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Diet and feeding observations from an unusual beluga harvest in 2014 near Ulukhaktok, Northwest Territories, Canada[1]

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Abstract: The Eastern Beaufort Sea (EBS) beluga (*Delphinapterus leucas*) population are an important traditional food for the Inuit of the Inuvialuit Settlement Region, Northwest Territories (NT) Canada. In 2014, over 30 beluga whales were harvested at Ulukhaktok, NT, the first occurrence of a large harvest in the area on record. Unlike observations from the established beluga harvest monitoring program in the Mackenzie Estuary, these belugas had numerous prey and prey items in their stomachs. Our study objectives were to combine traditional and local knowledge (TLK) from beluga hunters with the analysis of dissected stomachs to identify EBS beluga diet, feeding behaviour, as well as gain insights into potential drivers of the event. TLK holders witnessed foraging behaviors such as herding schools of fish. Stomach dissections revealed Sandlance (*Ammodytes* sp.) to be the predominant prey species, comprising 90% of identified otoliths, occurring in 92% of stomachs. The low presence of Arctic Cod (*Boreogadus saida*), a preferred prey types, raised questions about prey availability/accessibility and if alternative prey types can sustain beluga energetic needs. Based on interviews of TLK holders, avoidance of noise due to human activity, killer whale presence, and shifts in prey were factors that may have led to the increased beluga sightings near Ulukhaktok, NT.

Key words: beluga diet, stomach contents, traditional and local knowledge, Sandlance.

Résumé : Les bélugas (*Delphinapterus leucas*) de l'est de la mer de Beaufort (EMB) sont une source importante de nourriture traditionnelle pour les Inuits de la région désignée des Inuvialuit, aux Territoires du Nord-Ouest (T.N.-O.), Canada. En 2014, plus de 30 bélugas ont été capturés à Ulukhaktok, T.N.-O., le premier évènement de grande récolte dans la région enregistré. Contrairement aux observations provenant de la surveillance de récolte de bélugas établie dans l'estuaire du Mackenzie, ces bélugas avaient de nombreuses proies et d'éléments de proie dans leurs estomacs. Nos objectifs d'étude étaient de combiner les connaissances traditionnelles et locales (CTL) de chasseurs de bélugas avec l'analyse d'estomacs

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disséqués afin d'identifier le régime des bélugas de l'EMB, leur comportement alimentaire, ainsi que d'acquérir plus de connaissances sur les facteurs potentiels de cet événement. Les détenteurs des CTL ont été témoins de comportements de recherche de nourriture comme l'agrégation de bancs de poissons. Les dissections d'estomacs ont révélé le lançon (*Ammodytes* sp.) comme étant la principale espèce-proie, représentant 90% des otolithes identifiés et étant présent dans 92% des estomacs. La faible présence de morue arctique (*Boreogadus saida*), une proie préférée, a soulevé des questions à propos de leur disponibilité/accessibilité et à savoir si les autres options de proies peuvent supporter les besoins énergétiques des bélugas. Fondé sur des entrevues avec les détenteurs des CTL, l'évitement des sources sonores en raison de l'activité humaine, la présence d'épaulards et des changements de l'accessibilité des proies étaient des facteurs qui peuvent avoir mené à l'augmentation des observations de bélugas près d'Ulukhaktok T.N.-O. [Traduit par la Rédaction]

Mots-clés : régime alimentaire des bélugas, contenu d'estomac, connaissances traditionnelles et locales, lançon.

Introduction

Eastern Beaufort Sea (EBS) beluga whales (*Delphinapterus leucas*) are an important part of a traditional subsistence harvest by the Inupiat in Alaska and the Inuvialuit of the western Canadian Arctic (McGhee 1988; Huntington et al. 1999; Harwood et al. 2002). Beluga harvest monitoring programs have occurred at key harvest locations in the Mackenzie Estuary for 30+ years, and more recently in Darnley Bay (beginning in 1989) (Harwood et al. 2002; Harwood et al. 2015). Stomachs of whales harvested in the Mackenzie Estuary rarely contain contents (Harwood et al. 2002). As with all cetaceans, observing foraging behaviour and defining diet is challenged by access to observations, fecal and stomach samples. To compound this, the Mackenzie Estuary, where the EBS beluga aggregate and are harvested, is turbid, preventing visual observations of belugas below the water surface. As such, summer diet of EBS beluga has been examined and inferred with the use of biomarkers such as fatty acids and stable isotopes (Loseto et al. 2009) and hypothesized based on habitat use derived from telemetry (Loseto et al. 2008; Hauser et al. 2015).

For the first time on record, large numbers of beluga whales were observed near the communities of Sachs Harbour and Ulukhaktok, NT, Canada, throughout July and August 2014. Over 30 whales were harvested with 28 whales sampled from Ulukhakok ($n = 26$) and Sachs Harbour ($n = 2$). Prior to this event, only opportunistic subsistence harvests have occurred in the vicinity of these communities, with just seven whales landed from 2000 to 2012 (FJMC 2013). The EBS beluga visit offshore waters following their summer aggregation period in the Mackenzie Estuary (Richard et al. 2001). Beluga behaviour in Beaufort offshore waters, observed from aerial surveys, and inferred from telemetry tracks and habitat models, suggests that feeding is a key activity during this time, after whales have left the Mackenzie Estuary (Norton and Harwood 1985, Richard et al. 2001; Loseto et al. 2006; Hornby et al. 2017).

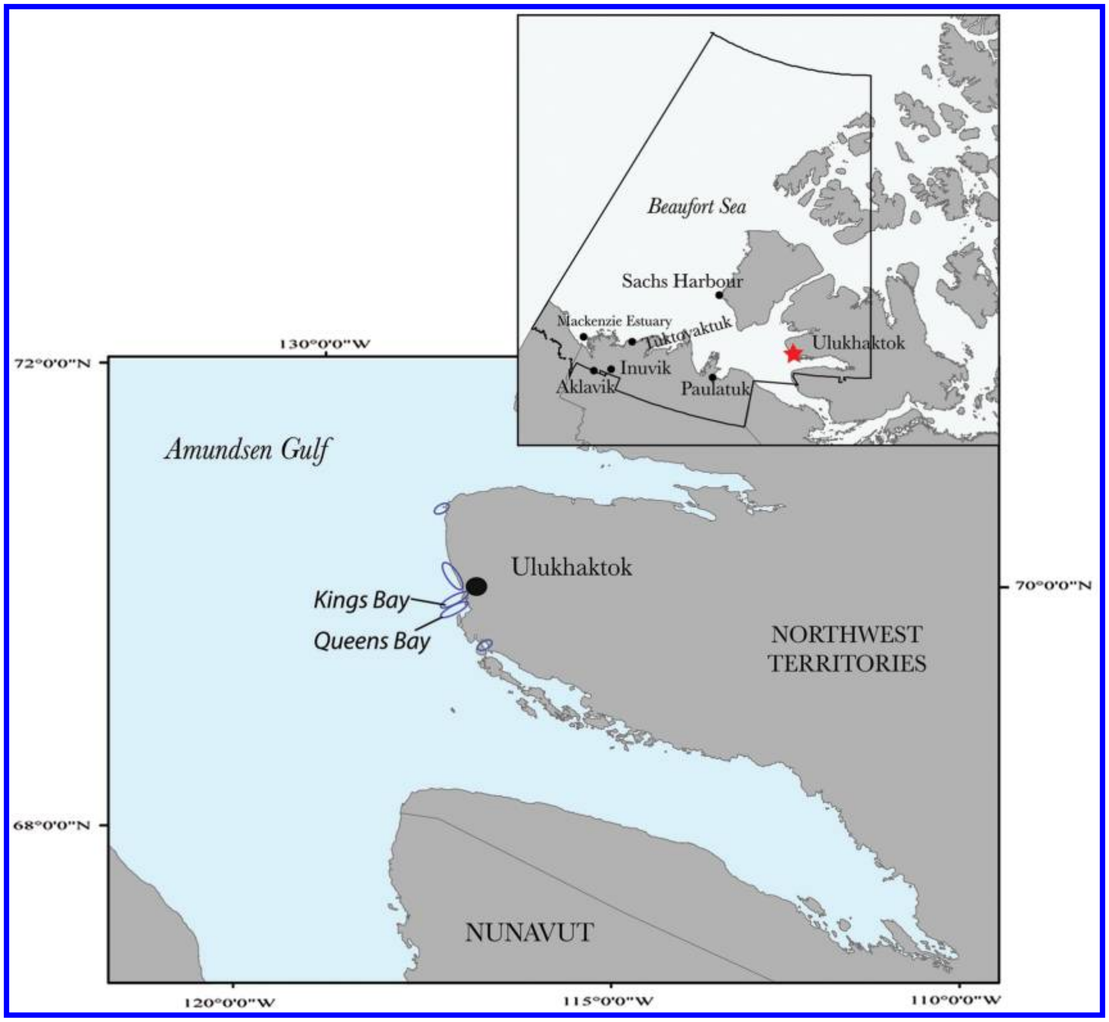
Whales harvested in the clear water areas near Ulukhaktok were observed to be feeding and stomachs from harvested whales were full of prey and prey items. The objective of our study was to take advantage of this rare opportunity and use a two-pronged approach to characterize beluga diet by recording traditional and local knowledge (TLK) about feeding behaviour and diet, and analyzing stomach contents from harvested whales. Together TLK and stomach content analyses are used to explore potential drivers for the rare event.

Methods

Study area

Beluga whales are traditionally harvested in the Mackenzie Estuary by community members from Aklavik, Inuvik, and Tuktoyaktuk, and in Darnley Bay by community members of

Fig. 1. Map of study area located in the Inuvialuit Settlement Region, NT, Canada. Communities of Aklavik, Inuvik, and Tuktoyaktuk harvest whales along the coast of the Mackenzie Estuary. Blue ellipses near the community of Ulukhaktok identify the areas where belugas were harvested in the summer of 2014.



Paulatuk, in the Inuvialuit Settlement Region (ISR), Canada (Fig. 1). However, in 2014, beluga whales were harvested outside of these common hunting areas near the communities of Ulukhaktok and Sachs Harbour. In efforts to better understand this unusual occurrence, morphometric data and tissue samples were collected at both locations, and TLK was collected at Ulukhaktok. Significant effort was made to record diet-related information, including both stomach content collections and observations of beluga feeding.

Sample collection and analysis

Samples were collected between 1 July and 15 August 2014, by harvesters, a representative from Fisheries and Oceans Canada (who also conducted TLK interviews), and a local volunteer. Measurements collected included length, girth, blubber thickness, sex, and colour (Harwood et al. 2002). Tissue collections included skin, blubber, muscle, jaws, and stomachs/stomach contents. Note there was variability in stomach collections; stomachs were either collected in whole or in part (at least one stomach compartment) and frozen, or only the contents were collected and frozen. Once belugas were measured and sampled, all tissues were frozen on site in a portable freezer at −20 °C and shipped to the Freshwater Institute (Winnipeg, MB, Canada) for analysis. Ages were determined from a thin section of a tooth by counting growth layer groups (GLG) in the dentine (Stewart et al. 2006). Sex was evaluated both on site as well as with genetic molecular analysis of blubber samples (Shaw et al. 2003). Frozen stomachs and stomach contents were thawed prior to dissection and prey identification. In total, 12 stomachs were examined for contents, including whole and partial stomachs. Stomach contents were processed using mesh sieves (500 μm to 1 mm) to remove otoliths and other vertebrate or invertebrate structures. Whole prey or prey structures (e.g., squid beaks and otoliths) were separated for identification to the lowest possible taxonomic level, and otoliths were used to identify fish taxa and age. Otoliths obtained from beluga stomachs were examined whole, submerged in water with the sulcus side facing downward. Annuli representing each year of growth were counted under reflected light (Winters 1981; Robards et al. 2002). Although an individual fish contains a pair of otoliths, each otolith found in the stomachs was treated as a distinct individual. The percent frequency of occurrence (%FO) was calculated by the number of stomachs containing a given prey type divided by the total number of stomachs.

Traditional and local knowledge interviews

Hunters' observations about beluga whales were recorded in Ulukhaktok, NT, between 7 August and 11 August 2014; therefore, observations about beluga whales harvested or observed between 12 August and 25 August were not recorded. Interviews began with background questions on the residence of the participants and their experience with harvesting and preparing belugas. Participants were asked to mark the location of beluga observations and harvest on a map and to complete a table about whale observations that included questions about feeding behaviour. Beluga sightings were possible at all times of day/night due to 24 h daylight between mid-May and the end of July; the length of day shortened in early August, with twilight (dawn and dusk) lasting approximately 5 h by mid-August (*Ulukhaktok, Northwest Territories, Canada—Sunrise, Sunset, and Daylength*). Interview participants were asked to describe the behaviour of the whales before they were being hunted; however, as the participants were actively hunting and travelling by boat at the time of the observations, the beluga behaviour may have been affected by the presence of the hunters. Interview responses were recorded in a notebook and were verified by participants for accuracy. Seven of the eight participants agreed to be named and the eighth was unable to provide consent due to health issues and remains anonymous.

The Olokhaktomiut Hunters and Trappers Committee (HTC) identified the interviewees (Supplementary Table S1[2]). All interview participants had resided in Ulukhaktok for a minimum of 25 years and maximum of 60 years; beluga harvesting experience varied for the participants but all interviewees had some beluga hunting experience (Supplementary Table S1[2] and Collings et al. 2018). One hunter participated in a cross-cultural knowledge exchange program on how to hunt and prepare whale and Arctic char (*Salvelinus alpinus*) and another hunter learned to hunt and prepare beluga from a harvester in Tuktoyaktuk. Hunters provided traditional knowledge (TK) and/or local knowledge, depending on their harvesting experience. We use the Inuvialuit definition of TLK as "the knowledge gained by Inuvialuit individuals through traditional learning patterns (stories/songs), and through living on and using the land" (Inuvik Community Corporation et al. 2006). Local knowledge

[2]Supplementary material is available with the article through the journal Web site at http://nrcresearchpress.com/doi/suppl/10.1139/as-2017-0046.

refers to informal knowledge that is personal and possibly expert (Raymond et al. 2010). Given that the interviewees had varying levels of beluga harvesting experience, we define the knowledge shared in interviews as traditional or local knowledge (TLK).

Results and Discussion

Beluga demographics

Twenty-six whales were opportunistically sampled and measured from 13 July to 25 August 2014 near Ulukhaktok, NT. Of these, nearly 30% were grey (including dark grey) and the remainder were white or white with yellow. Males typically represent 95% of landed whales from harvests near other ISR communities (Harwood et al. 2015), but the sex ratio from the 2014, Ulukhaktok harvest was 1:1. Estimated ages ranged from 5 to 56 years and averaged 27 years; where males were slightly younger (21.6 ± 16) than females (28.3 ± 16.1). Similarly, whales landed in the Mackenzie Estuary also have sex-related differences in age (Harwood et al. 2015). Beluga length ranged from 107 to 500 cm, and averaged 363 cm (±71 cm) with little difference among sexes. The total length range was comparable to whales landed in the Mackenzie Estuary and Darnley Bay; however, average length of males landed at Ulukhaktok was smaller (average 420 cm Mackenzie Estuary males, Harwood et al. 2015).

Blubber thickness in 2014 averaged 4.9 cm (±2.7) and was lower than whales harvested at other locations from 1999 to 2007 [>7.3 cm (Harwood et al. 2015)]. In a recent study, EBS beluga harvested from 2011 to 2014 had the lowest body condition index (based on blubber thickness) in 2014, and was thought to be due to lower abundance of Arctic cod (*Boreogadus saida*) (Choy et al. 2017). The thinner blubber measurements support the hypothesis that whales harvested near Ulukhaktok were expending more energy searching for alternative food sources in the absence of their preferred prey, Arctic cod.

Differences in length and sex of belugas harvested in Ulukhaktok relative to the Mackenzie Estuary may reflect sexual segregation of habitat use within their summer range (Loseto et al. 2006) and/or may reflect current harvest practices (Collings et al. 2018; Waugh et al. 2018). For example, community hunting bylaws provide guidance to avoid hunting females due to calving activity in the Mackenzie Estuary, and no such bylaws exist for Ulukhaktok (FJMC 2013).

Beluga diet

Characterizing the diet of EBS beluga defines the connectivity with the supporting ecosystem components (i.e., lower trophic levels, prey) and has been the focus of many studies (e.g., Loseto et al. 2009; Hauser et al. 2015; Hornby et al. 2017). Harwood et al. (2015) examined 634 beluga stomachs and found 94.5% and 86.5% from the Mackenzie Estuary and Darnley Bay, respectively, were empty. It is important to note that the beluga habitat use of the Mackenzie Estuary is not entirely understood, hypotheses include moulting, refuge, calving, feeding among others (Finley 1982; St. Aubin et al. 1990). Once they leave the estuary, they can travel extensive areas including areas as far north as Viscount Melville Sound where deep dives have been measured and hypothesized to be feeding episodes (Richard et al. 2001). The irregular or nonexistent harvests in these regions have limited the ability to investigate stomach contents outside of the estuary. During their spring migration from the Bering Sea, Alaskan harvests from 1983 to 2003 enabled the collection of stomach contents from 62 EBS whales. The predominant fish species identified was Arctic cod (82%) and other fishes included sculpins (Cottidae spp.), Saffron Cod (*Eleginus gracilis*), Walleye Pollock (*Theragra chalcogramma*), and Pacific Sandlance (*Ammodytes hexapterus*). Most stomachs (92%) also contained invertebrates, primarily shrimp and cephalopods (Quakenbush et al. 2015).

Fig. 2. Photograph taken by a Ulukhaktomuit harvester (G. Okheena) of a beluga whale with prey in its mouth. Prey is identified as Sandlance (*Ammodytes* sp.).

In this study, both mature (>10 GLG) (Robeck et al. 2005) and subadult neonate whales had full or partially full stomachs. Some harvester sampling data sheets were returned with incomplete or insufficient comments regarding beluga stomach contents. For example, if no comments were made under the "stomach contents" section, we interpreted this as the stomach either had not been checked or was not sampled. In one particular case, a female whale (ULU 14 19) was observed to have an empty stomach but a full mouth of food (Fig. 2). Of the whales sampled, seven stomachs contained partially digested fish and hard parts, the remainder contained only hard parts [(i.e., invertebrate structures, otoliths (Table 1)]. Sandlance otoliths had a 92% FO whereby >82.7% of all otoliths aged were between ages 1+ and 3+, while the maximum observed age was 6+. Nonbiota such as sand and pebbles were the second most FO at 75%. These observations support beluga feeding on Sandlance, and species known to burrow in substrate (Pearson et al. 1984). Sandlance larvae became the second most abundant fish larvae in the Beaufort Sea in 2011 following its first observation in 2010 (Falardeau et al. 2014). Among Arctic cod otoliths (n = 18), 63% were between ages 0+ and 2+, with a maximum age of 4+. Two eelpouts (*Lycodes* sp.) were examined to be ages 2+ and 5+, and one flounder (*Pleuronectidae* sp.) was identified as age 7+ (Table 1).

Observed Beluga Feeding behaviour

The clear water surrounding Ulukhaktok enabled direct visual observations of beluga behaviour below the water surface. Interviewees indicated that at least 14 of 20 groups of belugas observed between 1 July and 9 August 2014, were feeding in the vicinity of Ulukhaktok (Table 2). The number of whales in the feeding groups ranged from 1 to 15 individuals;

Table 1. Stomach content analyses with percent frequency of occurrence (% FO).

							Number of Otoliths per species					
Whale ID	Partially digested fish	Spines	Squid beak pieces	Invert. parts	Parasitic worms	Other	Sandlance (*Ammodytes* sp.)	Eelpout (Zoarcidae)	Sculplins (Cottidae)	Arctic cod (*B. saida*)	Flounder (*Pleuronectidae*)	Fourline Snakeblenny (*E. praecisus*)
ULU-14-04			20			Piece of garbage bag	147		4			3
ULU-14-06						sand	4					
ULU-14-07	65 Sandlance		>20	Present			218					
ULU-14-11		42				Sand	744		2			
ULU-14-14	45 Sandlance		5			Sand and pebbles	666					
ULU-14-16	1 large char											
ULU-14-18	20 Sandlance					Sand	59			11		
ULU-14-20		15	2	Present		Sand and pebbles	64					
ULU-14-21	187 Sandlance		10		2	Sand	647	1		4		
ULU-14-27			1				464					
ULU-14-30	15 Sandlance	Present	24		1	Sand	97					
ULU-14-UKN	42 Sandlance	31		Present	11	Vegetation	506	1			1	
% FO		25.0	50.0	25.0	25.0	75.0	91.7	16.7	16.7	16.7	8.3	8.3

Note: % FO is the number of stomachs that contained a prey species divided by the total number of stomachs that contained prey (×100).

Table 2. Summary of TLK observations of beluga feeding behaviours near Ulukhaktok during the summer harvest of 2014.

Feeding characteristic observed	Yes	No	Did not mention this
Beluga groups observed feeding	10–12	2	2
Beluga groups assumed to be feeding	4	5	0
Feeding behavior described	4	3	0
Feeding occurred in the . . .			
Day	1	2	3
Morning	2	1	3
Afternoon	3	1	3
Evening	2	2	3
Night	0	3	3
Belugas were observed to . . .			
trap fish by making a circle of bubbles and herding the school of fish to the belugas	2	0	5
spread out and feed, as well as communicate to one another	1	0	6
have fish in the mouth	1	0	6
be eating	2	0	5
Stomach contents contained . . .			
Char	4	0	4
Crawling fish (Aulayuk), Sandlance	1	2	4
Sand	1	2	4

Note: Interviewees are listed in Table S1.[2]

feeding groups were composed of adult whales (n = 10, white or white and light grey whales) or included newborn and (or) subadult (n = 4, blue/black whales; Suydam 2009). Feeding behaviour was described for four groups, and included the description by two interviewees of whales trapping fish by creating a circle of bubbles and herding schools of fish toward the middle of a group of feeding whales (A. Kudlak, G. Kudlak). Further details were not available about this observation, but to our knowledge, this is the first observation recorded for this type of foraging behaviour in beluga whales. Bubbles are used as a foraging strategy by humpback whales (*Megaptera novaeangliae*), which expel air to form a vertical cylinder-ring of bubbles around prey (Wiley et al. 2011); and, the carousel method used by killer whales (*Orcinus orca*) includes large bubbles being emitted close to the water's surface to assist with the capture of herring (Similä and Ugarte 1993). Beluga were also described as spreading out and feeding, communicating with one another, eating, and observed with fish in the mouth after the harvest (Fig. 2). Interviewees observed Arctic char and sand in the stomachs of the whales; however, interviewees did not share observations about beluga feeding from the ocean floor. The presence of sand in the stomachs of beluga is consistent with a diet that included Sandlance, as this species of forage fish is known to burrow in the seafloor (Bizzarro et al. 2016). One participant observed beluga whales eating small fish and Arctic Char at the mouth of the Kaylihok River (P. Ekpakohak).

Feeding was observed throughout the day, but more frequently in the afternoon and (or) evening, and not at night. It is relevant to include the time of day because it is complimentary to the observation being described; and, time of day influenced diving rates in some locations in the eastern Arctic (Heide-Jørgensen et al. 2001). The timing of observations is considered unbiased because interviewees hunted and observed beluga opportunistically.

Exploring drivers of the event

Prior to 2014, there were only sporadic harvests of beluga near the two outlying coastal communities of Sachs Harbour and Ulukhaktok (Strong 1989) with little details and supporting data about the events because they were outside the scope of the regular harvest monitoring program. The most recent harvests of belugas in Sachs Harbour (2008, 2010) occurred in the fall, and stomach contents predominantly included Greenland cod (*Gadus ogac*) (Loseto unpublished). During the fall, EBS beluga migrate westward towards their wintering habitat (Richard et al. 2001). The 2014 event occurred in the summer and may represent a change in the movement and relative distribution of EBS beluga. To be able to confirm a change in the population distribution there would be need for several years of systematic surveying. In the absence of such data, we consider this event to be an observation point of discussion about distribution shifts.

Two hypotheses were proposed by the interview participants for the change in distribution observed in 2014; they may have moved toward Ulukhaktok to avoid noise to the west of the community or possibly to avoid killer whales (*Orcinus orca*). Belugas are sensitive to anthropogenic noise (Finley et al. 1990; Lesage et al. 1999) and are known to move inshore in the presence of killer whales (Ferguson et al. 2000). A pack of killer whales close to Melville Island and killer whale sightings near Ulukhaktok and Sachs Harbour had been previously observed in 2013 (dorsal fins and seals hauling up on shore) (naturenorth.com/OCA/OCAsightings.html).

Given the lack of known disturbances at the time of the event, beluga may have shifted their seasonal distribution in the Beaufort Sea in relation to low availability of their preferred prey, Arctic cod. This is supported by the stomach content analyses and direct observation of beluga feeding by Ulukhaktomiut (Table 2). EBS belugas are thought to preferentially feed on Arctic cod (Loseto et al. 2009; Quakenbush et al. 2015), and satellite telemetry has revealed tagged whales making repeated dives to depths of ~200–400 m near the Beaufort Sea shelf break (Richard et al. 2001; Hauser et al. 2015), areas found to support dense aggregations of adult Arctic Cod (Geoffroy et al. 2016; Majewski et al. 2017). Further, analysis of beluga locations collected during aerial surveys in August of 2007–2009, suggest that habitat selection in the offshore Beaufort Sea is likely driven by feeding opportunities as beluga showed preference for environmental conditions associated with forage fish aggregations (Hornby et al. 2017). Recent analyses of Mackenzie Estuary harvested beluga whales showed isotopic niche breadth and carbon stable isotope ratios that support opportunistic feeding in 2014 relative to previous years (Choy et al. 2017). Net-validated hydroacoustic surveys identified low biomass of age 1+ Arctic cod throughout the southern Beaufort Sea and Amundsen Gulf during the 2014 open water season (Geoffroy et al. 2016) which might have led belugas to rely in other prey such as Sandlances in 2014.

Conclusions

We present information from TLK and stomach content analyses from an unusual beluga harvest near Ulukhaktok, NT in July and August of 2014 that provided a rare opportunity to collect information on demographics, behaviour, and direct diet information. Stomach contents and observations provided a short-term snapshot of beluga diet and foraging behaviour on Sandlance. Whether this was a unique event or one to become more commonly observed in the future remains to be seen and the significance of the event to the EBS population remains unclear.

Findings suggest that belugas are adaptable and can adjust their distribution, and foraging behaviour in response to ecosystem change as observed in other studies (O'Corry-Crowe et al. 2016). Consequences of a dietary shift from Arctic cod to Sandlance are not known. The two forage fishes may have comparable total energetic content (e.g., 4.70 ± 0.19 and 5.06 ± 0.11 $KJ \cdot g^{-1}$ ww for Arctic cod and Sandlance collected in Hudson Bay, respectively (Elliott and Gaston 2008), but may differ with respect to lipid quality (e.g., essential fatty acids). Further, belugas may expend more energy seeking alternative prey and foraging on Sandlance, a species known to burrow and undergo diurnal migrations (e.g., Pearson et al. 1984).

While this unusual event has not recurred in the three years since 2014, it may represent a future scenario. Research that integrates beluga distribution and diet together with environmental drivers over a longer period of time will provide a better understanding of responses to ecosystem change. Continuing the long-term partnership between scientists, co-management partners, and Inuvialuit hunters will enable integration of knowledge that is relevant to beluga ecology and management.

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