants received a $15 gift card to the local grocery store as a small gift following the interview. All of the interviews were recorded and transcribed by the researcher or RA, prior to content analysis (Kondracki et al. 2002).

Analysis, verification, and validation

Content analysis (Kondracki et al. 2002) was used to identify themes in the interview transcripts, harvester questionnaires, and Focus Group (FG) responses. Data from men and women, independent of age, were analyzed together because we were interested in overall characterization of beluga health and the development of local health indicators for management purposes. The participants' communities were included in the analysis to distinguish potential intercommunity variation in perspectives about beluga health and identify the themes that emerged consistently in the three communities. Following data analysis, beluga health characterization was broadly classified into three categories of knowledge based on the classification of TEK presented by Usher (2000):

1. factual knowledge of beluga health based on empirical observations by individuals;
2. value statements including moral and ethical statements about how to behave and a holistic understanding about human health; or,
3. cultural-based cosmology, which underlies the other categories, that provides explanations and guidance.

Codes were developed inductively (Bengtsson 2016) and text was classified as factual knowledge, value statements, or cultural-based cosmology. Factual knowledge was then organized into categories (e.g., external characteristics of whale) and subcategories when appropriate (e.g., blubber thickness). Manifest data analysis (Kondracki et al. 2002) was used to focus on what the informants said and the words themselves were used rather than attempting to interpret or find underlying meaning. The variables that were identified in the data could not be ranked because not all informants had the opportunity to discuss all the phenomena (Bengtsson 2016).

The data verification step included mailing or hand-delivering individual interview transcripts and research updates to all interviewees. Interviewees were invited to contact S. Ostertag if any errors were present in the transcript. In June and August 2015, FG meetings were held in each participating community to review synthesized data from the interviews and questionnaires. A total of 27 community members including active harvesters (men and women), youth, elders (active and nonactive harvesters), and whale monitors were selected by the local Hunters and Trappers Committees to participate in the FGs (Table 2). Some of these FG participants had been interviewed or had completed questionnaires previously, but others were experienced harvesters or youth that had not participated in earlier components of this study. To avoid interpretation bias, data were also reviewed with local HTCs, beluga monitors, RAs, the IGC, and FJMC.

Focus Group participants ($n = 22$) referred to as key informants met individually or in pairs with S. Ostertag in February 2016 (Inuvik, Paulatuk, and Tuktoyaktuk) and M. Wolki in March 2016 (Paulatuk) to validate findings and rank beluga characteristics as potential indicators of beluga health. These review sessions lasted between 30 min and 2 h and took place in peoples' homes (Inuvik, Tuktoyaktuk, and Paulatuk), the Tuktu Bed and Breakfast (Tuktoyaktuk), or the Tuktut Nogait Park Board Room (Paulatuk). The complete set of beluga characteristics established following content analysis was reviewed during these sessions. This review provided the opportunity for data validation with harvesters and monitors in the three communities, which was critical for identifying characteristics of beluga health that could be included as *local indicators* of health for future monitoring. The number of key informants that agreed or disagreed about each topic related to beluga health and beluga being "good to eat", and the percent agreement was determined and used for recommending potential *local indicators* of beluga health. Key informants received honoraria ($250) for participating in both the 2015 FGs and 2016 review sessions.

TEK in beluga monitoring

Local indicators of beluga health were identified based on the health characterization of beluga (i.e., category 1 TEK, Usher 2000) if >66% of reviewers agreed that the characteristic reflected beluga health. We used 66% as a threshold for identifying *local indicators* rather than a simple majority to avoid recommending *local indicators* that were inconsistently recognized by key informants as reflecting beluga health. Each potential *local indicator* was reviewed by the researchers to determine if the characteristic was feasible to monitor and could be comparable both spatially and temporally, based on the constraints of the current monitoring program in the ISR. TEK that reflected values about the environment (e.g., category 3 TEK, Usher 2000) and the Inuvialuit knowledge system (e.g., category 4 TEK, Usher 2000) were reviewed by the researchers to provide recommendations on how they may support beluga monitoring and management.

Results

Characterization of beluga health

The characterization of beluga health was organized into themes related to external appearance and behaviour (Table 3) and internal characteristics (Table 4) of belugas. Harvesters' responses to questionnaires about the health of harvested whales included descriptions such as the whale was good, normal, healthy, thinner than expected or very skinny. In 2014 and 2015, harvesters' responses to questionnaires indicated that the harvested belugas were healthy and none were identified as sick or in poor condition. Harvesters responding to the questionnaires following butchering of the whales did not refer to the internal organs or smell when characterizing the health of the harvested beluga. One whale harvested in 2014 close to Hendrickson Island had skin pox (small circular depressions in

Table 3. Beluga health characteristics about beluga whale health based on responses to interviews and semi-structured questionnaires.

Topic	C	*n*	%	Explanation	Representative quotes
Back	I, P, T	16	88	Healthy whales have a broad/wide back and the spine does not protrude.	"You see another whale and its round and slow that means it's a nice whale. How broad they are yeah". "Once in a while you get a sick whale — old age or something or from getting disease. Back is very thin if the whale is sick or starving". "Don't see the backbone on a healthy whale".
Round	I, T	16	63	Healthy whales are round, long whales are narrower/leaner but still have thick blubber.	"You know they're healthy when they got lots of fat, you know, that nice and round… That's how we know they're healthy". "Longer whales are thinner [smaller half girth] — they are called long, thin whales but they still have thick blubber, they are just narrower".
Rolls	I, P, T	17	76	Healthy whales have many rolls/love handles (lateral folds), older whales have more rolls. Skinny whales may also have rolls.	"You can pretty much tell a healthy whale if it's got a lot of rolls on its body". "Lovehandles and rolls are older ones". When you have lots of folding skin type, it's skinny. If it has lots of rolls, it's skinny".
Scars and wounds	I, P, T	12	67	Infected wounds or a greater quantity of scars may mean that the whale is sick.	"Even if healthy can have big scars". "Infected would mean it's sick, badly scarred maybe".
Marking on the skin	P, T	11	55	Marking on the skin reflect poorer health.	"I can remember a few times when we were out I was looking to [my dad] and he see some kind of marking on the whale on the skin color and he would say that's no good just by looking at it".
Colour	I, P, T	15	60	Healthy whales are "nice and white", but sick whales can also be white.	Whales are healthy "when they are nice and white". "If whale is less healthy, skin is a different colour, less white, more yellow". "Sick whale can also look very white; therefore, not a good indicator".
Diving	I, P, T	16	43	Diving behaviour is not related to beluga health.	"Something can be wrong and they can still dive normally".
Speed	I, P, T	13	62	Sick whales swim more slowly, but large whales also swim slowly.	"Small ten footers are speedy, if they are slow, wouldn't go for it because they should be fast". "You see another whale and it's round and slow that means it's a nice whale". "You look at belugas, you can always tell its activity. If it's sick, you'll notice it's kind of slow or different color".
Appear tired	I, P, T	15	73	If the whale appears to be tired, it is less healthy.	"Want to know why tired or slow. If an animal isn't trying to run away, something wrong, could be sick".
Breathing	P, T	11	64	Unhealthy whales surface more frequently to breathe.	"If they keep coming up, you know there's something's wrong with their lungs".

Note: Characteristics made about the external appearance of the whales that reflected beluga health were verified with community reviewers ($n = 22$). Reviewers that agreed with the statement are described by their community (C) defined as Inuvik (I), Paulatuk (P), and Tuktoyaktuk (T). The number of reviewers that responded to this statement is provided (n), and the percent of participants that agreed with the explanation is given based on the total responses (%).

Table 4. Beluga health characteristics about beluga whale health based on responses to interviews and semi-structured questionnaires.

Topic	C	*n*	%	Explanation	Representative quotes
Blubber thickness	I, P, T	10	90	Healthy whales have thick blubber, but blubber thickness varies and thin blubber does not necessarily indicate that a whale is unhealthy. Old whales or travelling whales may be starving.	"When you get a whale, it's really big, and when you cut it up it has a lot of blubber on it. That's the way we know that it's healthy. To prepare it for our winter food". "Some years thinner, some years thicker blubber. Never run into sick ones". "If an animal is healthy, it's always fat. It can't be that sick if it's that fat". "There's a difference between starving and being sick… depends on how they travel. If there's ice, hard time going through ice, have to wait awhile. Might bother them a bit, make them a bit skinny because travelling".
	I, P, T	15	94	Blubber thickness changes during the summer and is normally about 2″ in June and early July, and increases to 4–6″ in late July and August. Blubber thickness is 3–4 in. on a healthy whale. A skinny whale in a group of healthy whales or a thin whale late in the season means it is sick or old.	"The only thing I know, they tell us, when they first come out, their fat is very, about 2 inches instead of about 4 inches. And later on, end of July or August, the fat gets more". "you've got maybe four or five inches of blubber on the bottom of the *maktak* there so you know you've got a healthy, a good whale". "½ inch blubber means something is wrong". If it's skinny and with a group of fatter, healthier ones, then there is something wrong with it, because whales share". "At the beginning of season, they are thin, at end of season it it's thin, means it isn't healthy. Thin late in season means it is sick or old".
Texture of *uqsuq*	I, P, T	14	78	Texture of *uqsuq* does not vary with beluga health, although soft fat could indicate a very healthy whale.	"Well the texture [of the *uqsuq* is] usually it's always firm no matter what. Even if it's a sick whale it will still feel the same as the other ones it's just that the thickness is always going to be different". "Some have soft fat, must be really healthy".
Colour of *uqsuq*	P, T	12	42	*Uqsuq* can be orange if the whale is less healthy.	"[Fat is] like orange colour when they are not healthy. You know, that yellow, that orange fat that came out of that sick whale?"
Lumps in blubber/*uqsuq*	I, P, T	17	76	Lumps in blubber are not an indicator of poor health. A small number of lumps or small sacs with liquid in the blubber do not indicate poor health; lumps are from previous injuries and pus between *maktak* and skin is a bruise.	"If the lump in the blubber is big or there are many of them, the whale might be sick". "Lump in the backstrap, but whale still healthy. The Elders always say the whale is good [even if it has a lump]. All of the health properties of the whale outweigh the one piece of sickness/virus/disease". "Lumps in blubber from old injuries, cut it out". "Pus between *maktak* and skin on healthy animal may be from bumping".
Discolouration in *uqsuq*	I, T	12	33	Brown spots in the *uqsuq* if the whale is less healthy. Brown spots in *uqsuq* occur during processing.	"Unhealthy whales may be skinny and brown spots in the blubber or oil." "Brown spots in *uqsuq* are from ageing too much".

Table 4 (*concluded*).

Topic	C	*n*	%	Explanation	Representative quotes
Maktak thickness	P	8	63	*Maktak* may be thinner than ¾ in. on unhealthy whales.	"More *maktak*, oh ya, that's healthy, very healthy. Not too healthy anyway if it is thin".
Texture of muktuk	I, P	9	89	If the *maktak* disintegrates on the freshly harvested whale, the whale is sick. *Maktak* also falls apart when it is prepared incorrectly.	"about three years ago, one wasn't healthy… The white part of the *maktak* was just soft and coming out, coming out. Just took the samples, but it was sick. The whale was sick". "*Maktak* falls apart if it was hanging too long — wouldn't eat that. Boil too quickly it also falls apart".
Colour of meat	I, P, T	16	56	Meat on healthy whales is black.	"The darker meat is usually always healthy, if it's different color it's usually sick or weak".
Texture of meat	I, P, T	14	65	Meat on healthy whales is firm and not "falling apart". Meat may become watery if the whale is chased too much.	"But there was one that we had where the meat was really soft and falling apart so I threw that part away 'cause I was scared to eat it". "Press into the meat and the imprint doesn't stay there". "Mushy meat is not healthy. Not from being chased a long time". "If you chase the caribou for too long, it gets watery. Use whale net same problem. Meat doesn't taste good. Chase too much, makes the meat watery".
Quantity of meat	I, P, T	14	50	The amount of meat depends on health, age, size, and/or blubber thickness of the whale.	"On healthy whales, even the meat, just like the blubber, the meat is very bulky when you take the *maktak* out. In the whales that are very thin, the meat is not bulging out of the vertebrae". "Bigger whales have more meat, younger whales less".
Liver and heart	I, P, T	10	90	Spots on the liver or heart indicate that the whale is sick.	"Even if the liver or the heart or something had different marks on it. Then we would know. We wouldn't eat, we wouldn't eat things like that". "Heart doesn't get sickness part until it gets very sick. Protected by skin".
Lungs	I, P, T	5	100	In a sick whale, the thoracic (chest) cavity has white spots, the lungs may be stuck to the thoracic cavity or the pleura (lining of the inside of the thorax) sticks to the ribcage; whales can heal from this condition.	"We have to watch out for the lungs, you know, when they are sick or what". "As long as lungs not stuck to the body". "White spots in rib cage means it's infected by disease". "Skin dried up on the ribcage, but then they are fat so they must have got healed".
Smell	I, P, T	9	67	The smell of the whale changes if the whale is sick, even if it appears to be healthy.	"You know sometimes when you, you get a whale and you know it's healthy, and you open it up and you, you get a different smell out of it, you know right away that it's not good".

Note: Characteristics made about the internal appearance of the whales that reflected beluga health were verified with community reviewers ($n = 22$). Reviewers that agreed with the statement are described by their community (C) defined as Inuvik (I), Paulatuk (P), and Tuktoyaktuk (T). The number of reviewers that responded to this statement is provided (n), and the percent of participants that agreed with the explanation is given based on the total responses (%).

the skin) and one whale harvested in Darnley Bay had a 1 cm × 1 cm nodule in 2015; however, these whales were not considered unhealthy by the harvesters.

External characteristics that reflect beluga health were identified as the shape of the whale, presence of rolls or "lovehandles" (i.e., lateral folds), scars and wounds, markings, colour, and swimming behaviour (Table 3). More specifically, healthy whales have a broad, wide back, and may be round. The backbone is visible (i.e., protruding) on a thin whale, and it may have many rolls; however, a thin whale is not necessarily unhealthy. Harvesters avoid harvesting whales if they have markings or dark spots on the skin. Many participants described healthy whales as being nice and white; however, it was recognized that skin colour changes with moulting and an unhealthy whale could have white skin. Healthy whales may have scars, but the presence of infected wounds or a greater quantity of scars could indicate that the whale is sick. Harvesters have learned that experience and the external signs of beluga health are required to establish if belugas are healthy or not.

> "I have to check it, it comes up a couple of times to make sure that it's a good one. I have to say it again. You have to be experienced to hunt that kind... you have to be really experienced". Elder, Inuvik

Beluga diving behaviour and swimming speed may reflect animal health. Smaller whales are referred to as "road runners" as they travel faster than larger whales. If a whale is swimming slowly, the harvester will assess whether the animal is a small or large whale, to understand why it is swimming slowly. A whale that is small but swimming slowly may be tired or sick. A less healthy whale will often appear tired and may surface more frequently to breathe. Diving length (i.e., time under water) was identified in relation to health in some cases, but it was recognized that a sick whale can dive normally. It can be difficult to assess diving behaviour in the turbid water of the Mackenzie Delta because it is hard to keep track of multiple whales.

Internal examination was recognized by harvesters as being critical for knowing if belugas were healthy (Table 3). Blubber thickness was very commonly used to describe beluga health, but the complexity of blubber thickness as a characteristic of beluga health was discussed by research participants. Blubber thickness varies during the harvest season, but an animal with 0.5 in. of blubber or less was considered unhealthy. Healthy whales have about 4 or 5 in. of blubber by mid-July and whales that are thin later in the season are likely sick or old. Blubber thickness is also dependent on animal size and age; blubber thickness is less on younger and smaller whales than older and larger whales. Although blubber thickness is considered an important characteristic of beluga health, Inuvialuit recognize that a thin whale is not necessarily sick or unhealthy, but it may be "misfeeding" (i.e., starving) or old.

> "Skinny whales could be misfeeding... You can tell from the inside if the whale is less healthy". Elder, Paulatuk

> "At the beginning of season, they [belugas] are thin, at end of season it it's thin, means it isn't healthy. Thin late in season means it is sick or old". Harvester, Inuvik

Belugas have been observed with bruises that look like thick blood or blood vessels in the *maktak*. *Maktak* with blood vessels are discarded, but the whale is still considered healthy. Bruises were described as "pus between *maktak* and skin" and are generally removed from the *maktak* during preparation. Wounded areas may become infected if the wound is deep and penetrates the muscle. Lumps or brown spots in the blubber could indicate illness in the whale, but brown spots were also associated with poorly processing the

Table 5. Recommended indicators for beluga health based on the characterization of health by the Inuvialuit.

Body condition	Indicator	Monitoring tool	Feasibility	Comparability	Recommended indicator of body condition
Emaciated	Backbone protruding	Survey question	✓	X	✓
		Body condition chart	✓	✓	✓
		Photograph	X	✓	X
		Max. girth	✓	✓	✓
	0.5″ blubber thickness	Measurement at sternum	✓	✓	✓
	Rolls	Qualitative assessment	✓	X	✓
Average	Broad or round back	Survey question	✓	X	X
		Body condition chart	✓	✓	✓
		Photograph	X	✓	X
		Max. girth	✓	✓	✓
	2–4″ blubber at sternum June to mid-July	Measurement at sternum	✓	✓	✓
	>3″ blubber mid-July to September	Measurement at sternum	✓	✓	✓
	Rolls	Qualitative assessment	✓	X	✓
Very healthy	Broad or round back	Survey question	✓	X	✓
		Body condition chart	✓	✓	✓
		Photograph	X	✓	X
		Max. girth	✓	✓	✓
	Rolls	Qualitative assessment	✓	X	✓
	>6″ blubber mid-July to September	Measurement at sternum	✓	✓	✓

Note: Indicators are recommended if they are quantifiable or possible and were supported by >66% of Inuvialuit Focus Group participants.

uqsuq. A lump could be from an old injury and is likely a localized issue unless many lumps are observed in the *uqsuq*. Meat on healthy whales is black, the texture is firm, not disintegrating and without abnormalities (Table 4). The amount of meat changes with animal age and size, and whales with thin *uqsuq* may have thin meat.

> "Lump in the backstrap, but whale still healthy. The Elders always say the whale is good [even if it has a lump]. All of the health properties of the whale outweigh the one piece of sickness/virus/disease". Harvester, Paulatuk

During interviews, informants provided information about a small number of sick animals that were harvested in earlier years. Sick whales were described as having *maktak* that was soft and disintegrating, *uqsuq* that was orange or dark yellow, unusual appearance of lungs, parietal pleura (membrane between the lungs and ribcage) stuck to the ribcage, spots on the liver, or an unusual odour when the abdomen was opened.

Local indicators of health

Beluga health indicators that were identified by key informants were classified as indicators of body condition or indicators of infection or disease. Observations about harvested whales that received >66% support as potential indicators and could support body condition scoring include the shape of the back, blubber thickness, and presence of rolls (Table 5). TEK about body shape indicated that the backbone protrudes from an emaciated whale, but healthy whales have a broad or round back. TEK about beluga blubber thickness provides useful cut-off values to determine body condition of belugas that take into account the expected seasonal variation in blubber thickness of the harvested animals. Informants

suggested that rolls may occur on healthy, older, or skinny whales; therefore, the usefulness of recording the presence of rolls is questionable.

Indicators of infection or disease in beluga based on Inuvialuit TEK (>66% agreement) were the presence of an infected wound, disintegrating skin and skin lesions, lump in the blubber, unusual odour in the abdomen, spots on the liver, and the animal appearing to be tired and thin (Table 6). Informants did not provide information about possible causes of observed symptoms, which provides the opportunity for the co-production of knowledge between TEK holders and scientists to better understand the occurrence and etiology of disease (Table 6). Informants suggested that infected wounds or a greater quantity of scars may reflect illness in belugas. Bruises were described by informants as pus between the *maktak* and skin on healthy animal and were not considered indicators of health. Lumps in blubber were not considered relevant indicators of beluga health by informants but skin disintegrating was considered an indicator of a sick whale. Participants indicated that the odour of the whale changes if the animal is sick, even if it appears to be healthy. Spots on liver, heart, lungs, or parietal pleura (the lining of the inside of the chest wall) sticking to the ribcage were identified by informants as indicators that belugas are sick. Beluga whales that are lethargic and thin may be ill.

Cultural-based values and cosmology

Although the interviews and semi-structured questionnaires were primarily designed to capture the physical characterization of beluga health, responses also reflected Inuvialuit values and in a few cases, their worldview and the place of beluga in the Inuvialuit belief system. Inuvialuit values were evident in comments about how to behave when harvesting belugas, linkages between human and animal health, and the transmission of knowledge (Table 7). Respondents from Paulatuk identified that it was appropriate to hunt whales that appear to be sick to remove sick animals from the herd and reduce the suffering of animals. In two interviews conducted in Inuvik and Paulatuk, participants mentioned that they should not be picky; however, other informants from Inuvik and Tuktoyaktuk described themselves as selective hunters who select the whale that they harvested. Informants indicated that whales need to be respected, whales should not be wasted, and harvesting females with young should be avoided.

> "Take the whale even if it doesn't look good — eliminate sickness, keep from suffering. Not fussy". Harvester, Paulatuk

> "Respect the whale. Not leave the whale drowned or... respect the animals. Take what you need. Not waste it". Elder, Tuktoyaktuk

The transmission of knowledge to the younger generation was a common theme in interviews. The younger generation learns about beluga by watching the Elders or their parents. The need to pass along TEK about beluga extends beyond knowing if the whale is healthy and learning to hunt the whales and includes the critical knowledge about safely preparing beluga. The beluga monitors are considered an important source of knowledge for less experienced harvesters. Participants consistently suggested that the whole process of preparing beluga should be recorded, to ensure that future generations may learn the steps required to safely prepare beluga *maktak* and *mipku*.

> "It's not only monitoring, it should be Elders and parents taking responsibility in teaching their children and grandchildren how to prepare it 'cause one of these days there might be no jobs and they are going to have to survive on the land or on the water". Elder, Tuktoyaktuk

Table 6. Signs of infection and disease provided by Inuvialuit informants through interviews and Focus Groups and recommended monitoring action to determine cause of abnormalities.

Sign of infection or disease (provided by study participants)	Possible cause	Reference	Recommendation
Infected wound	May result from an underlying illness or disease	Vlasman and Campbell 2003	Photograph affected area. Collect sample of injured area plus surrounding normal tissue.
Disintegrating skin and skin lesions	Viral, fungal, or bacterial infection; environmental degradation and decreased immune function	Van Bressem et al. 2008; Mouton and Botha 2012	Photo of affected area, sample of affected area.
Lump in blubber	Calcified parasite	Vlasman and Campbell 2003	Collect sample of affected area plus surrounding normal tissue.
Unusual odour	Animal is sick	Inuvialuit informants	Record on monitoring form. Collect samples of heart, lung, liver, kidney, and spleen if possible.
Spots on liver	Serious illness; nutritional, toxic, or parasitic stressors	Martineau et al. 2002; Vlasman and Campbell 2003	Collect sample of affected area plus surrounding normal tissue. Collect samples of heart, lung, liver, kidney, and spleen if possible.
Tired and thin	Animal is sick	Inuvialuit informants	Collect samples of liver, heart, lung, liver, kidney, and spleen if possible.

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Table 7. Traditional ecological knowledge (TEK) about beluga health provided by interview and Focus Group (FG) participants that reflects the values and knowledge based on Inuvialuit cosmology.

Category of TEK	Category	C	Subcategory	Representative quote
Values	How to behave	P	Remove sick animals from the population	"Take the whale even if it doesn't look good — eliminate sickness, keep from suffering. Not fussy."
		I, P	Do not be picky when harvesting	"Told not to be picky, get what you can."
		I, T	Harvest selectively	"When I start calling the whale, I make sure that it doesn't have a young one. And then, I have to check it, it comes up a couple of times to make sure that it's a good one."
	Knowledge transmission	I, P, T	Elders and harvesters know if belugas are healthy	"I'm pretty confident with our whales you know. Still continue asking our Elders if the meat are still safe."
	Human health	I, P, T	Inuvialuit health is connected to animal health	"Whatever you eat is, if it is not healthy, then don't eat it".
Cultural-based cosmology	Explanation of observations	T	Marine mammals are healthy	"I think that all mammals that eat… fish and healthy stuff… they keep themselves healthy".
		I	Only healthy whales can migrate long distances	"Distant travel weeds out sick animals".
		I, P	Whales share	"If it's skinny and with a group of fatter, healthier ones, then there is something wrong with it, because whales share".
		I, P, T	A thin whale at the end of the season is sick or old.	"At the beginning of season, they are thin, at end of season it it's thin, means it isn't healthy. Thin late in season means it is sick or old".
		I, P, T	Old whales can be thin because they are sick	"These whales live so long, they can live to almost 100 years, so if you happen to catch an older whale, it can be sick".

Note: Communities (C) are defined as Inuvik (I), Paulatuk (P), and Tuktoyaktuk (T).

Elders also provide important guidance to the younger generation and younger harvesters look to Elders to determine if a beluga is healthy. Elders' knowledge is respected and recognized as integral to assessing beluga health in the three communities. Elders share their knowledge with their children, nieces, and nephews. Younger harvesters look to the Elders to make decisions if abnormalities are observed.

> "I'm pretty confident with our whales you know. Still continue asking our Elders if the meat are still safe". Whale monitor, Paulatuk
>
> "The Elders they know, you never question them". Harvester, Paulatuk

Beluga health and Inuvialuit health are linked, and it is widely recognized that sick animals should not be eaten. Elders and parents show younger generations that belugas are healthy by including beluga in their diet. Only healthy animals are consumed; therefore, beluga whales that are harvested and consumed are healthy. Elders were confident that they could assess beluga health based on their experience; however, there was a general expectation that DFO should provide human health guidance based on the results from the FMMCMP. Participants expressed concern about the length of time before results are returned to the communities. Although Inuvialuit believe that belugas are healthy, many participants requested information from the DFO about the health of belugas including presence of contaminants and diseases, changes in condition, unusual behaviour, and problems with the meat or *maktak*.

> "Whatever you eat is, if it is not healthy, then don't eat it". Elder, Inuvik
>
> "With all of his years' experience. We would know if it was sick. We wouldn't eat, we wouldn't eat things like that". Inuvik, Elder
>
> "All the whales seemed to be healthy. Nothing was reported anyway back from DFO... that's why they... taking samples, to make sure we are going to have healthy food". Whale monitor, Tuktoyaktuk
>
> "I think it is really important that [DFO] share the information of the data that they find. Whether it is a sick animal, whether it's got PCB or mercury, they should share that so we can make sure that our beluga whale is healthy all of the time, and that the population is healthy. Since they started working on the research, how come it take so long to share the data? And also to communicate with the Elders and the people about their findings, not three/four years later." Elder, Tuktoyaktuk

Belugas are considered healthy not only based on direct observations but also from the construction of knowledge from facts. Interviewees seldomly shared observations that could be categorized as reflecting the Inuvialuit knowledge system, but, in a few cases, explanations about beluga health moved from direct observations about belugas to an interpretation of these observations based on the beliefs of the informants. For example, in Tuktoyaktuk, belugas were considered to be healthy because they live in the ocean, consume fish, and migrate long distances (Table 7). In addition, belugas in a group of whales tend to be healthy but if one whale in the group was thinner than the others, it could be less healthy because belugas share. Older whales tend to be alone and if a lone whale is thin, it is likely sick or starving. Due to the long life spans of beluga, older whales can be thin because they are sick.

> "If it's skinny and with a group of fatter, healthier ones, then there is something wrong with it, because whales share". Elder, Inuvik

Discussion

Health characterization

The characterization of beluga health complements previously recorded TEK about beluga whales from the ISR (Byers and Roberts 1995; Hart and Amos 2004; Inuuvik Community Corporation et al. 2006; Waugh et al. 2018), Nunavut (Kilabuk 1998), Nunavik (O'Neil et al. 1997; Bre ton-Honeyman et al. 2016), Alaska (Huntington et al. 1999), and Russia (Mymrin et al. 1999). The observation of few sick animals in Nunavut was consistent with reports in the ISR that suggested that most belugas are healthy in the EBS population. Abnormalities and disease were reported infrequently in ringed seals (*Phoca hispida*) in Cape Dorset and hunters are confident that they are good to eat (Kushwaha 2007). Unlike observations shared about EBS beluga, Elders and hunters from Pangnirtung noted that small bumps on the back of beluga were related to the fatness of the body (Kilabuk 1998). Nunavik hunters reported that they know if animals are sick based on their behaviour, outward appearance, or various changes in the appearance of internal organs (O'Neil et al. 1997). These signs of illness were very similar to how beluga health was characterized by Inuvialuit in our study. Characteristics of healthy versus unhealthy ringed seal based on IQ interviews in Cape Dorset, NU, included that healthy seals have a smell that is easily recognized by an experienced hunter, the meat is dark red/black, the *uqsuq* is white and thick, and it tastes fresh (Kushwaha 2007), which was similar to what was reported for belugas in our study.

Seasonal variation in blubber thickness was reported by Inuit in Nunavik, with belugas reported to be fattest in late winter and early spring (i.e., before the spring migration) and thinnest during the fall [i.e., during the fall migration (Bre ton-Honeyman et al. 2016)]. This was similar to the reports from the ISR in which belugas were reported to be thinnest in June with blubber thickness of approximately 2 in. or 5 cm after their migration from the Bering Sea and fattest in late July and August with blubber thickness reaching 4–6 in. (10–15 cm). In Nunavik, the median blubber thickness in belugas was 4 cm (range = 1–9 cm) during the fall migration and 11 cm (range = 6.3–20 cm) during the spring migration (Breton-Honeyman et al. 2016). Seasonal fluctuation in blubber thickness was also reported by Cape Dorset Inuit in ringed seal (Kushwaha 2007), which is consistent with seasonal fluctuations of blubber thickness observed in EBS beluga by Inuvialuit. In addition, the *maktak* was reported to be thicker in spring and summer than in fall in Pangnirtung (Kilabuk 1998), which was consistent with observations of EBS beluga that *maktak* thickness varies with blubber thickness.

Local indicators

Current monitoring of EBS beluga includes maximal half girth, standard length, and blubber thickness at sternum, which can be used as indicators of beluga condition (e.g., Harwood et al. 2014; Choy et al. 2017). The condition indicators provided by Inuvialuit would complement existing indicators to monitor the health of belugas for the TNMPA. Including *local indicators* within the FMMCMP supports the principle of wildlife management prescribed by the IFA that the "relevant knowledge and experience of both the Inuvialuit and the scientific communities should be employed in order to achieve conservation" (IFA 1984, p. 53). *Local indicators* of beluga condition could provide valuable information about beluga health to complement existing measurements that have suggested a decrease in growth rate (Harwood et al. 2014) and variation in blubber thickness and maximum half girth associated with environmental conditions (Choy et al. 2017). Poor nutrition may reduce reproductive success in marine mammals, which could have repercussions at the population level (Burek et al. 2008).

Body condition indicators

Body condition scores are useful for assessing health, as survivability in marine mammals was linked to body condition (Pettis et al. 2004; Sharp et al. 2014). We recommend that a qualitative assessment of body condition be included in beluga monitoring to complement the measurement of animal half girth and blubber thickness currently recorded. In the ISR, Inuvialuit considered beluga whales with a broad or round back to be healthy animals, and the protrusion of the spine was considered to be a sign of a thin or unhealthy whale. Half girth is likely related to the width of the back; however, it may not adequately capture concavity ventrolateral to the dorsal fin or protrusion of the spine. Research on dead-stranded St. Lawrence Estuary (SLE) belugas (length >290 cm) found that condition scores based on visual evaluation of the body shape of stranded beluga whales were significantly correlated to animal weight (Larrat 2014). In addition, a consistent marker of emaciation in the common dolphin (*Delphinus delphis*) was wasting of the epaxial musculature, which was determined by the degree of concavity or convexity ventrolateral to the dorsal fin (Joblon et al. 2014). The relationship between girth and body shape of EBS beluga has not been explored; however, maximum circumference was significantly correlated to beluga mass in the SLE (Larrat 2014) and half girth of EBS beluga whales was identified as a condition index (Choy et al. 2017). A qualitative assessment of the concavity of the trunk and protrusion of the spine should be included in the monitoring program using a simple survey question about body shape, and a chart or photographs similar to those used by Joblon et al (2014) and Larrat (2014). Harvested belugas could be photographed with cranio-caudal and caudo-cranial views just above eye level to assist with comparability of across years and camps (Joblon et al. 2014); however, it is not feasible that every whale could be photographed adequately due to poor weather, time constraints, and the position of the beluga in the ocean.

Blubber thickness was consistently identified by key informants as an important indicator of beluga health and the presence of rolls was recommended as an indicator by 76% of reviewers. Blubber thickness needs to be interpreted based on the TEK shared in this study, in which clear cut-off values were provided that indicated the body condition of belugas throughout the harvesting season. The strength of blubber thickness as an indicator is that it is quantifiable, the weakness of this indicator is that blubber thickness may not reflect overall body condition in belugas (Larrat 2014; Choy et al. 2017). Blubber plays an important role in thermoregulation (Worthy and Edwards 1990; Dunkin et al. 2005); therefore, arctic cetaceans may avoid using energy reserves in blubber and instead may use muscle and other tissue as energy reserves (Koopman 2001; Koopman et al. 2002; Irvine et al. 2017). The EBS belugas undergo an extensive migration every spring and autumn, travelling between their wintering area in the Bering Sea to their summering area in the Beaufort (Richard et al. 2001). Therefore, seasonal variation in blubber thickness can be expected in this population. We recommend that future analyses incorporate the cut-off values for blubber thickness indicated in this study to score animals' body condition.

Although the presence of rolls or "love handles" on beluga was recommended as an indicator of health, there are challenges associated with recording the presence of rolls on harvested whales to support the evaluation of beluga health. To the best of our knowledge, rolls or lateral folds have not been used in previous studies as an indicator of body condition in cetaceans. The rolls described by informants likely include ventrolateral abdominal fat pads, which have been hypothesized as important vertical stabilizers in beluga, as they lack a dorsal fin (Werth and Ford 2012). These lateral folds were observed to be used for turning and during locomotion in both captive and wild beluga whales (Werth and Ford 2012). We recommend that observations about rolls be recorded but suggest caution in

their use as an indicator of body condition due to the difficulty of systematically recording presence/absence of rolls on beluga and the uncertainty with their meaning.

Indicators of infection or disease

Infectious diseases occur when a pathogen invades a host and negatively affects the host's ability to function (Burek et al. 2008). Therefore, monitoring infections and disease in EBS beluga through the use of local indicators would provide important information about immune function and overall health in this population. Beluga monitors in the ISR collect samples for Brucella spp., *Toxoplasma gondii*, and herpes virus screening; however, samples are not routinely screened for additional infectious diseases. Inuvialuit infrequently observed signs of infection or disease in belugas that are similar to those recorded in SLE and Cook Inlet beluga whale populations, which are listed as endangered due to declining populations (COSEWIC 2014; National Marine Fisheries Service 2017). These two populations have experienced dead strandings, which afforded the opportunity for necropsies to determine cause of death but may not be comparable to hunter-harvested beluga.

Wounds occur in beluga due to travel through ice, and attempted predation by polar bear (*Ursus maritimus*) and killer whales (*Orcinus orca*). Injuries may lead to poorer animal condition or the injury may result from an underlying illness or disease (Vlasman and Campbell 2003). If an infected wound is observed, a sample of the wound and surrounding tissue should be collected. Lumps in the blubber may be calcified parasites (Vlasman and Campbell 2003) and were recognized by informants as being localized and the beluga was still considered safe to eat if the lump was removed. This was similar to the observation of localized skin pox in two harvested whales that were not associated with poor health or risk to consumers by the respondents. Samples and photos of lumps observed in the blubber would aid in determining the causes of these lumps that are observed periodically. The primary role of the skin on cetaceans is to protect the animals from the environment; disease of cetacean skin may reflect environmental degradation or a compromised immune system (Mouton and Botha 2012). If *maktak* is observed to be disintegrating, this should be reported on the monitoring form, photos should be taken, and a sample should be frozen to assist in the identification of viral, bacterial, or fungal causes (Van Bressem et al. 2008). Odour was also identified as an indicator of ringed seal health by Inuit in Cape Dorset (Kushwaha 2007), but to our knowledge has not been described in the scientific literature.

Lesions and necrosis (death of tissue) have been frequently observed in the livers of stranded SLE beluga, possibly due to nutritional, toxic, or parasitic stressors (Martineau et al. 2002). It is important to note that TEK and western science agree that animals with spots on the liver should not be consumed. The presence of white spots on the liver may indicate a serious illness in affected animals (Vlasman and Campbell 2003). Heart lesions were observed in five Cook Inlet beluga, but they were not the cause of death in these stranded animals (Burek-Huntington et al. 2015). The liver is currently sampled for biomonitoring, making it a convenient organ to examine regularly, unlike the heart and lungs, which are generally not sampled or examined. If spots or other abnormalities are observed on the liver, a sample of liver tissue should be collected and frozen at −20 °C, and a photo taken. The collection of additional samples (i.e., heart, liver, kidney, and spleen) would support laboratory analyses to determine the cause of illness in animals that appear sick.

In marine mammals from the eastern Arctic, inflammation of the lungs was associated with bacterial pneumonia or lungworm infection (*Otostrongylus circumlitus*), resulting in the lung appearing darker and firmer than usual, visible abscesses, or presence of threadlike worms <7 cm in length (Vlasman and Campbell 2003). Verminous pneumonia caused the death of 24 beluga studied in the SLE (Lair et al. 2016). The observation of pleura sticking

to chest wall, or the pleura appearing dry may be associated with pleuritis. Pleuritis or pleurisy is the "inflammation of the pleura, the lining of the lungs, and the inside of the chest wall" (Barnett et al. 2001), which may be caused by pneumonia or other respiratory infection. In a captive beluga, the relationships between cutaneous and pleural mycobacteriosis and chronic pneumonia were unclear; however, mycobacteriosis was not the cause of beluga death (Bowenkamp et al. 2001).

Beluga whales that are lethargic and thin may be ill but reports of cetacean lethargy in the literature were unavailable. We suggest that harvesters report if the beluga whale appeared to be unusually tired during the hunt. If the whale appeared to be tired and was thin, liver, kidney, and spleen samples should be collected and the thoracic cavity opened if possible to view and sample the lungs and heart. Collecting additional photos and samples of the lungs of tired/sick beluga would support a better understanding of disease in EBS beluga. Quantifying or systematically recording the detection of an abnormal odour is not possible; therefore, we recommend that the beluga monitor record if an unusual odour is present and collect additional samples to allow for the identification of potential causes of illness.

Cultural-based values and cosmology in management

Our study provides specific examples of how Inuvialuit values about beluga health can shape beluga monitoring under the TNMPA and FMMCMP. The inclusion of Inuvialuit in the FJMC ensures their integration in the functions and decisions pertaining to fisheries management in the ISR (IFA 1984). Specifically, the Beaufort Sea Beluga Management Plan is firmly rooted in TK about beluga whales (Fisheries Joint Management Committee 2013), which is consistent with one of the goals of the IFA which is to "preserve Inuvialuit cultural identity and values within a changing northern society" (IFA 1984). Themes surrounding harvesting practices, the transmission of knowledge, knowledge about beluga health, and linkages between human and beluga health are explored in this section in the context of monitoring beluga health.

> "The knowledge, skills, the values placed on sharing and respect for the environment that are the foundations of Inuvialuit culture have long allowed people to live in harmony with nature and to thrive" (Arnold et al. 2011).

Avoiding females with calves and respecting belugas by not wasting them are both values that are reflected in local beluga hunting by-laws and guidelines that were developed by the Hunters and Trappers Committees of the ISR in conjunction with the FJMC. Areas that require additional exploration for monitoring include the selective harvesting practices and the removal of sick whales from the population, which have implications for monitoring beluga health. Our interviews indicated that selective harvesting is not practiced consistently in the ISR, which may have implications for the analysis of data from the FMMCMP. Differences in beluga size reported by Loseto et al. (2008) for Paulatuk and Tuktoyaktuk could be linked to the different harvesting strategies utilized in Kugmallit Bay (i.e., Inuvik and Tuktoyaktuk harvesters) compared to the Paulatuk area. Harvesters in Paulatuk may be less selective than harvesters in other communities, as they must harvest opportunistically when the whales travel along the coast of Darnley Bay. Although selective harvesting is not anticipated to affect analyses of growth rates or blubber thickness (Harwood et al. 2014), the FJMC may wish to include additional information about whether the harvested whale was selected or not. In addition, to better assess the health of the whales that are harvested the FJMC may wish to record the condition of whales in the group or if the harvested whale was alone.

Removing sick animals from the population was considered an appropriate action by respondents, which would provide an excellent opportunity to better understand health and disease in the EBS beluga population. Providing samples from sick or stranded animals to the Canadian Wildlife Health Cooperative would support the screening of belugas for diseases and parasites and the gathering of additional information pertaining to the health of wild populations (Canadian Wildlife Health Cooperative 2018). Stranded cetaceans provide critical information about individual illnesses and wholesale mortalities and trends in the levels of oceanic contaminants (Geraci and Lounsbury 1993, p. 4). Our research suggests that it may be culturally appropriate in the ISR for hunters to hunt sick whales to remove them from the population. However, cultural norms around dealing with sick animals must be fully addressed at the community and regional level. In Cape Dorset, harvesters are taught to leave unhealthy animals alone to be safe (Kushwaha 2007). Sampling less healthy or sick whales provides the opportunity to track changes in beluga health in a region undergoing rapid environmental changes; therefore, we recommend that the FJMC develop a protocol with communities for action to be taken if a sick whale is observed.

The transmission of knowledge from Elders and parents to the next generation is critical to ensuring that the next generation learns how to hunt, prepare beluga, and make decisions about food safety. In the community of Ulukhaktok, the availability of a teacher, usually a father or grandfather, was the determining factor for young men to learn land skills such as hunting, travelling, fishing, and weather forecasting (Pearce et al. 2011). In Nunavut, the importance of relationships between elders and youth was highlighted as essential for the transmission of Inuit knowledge (Laugrand and Oosten 2009). Although modern efforts to keep Inuit qaujimajatuqangit values alive in Nunavut were identified as being important, Laugrand and Oosten (2009) stressed that these initiatives cannot replace the transfer of knowledge within the family. In Ulukhaktok, experiential learning experiences coordinated by community seal monitors and the local school were important for the transmission of land skills for some research participants (Pearce et al. 2011). Therefore, the FJMC can likely play a role in supporting the transmission of land skills to younger generations by supporting programs for youth where they can learn land skills and by promoting opportunities for youth and elders to strengthen relationships. Employing youth and elders in the FMMCMP provides the opportunity for knowledge to be shared between the older and younger generations and would also benefit the scientists engaged in this program. Through such initiatives, youth would also learn two ways of knowing about beluga from an Inuvialuit and scientific perspective (Kofinas 2002). Increasing capacity in local communities has also been recognized as a mechanism to successfully include TEK in resource management decision-making (Manseau et al. 2005).

Beluga health research conducted under the DFO and FJMC provides data on contaminants (e.g., Loseto et al. 2015) and pathogens (e.g., Nielsen et al. 2001*a*, 2001*b*, 2018) that may have implications for human health. The Chief Public Health Officer (CPHO) of the Northwest Territories is responsible for issuing consumption advice when elevated levels of contaminants are found in traditional foods that could present a public health risk to consumers. The strong linkage between Inuvialuit health and environmental health creates the necessity for increased collaboration and communication between resource managers and the CPHO. We recommend that linkages between beluga and human health research are strengthened to ensure that the FMMCMP and related scientific studies on EBS beluga provide information to the CPHO. Examples of how this can occur include the use of contaminant data for belugas for a database for contaminants in traditional foods (Chan 1998) and the investigation into how food preparation affects contaminant levels in beluga food products (Binnington et al. 2017).

Using a variety of modes of communication fosters formal and informal relationships that are important for the co-production of knowledge (Armitage et al. 2011). We recommend that formats such as the 2016 Beluga Summit held in Inuvik, social media, updates posted to websites, community meetings, elders meetings, and reports be utilized to communicate beluga health results in the ISR. Based on our research, we suggest that meetings should be held in a space where community members feel comfortable, such as a community centre, local boardroom, or at a camp, and researchers presenting in such meetings should be familiar with the communities involved or co-present with a team member with experience in the community. Elders know if belugas are healthy; therefore, beluga research must be linked to human health and also needs to be communicated in ways that do not undermine or show disrespect for the knowledge held by elders.

Conclusions

The aim of this research was to document how beluga health is characterized by Inuvialuit to support the development of local health indicators and provide recommendations for greater inclusion of TEK in the FMMCMP. Inuvialuit values and cosmology are embedded in the FMMCMP due to the composition of the FJMC and this study provides recommendation for TEK to be directly included in beluga monitoring in the ISR. This research furthers our understanding of how Inuvialuit view beluga health based on the physical and behavioural characteristics of belugas and also identifies key values and aspects of the Inuvialuit knowledge system that may affect the FMMCMP. To support the co-production of knowledge, a suite of local indicators was developed that bridged TEK about beluga condition, illness, and disease with western science. If these indicators are used for beluga monitoring, they would provide valuable information about beluga health to complement existing measurements that have suggested a decrease of size-at-age (Harwood et al. 2014), variation in blubber thickness associated with environmental conditions (Choy et al. 2017), and exposure to contaminants (Loseto et al. 2015; Noël et al. 2018; Smythe et al. 2018), *Brucella* spp. (Nielsen et al. 2001*a*) and Influenza A (Nielsen et al. 2001*b*) in the EBS population. Identifying less healthy or sick whales provide the opportunity for additional sampling to occur, which can aid in tracking changes in beluga health in a region undergoing rapid environmental changes. The values held by Inuvialuit about belugas include the need for knowledge transmission from Elders to the younger generation about beluga health. Increased acknowledgement of the linkages between beluga and human health must be addressed by the FJMC to further strengthen the FMMCMP. This research provides a valuable contribution to adaptive co-management of beluga whales in the ISR. We recommend that Inuvialuit are engaged in the design and implementation of future beluga studies to ensure that TEK is recorded alongside western science to support adaptive co-management.

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References

Armitage, D., Berkes, F., Dale, A., Kocho-Schellenberg, E., and Patton, E. 2011. Co-management and the co-production of knowledge: learning to adapt in Canada's Arctic. Global Environ. Change, **21**: 995–1004. doi: 10.1016/j.gloenvcha.2011.04.006.

Arnold, C., Stephenson, W., Simpson, B., and Ho, Z. (eds.). 2011. Taimani: at that time. Inuvialuit Regional Corporation, Inuvik, N.W.T, Canada.

Barnett, J., Knight, A., and Stevens, M. 2001. Marine Mammal Medic Handbook. 2nd ed. British Divers Marine Life Rescue (BDMLR), Gillingham, UK.

Bengtsson, M. 2016. How to plan and perform a qualitative study using content analysis. NursingPlus Open, **2**: 8–14. doi: 10.1016/j.npls.2016.01.001.

Binnington, M.J., Lei, Y.D., Pokiak, L., Pokiak, J., Ostertag, S.K., Loseto, L.L., Chan, H.M., Yeung, L.W.Y., Huang, H., and Wania, F. 2017. Effects of preparation on nutrient and environmental contaminant levels in Arctic beluga whale (*Delphinapterus leucas*) traditional foods. Environ. Sci. Process Impacts, **19**(8): 1000–1015. doi: 10.1039/c7em00167c. PMID: 28752885.

Bowenkamp, K., Frasca, S., Jr., Draghi, A., Tsongalis, G., Koerting, C., Hinckley, L., de Guise, S., Montali, R.J., Goertz, C.E.C., St. Aubin, D.J., and Lawrence, D.J. 2001. Mycobacterium marinum dermatitis and panniculitis with chronic pleuritis in a captive white whale (*Delphinapterus Leucas*) with aortic rupture. J. Vet. Diagn. Invest. **13**(6): 524–530. doi: 10.1177/104063870101300613. PMID: 11724146.

Breton-Honeyman, K., Hammill, M.O., Furgal, C.M., and Hickie, B. 2016. Inuit Knowledge of beluga whale (*Delphinapterus leucas*) foraging ecology in Nunavik (Arctic Quebec), Canada. Can. J. Zool. **94**: 713–726. doi: 10.1139/cjz-2015-0259.

Burek, K.A., Gulland, F.M.D., and O'Hara, T.M. 2008. Effects of climate change on arctic marine mammal health. Ecol. Appl. **18**(2 Suppl.): S126–s134. doi: 10.1890/06-0553.1. PMID: 18494366.

Burek-Huntington, K.A., Dushane, J.L., Goertz, C.E.C., Measures, L.N., Romero, C.H., and Raverty, S.A. 2015. Morbidity and mortality in stranded Cook Inlet beluga whales *Delphinapterus leucas*. Dis. Aquat. Org. **114**: 45–60. doi: 10.3354/dao02839. PMID: 25958805.

Byers, T., and Roberts, L.M. 1995. Harpoons and Ulus: collective wisdom and traditions of Inuvialuit regarding the beluga ("qilalugaq") in the Mackenzie River estuary. Byers Environmental Studies, Winnipeg, Man., Canada.

Canadian Wildlife Health Cooperative. 2018. Report and Submit. [Online]. Available from http://www.cwhc-rcsf.ca/report_submit.php [accessed 1 March 2018].

Chan, H.M. 2009. A database for environmental contaminants in traditional foods in northern and arctic Canada: development and applications. Food Addit. Contam. **15**(2): 127–134. doi: 10.1080/02652039809374621.

Choy, E.S., Rosenberg, B., Roth, J.D., and Loseto, L.L. 2017. Inter-annual variation in environmental factors affect the prey and body condition of beluga whales in the eastern Beaufort Sea. Mar. Ecol.: Prog. Ser. **579**: 213–225. doi 10.3354/meps12256.

COSEWIC. 2014. COSEWIC assessment and status report on the Beluga Whale Delphinapterus leucas, St. Lawrence Estuary population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ont., Canada. pp. xii + 64.

Davidson-Hunt, I.J., and O'Flaherty, R.M. 2007. Researchers, indigenous peoples, and place-based learning communities. Soc. Nat. Resour. **20**(4): 291–305. doi: 10.1080/08941920601161312.

Desforges, J.P., Ross, P.S., Dangerfield, N., Palace, V.P., Whiticar, M., and Loseto, L.L. 2013. Vitamin A and E profiles as biomarkers of PCB exposure in beluga whales (*Delphinapterus leucas*) from the western Canadian Arctic. Aquat. Toxicol. **15**(142–143): 317–328. doi: 10.1016/j.aquatox.2013.08.004. PMID: 24077185.

Dunkin, R.C., McLellan, W.A., Blum, J.E., and Pabst, D.A. 2005. The ontogenetic changes in the thermal properties of blubber from Atlantic bottlenose dolphin *Tursiops truncatus*. J. Exp. Biol. **208**: 1469–1480. doi: 10.1242/jeb.01559. PMID: 15802671.

Fisheries Joint Management Committee. 2013. Beaufort Sea beluga management plan. 4th amended printing. FJMC, Inuvik, N.W.T., Canada.

Fisheries Joint Management Committee. 2017. FJMC vision. [Online]. Available from https://fjmc.ca/about-us/fjmc-vision/ [accessed 2 October 2017].

Frouin, H., Loseto, L.L., Stern, G.A., Haulena, M., and Ross, P.S. 2012. Mercury toxicity in beluga whale lymphocytes: limited effects of selenium protection. Aquat. Toxicol. **109**: 185–193. doi: 10.1016/j.aquatox.2011.09.021. PMID: 22018916.

Geraci, J.R., and Lounsbury, V.J. 1993. Marine mammals ashore. A field guide for strandings. Texas A&M University Sea Grant College Program, Galveston, Tex., USA.
Government of the Northwest Territories. 2005. Traditional knowledge 53.03. [Online]. Available from http://www.enr.gov.nt.ca/sites/enr/files/documents/53_03_traditional_knowledge_policy.pdf [accessed 2 October 2017].
Hart, E., and Amos, B. 2004. Learning about marine resources and their use through Inuvialuit oral history. Inuvialuit Cultural Resource Centre, Inuvik, N.W.T., Canada.
Harwood, L.A., Lacozza, J., Auld, J.C., Norton, P., and Loseto, L.L. 2014. Belugas in the Mackenzie River estuary, NT, Canada: habitat use and hot spots in the Tarium Niryutait Marine Protected Area. Ocean Coastal Manage. **100**: 128–138. doi: 10.1016/j.ocecoaman.2014.08.004.
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. Canadian Manuscript Report Fisheries Aquatic Sciences 3059. Fisheries and Oceans Canada, Winnipeg, Man., Canada. vi + 32 pp.
Hill, P.S., and DeMaster, D.P. 1999. Alaska marine mammal stock assessments, 1999. NOAA Technical Memorandum NMFS-AFSC-110. US Department of Commerce, Seattle, Wash., USA. [Online]. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/ak1999.pdf.
Huntington, H.P. 1998. Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge. Arctic, **51**(3): 237–242. doi: 10.14430/arctic1065.
Huntington, H.P. 2000. Using traditional ecological knowledge in science: methods and applications. Ecol. Appl. **10**: 1270–1274. doi: 10.1890/1051-0761(2000)010[1270:UTEKIS]2.0.CO;2.
Huntington, H.P., Buckland, C., Elim, C., Koyuk, C., Lay, C.P., and Shaktoolik, C. 1999. Traditional knowledge of the ecology of beluga whales (*Delphinapterus leucas*) in the eastern Chukchi and northern Bering Seas, Alaska. Arctic, **52**: 49–61. doi: 10.14430/arctic909.
IFA. 1984. The Western Arctic claim. Inuvialuit Final Agreement, Inuvik, N.W.T., Canada.
Inuuvik Community Corporation, Tuktuuyaqtuuq Community Corporation, and Aklarvik Community Corporation. 2006. Inuvialuit Settlement Region Traditional Knowledge Report. Mackenzie Project Environmental Group, Inuvik, N.W.T., Canada. pp. 6–1, 11–3–11-5. [Online]. Available from http://www.capekrusenstern.org/docs/icc_study_2006.pdf [1 Oct. 2017].
Irvine, L.G., Thums, M., Hanson, C.E., McMahon, C.R., and Hindell, M.A. 2017. Quantifying the energy stores of capital breeding humpback whales and income breeding sperm whales using historical whaling records. R. Soc. Open Sci. **4**(3): 160290. doi: 10.1098/rsos.160290. PMID: 28405350.
Joblon, M.J., Pokras, M.A., Morse, B., Harry, C.T., Rose, K.S., Sharp, S.M., Niemeyer, M.E., Patchett, K.M., Sharp, W.B., and Moore, M.J. 2014. Body condition scoring system for delphinids based on short-beaked common dolphins (*Delphinus delphis*). J. Mar. Anim. Ecol. **7**: 5–13.
Kilabuk, P. 1998. A study of Inuit knowledge of the Southeast Baffin beluga. Nunavut Wildlife Management Board, Iqaluit, N.W.T., Canada. 74 pp.
Kofinas, G. 2002. Community contributions to ecological monitoring. *In* The Earth is faster now: indigenous observations of Arctic environmental change. *Edited by* I. Krupnik and D. Jolly. ARCUS, Fairbanks, Alaska, USA. pp. 55–91.
Koopman, H.N. 2001. The structure and function of the blubber of odontocetes. Ph.D. thesis, Duke University, Durham, N.C., USA.
Kondracki, N.L., Wellman, N.S., and Amundson, D.R. 2002. Content analysis: review of methods and their applications in nutrition education. J. Nutr. Educ. Behav. **34**: 224–230. doi: 10.1016/S1499-4046(06)60097-3. PMID: 12217266.
Koopman, H.N., Pabst, D.A., McLellan, W.A., Dillaman, R.M., and Read, A.J. 2002. Changes in blubber distribution and morphology associated with starvation in the harbor porpoise (*Phocoena phocoena*): evidence for regional differences in blubber structure and function. Physiol. Biochem. Zool. **75**: 498–512. doi: 10.1086/342799. PMID: 12529851.
Kushwaha, A. 2007. Monitoring environmental change using Inuit Qaujimajatuqanjit in Cape Dorset, Nunavut. Master's thesis, Carleton University, Ottawa, Ont., Canada.
Laidre, K.L., Stirling, I., Lowry, L.F., Wiig, Ø., Heide-Jørgensen, M.P., and Ferguson, S.H. 2008. Quantifying the sensitivity of arctic marine mammals to climate-induced habitat change. Ecol. Appl. **18**(Special Issue 2): S97–S125. doi: 10.1890/06-0546.1.
Lair, S., Measures, L.N., and Martineau, D. 2016. Pathologic findings and trends in mortality in the beluga (*Delphinapterus leucas*) population of the St Lawrence Estuary, Quebec, Canada, from 1983 to 2012. Vet. Pathol. **53**(1): 22–36. doi: 10.1177/0300985815604726. PMID: 26374277.
Larrat, S. 2014. Indices de condition corporelle chez le béluga du Saint-Laurent: utilisation rétrospective de données morphologiques recueillies lors de necropsies. M.Sc. thesis, Université de Montréal, Montreal, Que., Canada.
Laugrand, F., and Oosten, J. 2009. Transfer of Inuit qaujimajatuqangit in modern Inuit society. Études/Inuit/ Studies, **33**(1–2): 115–152. doi: 10.7202/044963ar.
Loseto, L.L., Stern, G.A., and Ferguson, S.H. 2008. Size and biomagnification: how habitat selection explains beluga mercury levels. Environ. Sci. Technol. **42**(11): 3982–3988. doi: 10.1021/es7024388. PMID: 18589955.
Loseto, L.L., Wazny, T., Cleator, H., Ayles, B., Cobb, D., Harwood, L., Michel, C., Nielsen, O., Paulic, J., Postma, L., Ramlal, P., Reist, J., Richard, P., Ross, P.S., Solomon, S., Walkusz, W., Weilgart, L., and Williams, B. 2010. Information in support of indicator selection for monitoring the Tarium Niryutait Marine Protected Area (TNMPA). DFO Can. Sci. Advis. Sec. Res., Doc. 2010/094: vi + 47.
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 Environ. **15**(509–510): 226–236. doi: 10.1016/j.scitotenv.2014.10.110.

Manseau, M., Parlee, B., and Ayles, G.B. 2005. A place for traditional ecological knowledge in resource management. *In* Breaking ice: renewable resource and ocean management in the Canadian north. *Edited by* F. Berkes, R. Huebert, H. Fast, M. Manseau, and A. Diduck. University of Calgary Press, Calgary, Alta., Canada. pp. 141164.

Martineau, D., Lemberger, K., Dallaire, A., Labelle, P., Lipscomb, T.P., and Michel, P. 2002. Cancer in wildlife, a case study: beluga from the St. Lawrence estuary, Quebec, Canada. Environ. Health Perspect. **110**(3): 285–292. doi: 10.1289/ehp.02110285. PMID: 11882480.

McGhee, R. 1988. Beluga hunters: an archaeological reconstruction of the history and culture of the Mackenzie Delta Kittegaryumiut. St. John's: Institute of Social and Economic Research, Memorial University of Newfoundland.

Mouton, M., and Botha, A. 2012. Cutaneous lesions in cetaceans: an indicator of ecosystem status? *In* New approaches to the study of marine mammals. *Edited by* A. Romero. InTech. pp. 123–150.

Mymrin, N.I., The Communities of Novoe Chaplino, Sireniki, Uelen, Yanrakinnot and Henry P. Huntington. 1999. Traditional knowledge of the ecology of beluga whales (*Delphinapterus leucas*) in the northern Bering Sea, Chukotka, Russia. Arctic, **52**(1): 62–70. doi: 10.14430/arctic910.

National Marine Fisheries Service. 2017. Status review: cook inlet beluga DPS. Marine Mammal Laboratory. Seattle, Wash., USA.

Nielsen, O, Stewart, R.E.A., Nielsen, K., Measures, L., and Duignan, P. 2001*a*. Serologic survey of *Brucella* spp. antibodies in some marine mammals of North America. J. Wildlife Dis. **37**(1): 89–100. doi: 10.7589/0090-3558-37.1.89.

Nielsen, O., Clavijo, A., and Boughen, J.A. 2001*b*. Serologic evidence of influenza A infection in marine mammals of arctic Canada. J. Wildlife Dis. **37**(4): 820–825. doi: 10.7589/0090-3558-37.4.820.

Nielsen, O., Burek-Huntington, K.A., Loseto, L.L., Morell, M., and Romero, C.H. 2018. Alphaherpesvirus: isolation, identification, partial characterisation, associated pathologic findings, and epidemiology in beluga whales (*Delphinapterus leucas*) in Alaska and Arctic Canada. Arct. Sci. **4**. This issue. doi: 10.1139/as-2017-0043.

Noël, M., Loseto, L.L., Helbing, C.C., Veldhoen, N., Dangerfield, N.J., and Ross, P.S. 2014. PCBs are associated with altered gene transcript profiles in arctic beluga whales (*Delphinapterus leucas*). Environ. Sci. Technol. **48**(5): 2942–2951. doi: 10.1021/es403217r.

Noël, M., Loseto, L.L., and Stern, G. 2018. Legacy contaminants in the eastern Beaufort Sea beluga whales (*Delphinapterus leucas*): are temporal trends reflecting regulations? Arct. Sci. **4**. This issue. doi: 10.1139/AS-2017-0049.

Northern Contaminants Program. 2017*a*. Environmental monitoring and research. [Online]. Available from http://www.science.gc.ca/eic/site/063.nsf/eng/h_D1A0F3B6.html [accessed 2 October 2017].

Northern Contaminants Program. 2017*b*. Environmental monitoring and research. [Online]. Available from http://www.science.gc.ca/eic/site/063.nsf/eng/h_034936B1.html [accessed 2 October 2017].

NWT Bureau of Statistics. 2016*a*. Paulatuk statistical profile. [Online]. Available from http://www.statsnwt.ca/community-data/Profile-PDF/Paulatuk.pdf [accessed 2 October 2017].

NWT Bureau of Statistics. 2016*b*. Tuktoyaktuk statistical profile. [Online]. Available from http://www.statsnwt.ca/community-data/Profile-PDF/Tuktoyaktuk.pdf [accessed 2 October 2017].

NWT Bureau of Statistics. 2016*c*. Inuvik statistical profile. [Online]. Available from http://www.statsnwt.ca/community-data/Profile-PDF/Inuvik.pdf [accessed 2 October 2017].

O'Neil, J., Elias, B., and Yassi, A. 1997. Poisoned food: cultural resistance to the contaminants discourse. Arct. Anthropol. **34**: 29–40.

Ostertag, S.K., and Chan, H.M. 2018. Biomarkers of the cholinergic and dopaminergic signaling pathways in Arctic beluga whales (*Delphinapterus leucas*): relationship to methylmercury and selenium. Arct. Sci. **4**. This issue. doi: 10.1139/as-2017-0033.

Ostertag, S. K., Shaw, A.C., Basu, N., and Chan, H.M. 2014. Molecular and neurochemical biomarkers in Arctic beluga whales (*Delphinapterus leucas*) were correlated to brain mercury and selenium concentrations. Environ. Sci. Technol. **48**: 11551–11559. doi: 10.1021/es501369b. PMID: 25171565.

Pearce, T., Wright, H., Notaina, R., Kudlak, A., Smit, B., Ford, J.D., and Furgal, C. 2011. Transmission of environmental knowledge and land skills among Inuit men in Ulukhaktok, Northwest Territories, Canada. Hum. Ecol. **39**(3): 271–288. doi: 10.1007/s10745-011-9403-1.

Pettis, H., Rolland, R., Hamilton, P., Knowlton, A., Kraus, S., and Brault, S. 2004. Visual health assessment of North Atlantic right whales (*Eubalaena glacialis*) using photographs. Can. J. Zool. **82**: 8–19. doi: 10.1139/z03-207.

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

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**: 223–236.

Sharp, S.M., Knoll, J.S., Moore, M.J., Moore, K.M., Harry, C.T., Hoppe, J.M., Niemeyer, M.E., Robinson, I., Rose, K.S., Sharp, W.B., and Rotstein, D. 2014. Hematological, biochemical, and morphological parameters as prognostic indicators for stranded common dolphins (*Delphinus delphis*) from Cape Cod, Massachusetts, U.S.A. Mar. Mammal Sci. **30**(3): 864–887. doi: 10.1111/mms.12093.

Smythe, T.A., Loseto, L.L., Bignert, A., Rosenberg, B., Budakowski, W., Halldorson, T., Pleskach, K., and Tomy, G.T. 2018. Temporal trends of brominated and fluorinated contaminants in Canadian Arctic beluga (*Delphinapterus leucas*). Arct. Sci. **4**. This issue. doi: 10.1139/AS-2017-0044.

Usher, P.J. 2000. Traditional ecological knowledge in environmental assessment and management. Arctic, **53**(2): 183–93.

Van Bressem, M.-F., Van Waerebeek, K., Flach, L., César Reyes, J., César de Oliveira Santos, M., Siciliano, S., Echegaray, M., Viddi, F., Felix, F., Crespo, E., Sanino, G.P., Avila, I.C., Fraijia, N., and Castro, C. 2008. Skin diseases in cetaceans. Conference: Workshop on Cetacean Skin Diseases, International Whaling Commission, 30–31 May 2008.

Vlasman, K.L., and Campbell, G.D. 2003. Field guide: diseases and parasites of marine mammals of the eastern Canadian Arctic. Canadian Cooperative Wildlife Health Centre, Saskatoon, Sask., Canada.

Waugh, D., Pearce, T., Ostertag, S.K., Pokiak, V., Collings, P., and Loseto, L.L. 2018. Inuvialuit traditional ecological knowledge of beluga whale (*Delphinapterus leucas*) under changing climatic conditions in Tuktoyaktuk, NT. Arct. Sci. **4**. This issue. doi: 10.1139/AS-2017-0034.

Werth, A.J., and Ford, T.J., Jr. 2012. Abdominal fat pads act as control surfaces in lieu of dorsal fins in the beluga (*Delphinapterus*). Mar. Mammal Sci. **28**: E516–E527. doi: 10.1111/j.1748-7692.2012.00567.x.

Wesche, S.D., and Chan, H.M. 2010. Adapting to the impacts of climate change on food security among Inuit in the Western Canadian Arctic. Ecohealth, **7**(3): 361–373. doi: 10.1007/s10393-010-0344-8. PMID: 20680394.

Worthy, G.A.J., and Edwards, E.F. 1990. Morphometric and biochemical factors affecting heat loss in a small temperate cetacean (*Phocoena phocoena*) and a small tropical cetacean (*Stenella attenuata*). Physiol. Zool. **63**: 432–442. doi: 10.1086/physzool.63.2.30158506.