Examining the Health and Energetic Impacts of Climate-Induced Prey Shifts on Beluga Whales Using Community-Based Research

by Emily S. Choy

INTRODUCTION

THE LOSS OF SEA ICE DUE TO CLIMATE CHANGE is altering the structure of Arctic marine ecosystems. Sea ice plays a critical role in the life histories of many Arctic marine mammals that use ice as foraging habitat, a platform for raising young, and protection from predators (Moore and Huntington, 2008). Declines in sea ice are predicted to bring challenges to ice-associated and ice-obligate marine mammals, such as alterations in prey abundance and migration routes, as well as increases in human activities. As long-lived species with low reproductive rates, Arctic marine mammals may not be able to adapt to the rapid pace of environmental change. Whether climate change will have negative impacts on sea-ice associated marine mammals is uncertain because there is insufficient baseline information on their diet, population dynamics, and physical condition (Burek et al., 2008).

Beluga whales (*Delphinapterus leucas*) are the most abundant Arctic odontocetes with a circumpolar distribution and are a potential indicator species for the effects of climate change. The eastern Beaufort Sea (EBS) beluga population is one of Canada's largest, with an estimated 39 258 individuals (Harwood and Smith, 2002; Laidre, 2007). During the spring, the EBS population migrates from the Bering Strait to summer and reproduce in the Mackenzie Delta estuary and eastern Beaufort Sea. The beluga whale is a sea-ice-associated marine mammal, and the EBS population selects habitat on the basis of sea ice concentrations: nursing females with young calves select coastal habitat, large males inhabit ice-covered areas, and medium-sized males and females with older calves use mixed ice-covered habitat (Loseto et al., 2006). Since EBS belugas use marine, estuarine, coastal, and deep-water habitats, they are considered a sentinel species for changes in the Mackenzie Delta and the overall health of the Beaufort Sea ecosystem.

Some of the predicted effects of climate change are shifts in the distribution, abundance, and composition of prey communities (Litzow et al., 2006). The "junk food hypothesis" attributes declines in productivity of marine mammals to a switch from high- to low-quality prey (gross energy density) and has been linked to nutritional stress and the decline of Arctic marine mammal populations, such as the Alaskan stellar sea lions (*Eumetopias jubatus*) (Rosen and Trites, 2000). Arctic cod (*Boreogadus saida*) has been identified as a major prey species for the EBS beluga population (Loseto et al., 2009) and is an important lipid-rich prey to several marine mammal and seabird species (Welch et al., 1993; Harter et al., 2013). Since it is a sea-ice-associated fish, Arctic cod is predicted to reduce its range and decline in abundance with the loss of sea ice (Hop and Gjøsæter, 2013). The summer diet of beluga whales is important for building blubber stores. Beluga whales from Cook Inlet arrive at their summer foraging habitat with blubber depths of 5–8 cm; however, by the fall, blubber depths are observed to be almost 30 cm (Huntington, 2000). Reductions in blubber thickness due to declines in prey abundance and quality can compromise immune response, thermoregulation, and reproductive success of beluga whales, leading to adverse effects at the population level (Burek et al., 2008). Along with climate-induced prey shifts, northward expansion of marine mammal ranges may also increase competition with beluga whales for prey resources (Laidre et al., 2008).

The primary objective of my research is to study the potential energetic consequences of prey shifts for the Beaufort Sea beluga population. Declines in sea ice may affect the ice-covered foraging habitat of large males; however, young calves and nursing females will likely be most vulnerable to declines in prey quality. Given that belugas are generalist predators, they may succeed in shifting their diet to new prey species (Bluhm and Gradinger, 2008; Laidre et al., 2008). My five sub-objectives are to (1) establish the current nutritional and physical condition of belugas; (2) examine the importance of pelagic and offshore prey to diet; (3) study specialized diving physiology and behaviour; (4) quantify diving energetics; and (5) create a bioenergetic model to calculate consumption rates of belugas and the overall energetic requirements of the population. Blubber, the main energy storage tissue of marine mammals, will be used both as an indicator of nutritional stress and to examine dietary changes. Since harvested whales typically have empty stomachs (Harwood and Smith, 2002), ecological tracers such as carbon and nitrogen stable isotope signatures from muscle and liver tissues and fatty acid signatures in blubber tissues will be used to establish trophic linkages and examine diet. Most fatty acids are assimilated through diet, and are long chains consisting of 12 to 24 carbon atoms, with a methyl molecule at one end and a carboxyl acid at the other (Budge et al., 2006). Fatty acid signatures of prey species and blubber will be compared in order to identify dietary linkages, under the hypothesis that the fatty acid composition of important prey species will be strongly correlated with fatty acid signatures in the inner blubber layers. Hematology will be analyzed for baseline health data and will also serve my goal of examining diving physiology by measuring oxygen storage capacity. Maximum dive duration across several Odontocete species has been found to be significantly correlated with body oxygen stores and myoglobin content in the *longissimus dorsi* muscle (Noren and Williams, 2000).

FIG. 1. Study location: Mackenzie Delta Region, Northwest Territories.

FIG. 2. Emily Choy with beluga monitor John Day measuring the length of a harvested beluga whale.

METHODS

Beaufort Sea beluga whales are an important subsistence food type for northern communities located in the Inuvialuit Settlement Region of the Northwest Territories. The Inuvialuit beluga hunt has taken place for over 500 years, and the continued availability of large-sized and old-aged belugas has demonstrated the sustainability of these hunts with little impact on the demographics of the population (Harwood and Smith, 2002). Collaboration with traditional Inuvialuit subsistence hunting camps is a unique and invaluable opportunity to obtain biological tissues from an otherwise inaccessible species, as well as to compare and contrast scientific data with traditional knowledge. Building on community harvest programs, the community of Tuktoyaktuk and Fisheries and Oceans Canada developed research partnerships in the year 2000 to study contaminants, disease, and health on whales harvested at Hendrickson Island. This program has expanded across other scientific disciplines and to other hunting camps, such as Brown's Harbour, East White Fish, and Kendall Island, across the Inuvialuit Settlement Region. For three summers (in July of 2012 – 14), I worked at traditional beluga hunting camps on Kendall Island in the Beaufort Sea-Mackenzie Delta Region of the Northwest Territories (Fig. 1). As part of a community-based monitoring team, I worked closely with beluga monitors, youth as research assistants, hunters, and community members to monitor the health and physical condition of beluga whales and to collect samples for scientific research. We took morphometric measurements, such as body size, fluke, flipper, and half-girth widths of the hunted belugas (Fig. 2). To examine variability of blubber thickness in belugas, I measured blubber depths along five half-girth widths and from 15 other body locations selected on the basis of previously published blubber thickness measurements from belugas in Hudson Bay and the body locations where emaciated harbour porpoises (*Phocoena phocoena*) lost the most blubber (Doidge, 1990; Koopman et al., 2002). To control for the influence of body size, blubber thickness measurements were normalized to body length for statistical comparisons.

For three years in July (2011 – 13) at Hendrickson Island, East Whitefish, Brown's Harbour, and Kendall Island, blubber samples were collected from the thorax of harvested belugas and frozen at −20˚C for fatty acid analysis. At the laboratory of the Freshwater Institute in Winnipeg, Manitoba, blubber was divided equally into three sections: the inner, middle, and outer layers. Blubber layer thickness was measured to the nearest millimetre, and each section was analyzed for fatty acid signatures. Fish and invertebrate prey species were provided by the Beaufort Regional Environmental Assessment (BREA) program, the first comprehensive baseline study of marine fish diversity in the Canadian Beaufort Sea. These potential prey species were also analyzed for fatty acid and stable isotope signatures. I measured spleen mass and collected blood and muscle tissues from harvested belugas and froze them at −80˚C (Fig. 3). These measurements and samples served as indicators of both oxygen storage capacity and diving ability.

PRELIMINARY RESULTS

Blubber thickness measurements from 25 whales were collected from Kendall Island. The thickest blubber measurements were located at the dorsal ridge of the belugas (mean = 9.02 cm), and was consistent for males (mean = 9.55 cm) and females (mean = 8.09 cm). For females, blubber was most variable at the dorsal position of the anus [coefficient of variation (CV) = 47.7%], whereas for males, blubber was most variable at the ventral position of the neck (CV = 33.7%). The widest half-girth was measured at the midthoracic position (mean = 109.9 cm) and was thickest for both males (mean = 114.7 cm) and females (mean = 101.2 cm). Hunter observations corroborated the identification of the dorsal ridge position as having the thickest

FIG. 3. Emily taking whole blood samples from a beluga for hemoglobin analysis.

blubber (Fisheries Joint Management Committee, pers. comm. 2014). There was no significant difference in blubber thickness measurements between male and female belugas; however, sampling bias may be a confounding factor, since measurements were collected from only seven females in total. Large male belugas are preferentially harvested by Inuit hunters.

Blubber samples from approximately 140 beluga whales were collected and analyzed for the proportional compositions of fatty acid signatures. Fatty acid signatures demonstrated stratification within blubber layers, with carbon chain length increasing with blubber depth. Higher proportions of polyunsaturated fatty acids and omega-3 fatty acids were found in the inner layer, whereas a higher proportion of monounsaturated fatty acids was found in the outer blubber layer. The fatty acid composition of blubber will be compared to the signatures of 16 demersal fish species ($n = 292$) in order to identify potential prey. Physiological differences in oxygen storage capacity were found between male and female belugas, which may reflect differences in diving ability.

SIGNIFICANCE

Although two years of body condition data is just a snapshot of the health and nutritional status of belugas, long-term monitoring may help to detect changes in blubber thickness in relation to prey and environmental changes. Since the eastern Beaufort Sea belugas are currently a healthy population, these measurements may be used to establish a baseline for long-term changes in beluga health and to measure the potential effects of prey changes on nutritional stress of the belugas. Changes in the fatty acid signatures of beluga blubber may also allow us to detect changes over time in the diet of belugas. Marine mammals such as beluga whales also have an important role as a traditional harvest in the subsistence lifestyle of northern communities. Muktuk, or blubber, a traditional food of the Inuvialuit people, is high in vitamins A, C, D, and E, as well as omega-3 and omega-6 fatty acids (Kuhnlein et al., 2006; Reynolds et al., 2006). Therefore, changes to the health and abundance of Arctic marine mammals may also have significant cultural and health impacts on Inuit communities.

There has been little research on the use of physiological attributes of marine mammals to predict their vulnerability to climate change. An understanding of potential physiological limits of beluga whales and the relationship between diving physiology and foraging behaviour may be important in developing conservation strategies for the population. There is also a major gap in our understanding of the energetic requirements of wild cetaceans. Using the data I have acquired on beluga physiology, physical condition, and diet, I plan to build bioenergetic models for different age, sex, and reproductive classes of belugas to predict consumption rates and the consequences of prey shifts (e.g., from high-energy to low-energy prey) on energetics. Because beluga whales have a circumpolar distribution with 29 provisional management stocks (Jefferson et al., 2012), results from my research may be incorporated into beluga health and conservation management programs throughout the Arctic. Findings from this research may also be used to predict the effects of climate-induced ecosystem changes on other Arctic odontocetes, such as narwhals (*Monodon monoceros*) and sea-ice associated marine mammals.

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