SPRING DISTRIBUTION AND HABITAT USE OF BELUGAS (*DELPHINAPTERUS LEUCAS*) IN THE EASTERN BEAUFORT SEA

by

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A thesis submitted to the
Faculty of Graduate Studies
in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

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ABSTRACT

An understanding of the adaptability of belugas (*Delphinapterus leucas*) to changing ice-conditions is required to interpret and predict possible changes in habitat selection in response to projected loss of sea ice throughout the circumpolar Arctic. Beluga spring distribution in the eastern Beaufort Sea was described by analyzing observations from aerial surveys conducted from 1975 to 1979. Repeated surveys along the Franklin Bay fast-ice edge in June 2008 were used to study the distribution and behaviour of belugas and bowheads. Despite inter-annual variability in ice extent, belugas consistently selected areas with water depths of 200-500 m, heavy ice concentrations (8/10 to 10/10) and seafloor slope ≥0.5 degrees in spring 1975 to 1979. While predator avoidance may partially explain the observed distribution, foraging success likely has more influence on beluga habitat selection in the spring. In ice-covered offshore regions, belugas may be engaged in under-ice and deep water foraging on Arctic cod (*Boreogadus saida*). In lighter ice years, belugas may expand their distribution and shift shoreward to take advantage of high prey densities along fast-ice edges. Both belugas and bowheads appeared to be feeding along the Franklin Bay ice edge in June 2008. More research is required to examine and compare possible changes in distribution since the late 1970s and to investigate the factors driving the patterns described.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank my thesis committee, Dr. David Barber, Mr. Pierre Richard, Dr. Steven Ferguson and Dr. Gail Davoren. Your combined wealth of experience and knowledge has been invaluable to me as I completed my thesis project. My gratitude also goes to Dr. Stirling for the generous use of the beluga data from the Canadian Wildlife Service and his sage advice on their interpretation and analysis. It has been an honour to work with all of you on this thesis project.

To all of the researchers, students and support staff at the Center for Earth Observation Science (CEOS), thank you for your assistance, helpful advice and chats over coffee.

J'aimerais aussi remercier mes parents, Armand et Denyse Asselin. J'apprécie la confiance que vous avez toujours eue en moi et en mon succès académique. Grâce à vous, je n'ai jamais douté que j'avais les habilités nécessaires pour accomplir n'importe quoi.

And to my partner, Garth Hardy, whose constant support I appreciate more than he knows.

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THESIS FORMAT AND MANUSCRIPT CLAIMS

This thesis is presented in a manuscript format. Chapters 2 and 3 are written in manuscript style containing an Abstract, Introduction, Methods, Results, Discussion, Acknowledgements and References. Chapter 1 introduces the overall theme and reviews the pertinent literature. Chapter 4 summarizes the significant findings of the thesis and provides directions for further research.

Chapter 2: Asselin NC, Barber DG, Stirling I, Ferguson SH, Richard PR (2010) Beluga (*Delphinapterus leucas*) habitat selection in the eastern Beaufort Sea in spring, 1975 to 1979. This manuscript was accepted (pending revisions) by Polar Biology in October 2010. Natalie Asselin requested the data (collected by IS), conducted the analyses, and wrote the manuscript, all with the participation and guidance of the co-authors.

Chapter 3: Asselin NC, Barber DG, Richard PR, Ferguson SH. Occurrence, distribution and behaviour of beluga (*Delphinapterus leucas*) and bowhead whales (*Balaena mysticetus*) at the Franklin Bay ice edge in June 2008. This manuscript is in revision for submission to a peer-reviewed journal (to be determined). Natalie Asselin collected the data, conducted the analyses and wrote the manuscript, all with the participation and guidance of the co-authors.

CHAPTER 1: GENERAL INTRODUCTION

1.1 INTRODUCTION

Arctic ecology and oceanography were the topics of numerous studies in the 1970s and early 1980s (e.g. Bradstreet and Finley 1977; Sekerak and Richardson 1978; Fraker and Fraker 1982; Davis and Evans 1982). This coincided with a push for oil development in the Beaufort Sea and a need for further research to assess the environmental impacts of such developments. Ice breaker traffic was also a concern at the time (Stirling 1980). Currently, the Canadian Arctic is once again the subject of intensified research due to a renewed interest in oil development and changes in ice concentrations and extent resulting from climate change. The circumpolar flaw lead in the Beaufort Sea, as a recurring polynya, has been shown to be of importance to belugas as a feeding area and during their migration (Stirling et al. 1981). This research seeks to describe the distribution and habitat use of belugas in the eastern Beaufort Sea (EBS) in spring so as to further the understanding of the ecological significance of the flaw lead to belugas. This beluga project is a component of the Circumpolar Flaw Lead (CFL) System Study which is an International Polar Year (IPY) project (Barber et al. 2010).

The Arctic environment is characterized by large seasonal fluctuations in temperature, light and sea ice extent. While a better understanding of Arctic habitats has always been important, this importance is underlined by the prediction that climate change will have greater impacts in polar regions (IPCC 2007). These impacts are already being seen. Specifically, from 1981 to 2001, the Beaufort Sea experienced a warming in surface temperature (Comiso 2003); from 1979 to 2006, the Arctic Ocean saw a decline of 9900± 1300km^2/yr in sea ice extent and a decrease in ice concentrations (Parkinson and Cavalieri 2008). These changes in ice cover may be problematic as marine mammals have evolved to take advantage of the unique Arctic habitats created by sea ice cover. Some animals, such as polar bears, rely on sea ice and are never found far from it, while others, such as belugas, have evolved to exploit this habitat through morphological, physiological or behavioural adaptations (Ainley et al. 2003). Arctic adaptations in the beluga include a dorsal ridge and a lack of dorsal fin, which is likely advantageous when encountering heavy ice, as well as a thick blubber layer, for insulation from the cold (Harrington 2008).

1.2 SPRING MIGRATION

Belugas in Canada are found in the Beaufort Sea, Lancaster Sound, Baffin Bay, Cumberland Sound, Hudson Bay, James Bay, Ungava Bay and in the St-Lawrence estuary (Department of Fisheries and Oceans 2002). The beluga population of the eastern Beaufort Sea over-winters in the Bering Sea (Department of Fisheries and Oceans 2002) along with at least four populations that summer in Alaskan waters (O'Corry-Crowe et al. 1997). In the Bering Sea, belugas have been reported to winter in and along the front of the seasonal ice pack and possibly venture farther north in persistent natural openings (Fay 1974). While Heide-Jørgensen and Reeves (1996) deem the timing of the beluga migration in west Greenland to be linked to photoperiod, Huntington et al. (1999) and Mymrin et al. (1999) found that the timing and direction of spring beluga migration in the Bering Sea is dependent on ice conditions. These belugas begin migrating as early as March (Huntington et al.1999; Mymrin et al. 1999) so that by April and May, they are migrating eastward past Point Barrow and through the Alaskan Beaufort Sea (Harwood and Smith 2002). Belugas are thought to move to the southeast Beaufort Sea through leads far offshore (Fraker 1979), arriving off the west coast of Banks Island in late May and early June (Harwood and Smith 2002). The use of the shore lead system allows belugas to arrive in the EBS two months prior to ice break-up (Stirling et al. 1981). The earliest recorded sighting of beluga in the eastern Beaufort Sea is 23 May 1977 when twenty-eight whales were seen between Sachs Harbour and Cape Bathurst (Fraker 1979). Belugas then feed along the ice edge in Amundsen Gulf for four to six weeks before migrating into the Mackenzie estuary (Fraker 1979). Notably, belugas are also known to occupy the area around Cape Bathurst throughout the summer (Stirling et al. 1981) and to travel back and forth from the Mackenzie estuary to offshore regions throughout the summer season (Richard et al. 2001).

1.3 BEHAVIOUR AT ICE EDGES

The occurrence of belugas and other marine mammals at ice edges and in polynyas has been recorded throughout the North American Arctic (e.g. Johnson et al. 1976; Bradstreet and Finley 1977; Sekerak and Richardson 1978; Fraker 1979; Stirling 1980; Bradstreet 1982; Fraker and Fraker 1982; Norton and Harwood 1986; Crawford and Jorgenson 1990; Cosens and Dueck 1991; Stirling 1997; Richard et al. 1998; Stewart 2001; Harwood and Smith 2002). Cosens and Dueck (1991) found that during the spring migration, at the beginning of break-up, beluga group size was larger along the Lancaster Sound ice edge than in open water. After cracks had formed in the ice, the larger groups were found within the cracks and in pan ice while smaller groups congregated at the ice edge (Cosens and Dueck 1991). While the main beluga behaviour observed was directed movement, other behaviours, described as "circling", "diving", "back exposed", "hanging" and social "interactions", were also observed (Cosens and Dueck 1991). At the Pond Inlet ice edge in 1978 and 1979, Bradstreet (1982) also documented belugas engaged in directed movement as well as diving under the edge and back and forth movement. The function of the diving was unclear (Bradstreet 1982).

While numerous reports and articles have noted a relationship between belugas and ice edges, some research has found it to be insignificant. For example, Bradstreet and Finley (1977) found no major concentrations of belugas in association with ice edges during 1974, 1975 and 1976 in Barrow Strait and concluded that belugas do not appear to be particularly drawn to that habitat. Sekerak and Richardson (1978), as part of the same fast-ice edge study, also stated there was no clear evidence that belugas were attracted to ice edges in the spring but noted that Arctic cod, a major part of beluga diet, are associated with ice. In late summer, belugas have been seen diving under the ice in Allen Bay, Cornwallis Island (Sekerak and Richardson 1978).

1.4 ROLE OF SEA ICE

Two Traditional Ecological Knowledge (TEK) studies, one in Alaska (Huntington et al. 1999) and one in Chukotka, Russia (Mymrin et al. 1999) yield some information as to the activities of belugas at ice edges. In Norton Bay, belugas feed under the ice first on herring (*Clupea pallasi*) and later on tomcod (*Eleginus gracilis*), going far under the rotting ice in late spring (Huntington et al. 1999). In Chukotka, when belugas are feeding at the ice edge, they dive under the ice as a group, staying under for periods of five to ten minutes (Mymrin et al. 1999). Feeding behaviour also involves swimming and diving in different directions while often returning to breathe at the same place (Mymrin et al. 1999). In contrast, during the migration, dives last less than five minutes and animals swim in one direction and disappear quickly (Mymrin et al. 1999). Belugas are also known to follow the ice and use it as a refuge from predators (Mymrin et al. 1999) such as killer whales (*Orcinus orca)*.

One of the main differences between the Lancaster Sound ice edge and the ice-edge in Amundsen Gulf is that, in Lancaster Sound, the sea ice is a barrier to movement as belugas are awaiting break-up to continue their migration west (Smith and Martin 1994; Department of Fisheries and Ocean 2002). In contrast, in the EBS, while belugas aggregate in the Mackenzie estuary in summer (Harwood et al. 1996, Harwood and Smith 2002), some have been known to remain at the ice edge when movement into the estuary was possible (Fraker 1979). The circumpolar flaw lead ice edge in Amundsen Gulf is not a barrier belugas must cross to continue their migration to their summering areas (Department of Fisheries and Oceans 2000). Similarly, the Cape Bathurst polynya is different than other recurring polynyas. Belugas from the North Water polynya, penetrate the first cracks and open water in Lancaster Sound, Jones Sound and other water bodies as soon as possible in the spring (Stirling et al. 1981). Once again, this differs from the behaviour at the ice edge in the EBS where belugas remain at the ice edge when movement south is possible (Fraker 1979).

The role of the sea ice in the life cycle of the beluga has been discussed inconclusively by numerous authors. While the migration of belugas is largely dictated by sea ice, with belugas leaving the Beaufort Sea at freeze-up and returning at break-up, the role of sea ice probably extends beyond a barrier to movement. Belugas possibly seek protection from killer whales by staying within the pack ice in the Bering Sea (Fay 1974; Mymrin et al. 1999) where this predator is known to penetrate into the edge of the pack up to about 10 km from open water (Lowry et al. 1987). Sea ice is also a substrate for algal growth (Fay 1974) which can increase productivity, particularly along edges (Dunbar 1981). The association of ice edges with increased biological productivity has long been noted (Stirling 1997). Recurring polynyas, which occur in the same place and time each year, are considered more biologically important as migrating or over-wintering animals learn to depend on their presence (Stirling 1997; Fig 1.1).

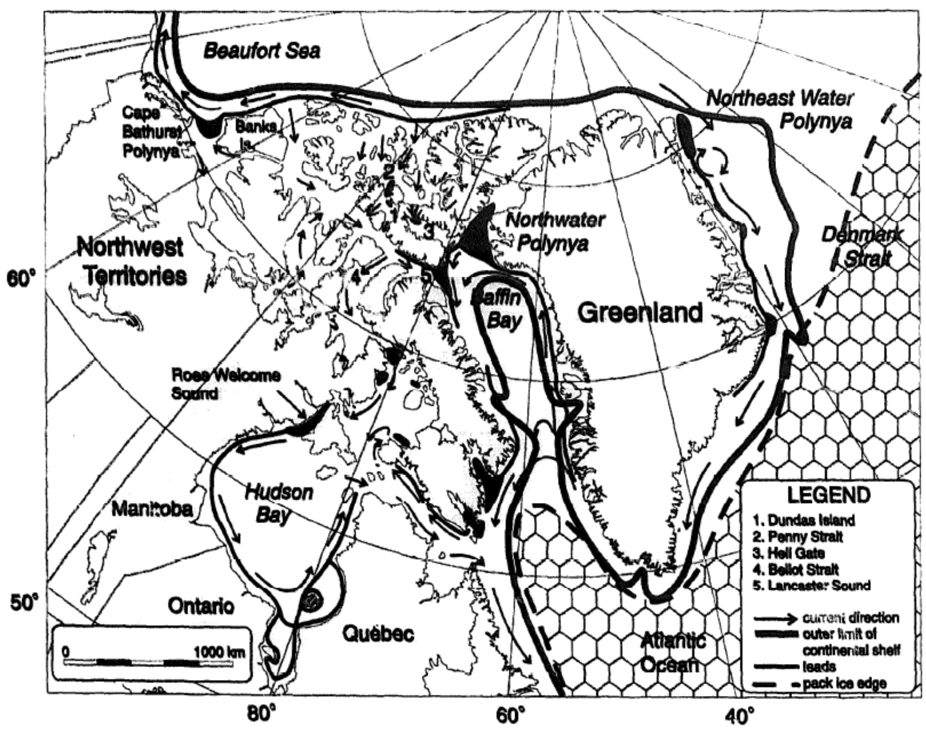

Fig. 1.1 Distribution of major recurring polynyas and shore lead systems in the Canadian and Greenland Arctic in spring. (Reprinted from: Stirling I (1997) The importance of polynyas, ice edges, and leads to marine mammals and birds. J Mar Syst 10: 9-21, used with permission from Elsevier.)

Stirling (1997) gave several possible explanations for the relative abundance of seabirds and marine mammals at ice edges or in polynyas. For cetaceans in particular, these are: calmer water which facilitates resting on the surface and diving for food; a barrier to migration, navigation aids to migrating species; access to air; access to open water for feeding seabirds; habitat in which to escape from predators; and, notably, the possibility of increased productivity near the ice-water interface (Stirling 1997). Stirling (1980) questioned whether it was only access to water that made polynyas so important to marine mammals or whether they were more biologically productive than other areas. There is some evidence that the areas of polynyas and ice edges are biologically important for reasons that go beyond the access to air and open water. For example, in Amundsen Gulf, belugas have been shown to use the area of the spring ice-edge throughout the open-water season (Stirling et al. 1981; Richard et al. 2001).

1.5 KNOWLEDGE GAPS

In the Canadian Beaufort Sea, numerous studies have been conducted regarding the use of the Mackenzie estuary by belugas (e.g. Fraker et al. 1979; Fraker and Fraker 1982; Norton and Harwood 1986). Beluga use of the Amundsen Gulf and the Beaufort Sea as a whole has been studied throughout the summer and fall seasons (e.g. Davis and Evans 1982; Harwood and Norton 1996; Harwood et al. 1996; Richard et al. 1997; Richard et al. 2001; Loseto et al. 2006; Loseto et al. 2008). Fraker (1979) studied the migration route of belugas and bowheads from the Bering Sea to the Beaufort Sea. However, this study was not systematic and did not target the use of the Amundsen Gulf flaw lead or the ice edge environment.

While satellite-linked transmitters have proven useful in studying the summer and fall distribution and movements of EBS belugas (Richard et al. 1997; Barber et al. 2001; Richard et al. 2001; Loseto et al. 2006), they have produced no data for spring. In the Beaufort Sea, satellite-linked transmitters used in 1993, 1995 and 1997 had median tag longevities of 31, 38 and 81 days respectively (Richard et al. 2001). In later deployments, one tag has lasted over the 2004-2005 winter (Pierre Richard, unpublished data). It was attached to a male beluga that travelled from the Bering Sea to an area north of Banks Island in the spring but the tag gave few locations during that period. The technical limitations of the satellite tags combined with the length and timing of the ice-free season in the Beaufort Sea have led to a gap in knowledge for the spring period (Richard et al. 1997).

Currently in the EBS, there is a lack of understanding of the distribution of belugas in the spring, their behaviour and their association with sea ice. Further research is needed to fill in baseline information from which to assess the impacts of future changes in habitat, whether related to industrial development, climate change or other human-induced disturbances.

1.6 RESEARCH OBJECTIVES

The main objective of this research is to understand the ecological significance of the flaw lead habitat to belugas in the EBS (Fig 1.2). Chapter 2 examines the distribution and habitat associations of belugas throughout the region in June using a historical dataset from 1975 to 1979. Chapter 3 focuses on the Franklin Bay ice edge, in June 2008. As both belugas and bowhead whales (*Balaena mysticetus*) were observed at the fast-ice edge, chapter 3 examines the distribution and behaviour of these two cetaceans. Chapter 4 summarizes the major findings and conclusions of this project, discusses its implications and examines future research directions.

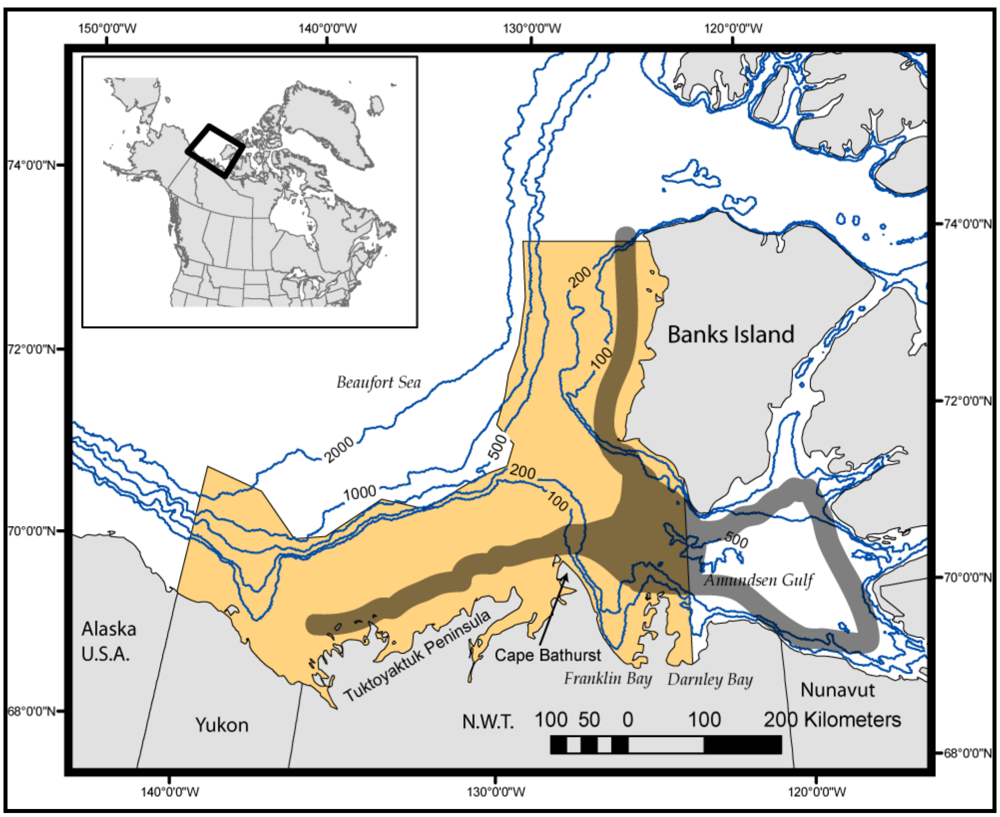

Fig 1.1 Study area (orange) with bathymetry (Jakobsson et al. 2008) and the area normally occupied by the flaw lead system (shaded, Galley et al. 2008)

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CHAPTER 2: BELUGA (*DELPHINAPTERUS LEUCAS*) HABITAT SELECTION IN THE EASTERN BEAUFORT SEA IN SPRING, 1975 TO 1979

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2.1 ABSTRACT

An understanding of the adaptability of belugas (*Delphinapterus leucas*) to changing ice-conditions is required to interpret and predict possible changes in habitat selection in response to projected loss of sea ice throughout the circumpolar Arctic. We analyzed beluga observations made during spring aerial surveys for ringed seals conducted from 1975 to 1979 in the eastern Beaufort Sea. Despite inter-annual variability in the extent and distribution of sea ice, belugas consistently selected areas with water depths of 200-500 m and heavy ice concentrations (8/10 to 10/10) while areas of open water to light ice concentrations (0/10 to 1/10) were not selected. Belugas were also found in proximity to regions with ≥0.5 degrees seafloor slope which include the continental slope and other areas with the potential for oceanographic upwellings. In most years (4 of 5), fast-ice edges and coastal areas were not selected. In the lightest ice year analyzed, belugas showed less specificity in habitat selection as their distribution expanded and shifted shoreward to fast-ice edges. The observed distribution is discussed in terms of predator-prey relationships particularly with reference to beluga feeding on Arctic cod (*Boreogadus saida*). More research is required to examine and compare possible changes in distribution since the late 1970s and to investigate the factors driving the patterns described.

2.2 INTRODUCTION

Understanding the habitat selection of animals is necessary to identify habitats critical to their survival. Arctic marine mammals are adapted to survive in a highly variable environment with large seasonal fluxes in temperature, light, and sea-ice cover. In Canada's western Arctic, the summer range of beluga whales (*Delphinapterus leucas*) extends into the eastern Beaufort Sea (EBS) where they have been an important resource for the Inuvialuit in the area for centuries (Harwood and Smith 2002). Belugas are an ice-adapted species having evolved morphological, physiological and/or behavioural characteristics that enable them to exploit sea ice habitat (Ainley et al. 2003). Climate change is already evident in the EBS in the reduction of sea ice concentrations and extent (Parkinson and Cavalieri 2008) and further reductions are anticipated (Barber et al. 2008). By understanding the habitats used by beluga, the impacts of climate change and industrial development may be better mitigated.

While belugas from the EBS winter in the Bering Sea, they appear to leave their wintering grounds as soon as sufficient cracks form in the ice to permit travel (Fraker 1979). In March and April, these belugas enter the shore-lead system west of Alaska (Stirling 1980). They arrive in the EBS in late May and early June (Fraker 1979). Current research has shown that some animals remain in the EBS until November, at which point they travel towards the Bering Sea (Richard et al. 2001b). Through the use of satellite-linked transmitters, the summer and fall habitat selection of belugas has been studied in the EBS (e.g. Richard et al. 1997; Richard et al. 2001b; Loseto et al. 2006) and in other regions of the circumpolar Arctic (e.g. Smith and Martin 1994; Barber et al. 2001; Richard et al. 2001a; Suydam et al. 2001; Hobbs et al. 2005). While data collected through satellite tracking offers detailed information on movements and dive behaviour (see examples above for details), they have some limitations. In the case of the spring habitat, the longevity of the tags has proven to be the main limitation as animals are captured and equipped with satellite-linked transmitters in the summer. Some average (maximum) transmitter longevities for beluga reported in the literature are 42 (60) days (Richard et al. 1998), 84 (126) days (Richard et al. 2001a) and 132 (240) days (Hobbs et al. 2005). Another limitation is the small number of belugas tagged for example 6 (Richard et al. 1998), 14 (Hobbs et al. 2005) and 21 (Richard et al. 2001a), which can impact the validity of the results (Leban et al. 2001).

Beyond the limitations of the satellite-linked transmitters, their use is quite recent. While rudimentary versions existed as early as the 1970s (Kenward 2001), satellite-linked transmitters were first deployed on belugas in the Canadian Arctic in 1989 (Martin and Smith 1992) and in the EBS in 1993 (Richard et al. 2001b). Prior to this time, other techniques such as ship-based surveys and aerial surveys were used to study animal distributions and habitat selection (e.g. Stirling et al. 1977, 1982; Cosens and Dueck 1991; Laidre et al. 2000). In the 1970s, the Beaufort Sea was the site of extensive research partially due to the push for oil development in the area and a need to better understand its potential impacts (Stirling 1980). Partly through the Beaufort Sea Project, research resulted in a better understanding of the ecosystem including the physical and chemical oceanography (Herlinveaux and de Lange Boom 1975; Wong et al. 1981), the biological productivity (Grainger 1975; Wacasey 1975), the ice climatology (Markham 1975) and certain animals such as seabirds (Barry 1976), seals (Stirling et al. 1982) and belugas (Fraker 1979). During seal surveys conducted by the Canadian Wildlife Service (CWS) from 1975-1979 (Stirling et al. 1982), sightings of all marine mammals, including belugas, were recorded. The data on belugas from these surveys provide an opportunity to document their distribution and habitat selection in the EBS in the spring in the mid to late 1970s, which can serve as a baseline from which to evaluate the impacts of future changes in sea ice areal extent.

Previous work on beluga habitat selection has focused on summer and fall. Loseto et al. (2006) found that EBS belugas primarily select areas with open water (0/10 ice concentrations) followed by closed ice (9/10 to 10/10 ice concentrations) in offshore waters of more than 200 m depth during the open-water season (July to freeze-up). Similarly, in the Alaskan Beaufort Sea, belugas were observed more than expected in 201-2000 m of water and were mainly associated with two habitats: open water/light ice (1-10%) and heavy ice (71-100%) in summer (Moore et al. 2000). Barber et al. (2001) looking at belugas throughout the east and west Arctic in summer and fall, also examined their distribution in respect to bathymetry and sea ice concentration. They concluded that belugas primarily select shallow waters but also show a preference for waters 500 m deep (Barber et al. 2001). Furthermore, Barber et al. (2001) determined that belugas showed a preference for light ice conditions (0/10) and an avoidance of 10/10 ice.

Following on this previous research, in this paper, we analyze the distribution and habitat selection of belugas in the EBS in June of 1975 to 1979 by examining the locations of animals sighted in relation to ice characteristics and bathymetry.

2.3 MATERIALS AND METHODS

2.3.1 Study area

The study area is in the EBS, east of 140°W and south of 74°N (Fig. 2.1). It is bound in the west, east and north by the border between Alaska and Yukon, the east side of Darnley Bay in Amundsen Gulf and the northern coast of Banks Island, respectively. In the southern part of the study area, the Continental Shelf extends ~120 km out from shore to a depth of ~80 m (Carmack et al. 2004). Similarly, the west side of Banks Island is also characterized by a shelf that extends ~100 km out from shore to a depth of ~200 m. Beyond these shelves, the water depth increases rapidly to about 1500 m in the southern portion and 2500 m in the northern portion. In Amundsen Gulf, shallower areas are found within Franklin Bay and Darnley Bay while deeper waters (up to 650 m) are found in the center (Fig. 2.1).

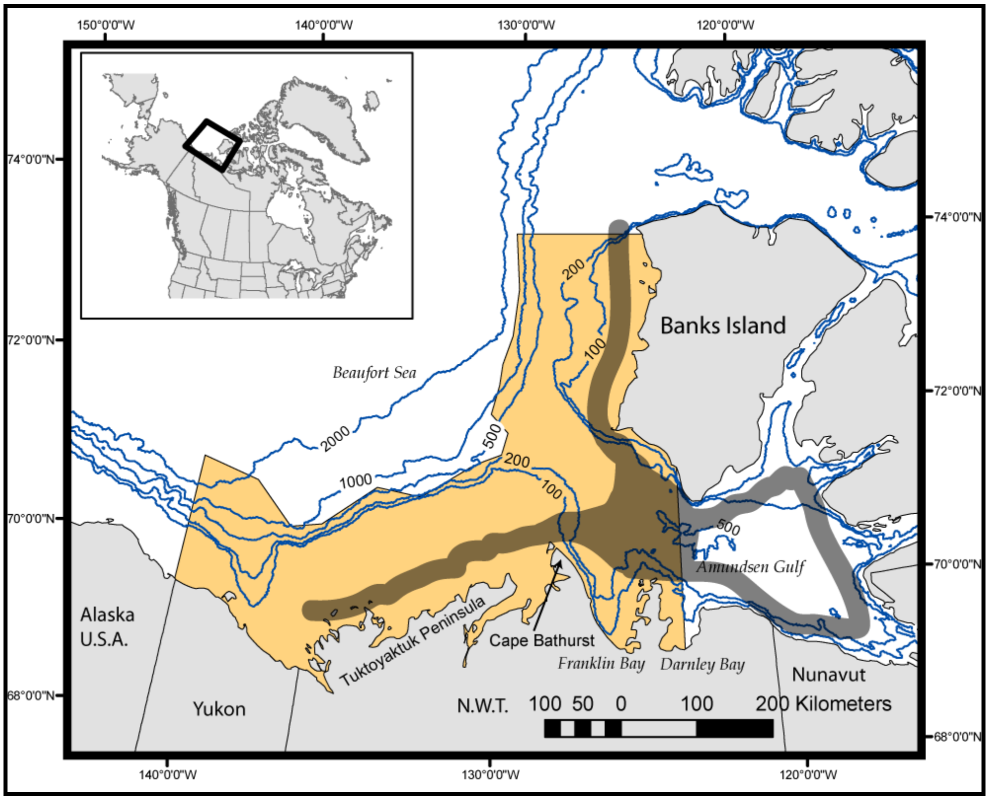

Fig 2.1 Study area (orange) with bathymetry (Jakobsson et al. 2008) and the area normally occupied by the flaw lead system (shaded, Galley et al. 2008)

Surface waters in the Beaufort Sea, primarily originate from the Pacific, are relatively fresh, cold and nutrient-rich (McLaughlin et al. 1996), and circulate in a clockwise direction (Coachman and Aagaard 1974). Below this top 40-60 m, major circulation is counter-clockwise, and known as the Beaufort undercurrent (Aagaard et al. 1989). Between approximately 200 and 600 m is a region with warmer waters of Atlantic origin while colder, more saline water is found at depth (McLaughlin et al. 1996).

Barber and Hanesiak (2004) describe three general ice areas within the EBS: the offshore pack, the fast-ice and the Cape Bathurst Polynya complex. The offshore pack is composed of multi-year and first-year ice (Barber and Hanesiak 2004) that generally circulates in a clockwise direction, but is subject to occasional reversals, mainly in summer (Lukovich and Barber 2006; Asplin et al. 2009). Fast-ice forms annually along the coast over the continental shelves (Barber and Hanesiak 2004). The Cape Bathurst Polynya complex is a combination of recurrent flaw leads and the sensible/latent heat polynya within Amundsen Gulf (Barber and Hanesiak 2004). The extents of the flaw lead system and the offshore cracks in the ice are linked to ice circulation, with heavier ice conditions in the region when the pack is moving in a clockwise direction (Proshutinksy et al. 2002). Based on data from 1980-2004, Galley et al. (2008) found that on average, break-up took two weeks beginning in the flaw lead north of Tuktoyaktuk Peninsula and west of Banks Island in late May with western Amundsen Gulf beginning to break up in early to mid-June followed by eastern Amundsen Gulf in late June. Fast-ice in the region begins to break up in late July (Galley et al. 2008).

2.3.2 Field Methods and Data Sets

2.3.2.1 Beluga observations

Beluga sightings were collected during seal surveys conducted by the CWS in mid to late June of 1975 to 1979 (Table 2.1). The methods employed for these surveys are described in Stirling et al. (1977, 1982) Methods for the analysis of the beluga sightings are described here. The survey had 101 transects in which north-south transects were 15' of longitude apart and east-west transects were 5' of latitude apart and all extended 160 km out from the coast at a 90° angle. In an attempt to reduce bias, and because of budgetary limitations, 60% of these transects were selected using a stratified random sampling design (Stirling et al. 1977, Fig. 2.2).

Table 2.1 Summary of field data

Year	Date Range (No. of days)	No. of transects	Total Transect Length (km)	No. of Sample Periods	Belugas Sighted	CIS Charts
1975	June 12-20 (9)	57	4937	610	362	1975/06/20
1976	June 16-29 (12)	60	9838	1180	283	1976/06/18, 1976/06/25, 1976/07/02
1977	June 12-21 (9)	60	9537	1214	176	1977/06/17, 1977/06/24
1978	June 13-25 (11)	60	9035	1089	141	1978/06/16, 1978/06/22, 1978/06/29
1979	June 15-25 (10)	52	6491	825	140	1979/06/21, 1979/06/28
Total	**June 12-29**	**60**	**39,838**	**4918**	**1102**	**11 charts**

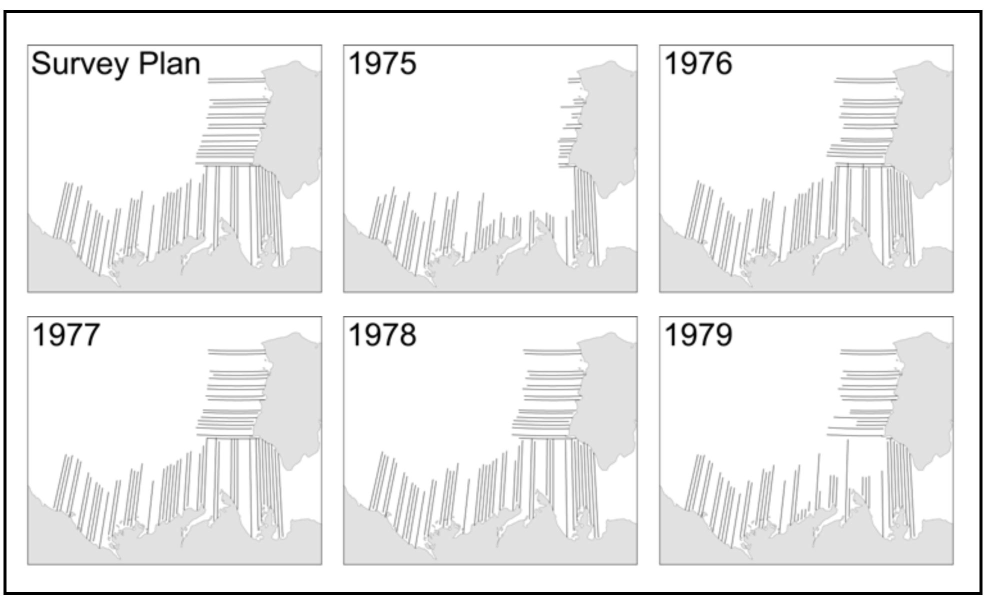

Fig 2.2 Survey plan and transects flown (in black) for each survey year

The transects selected were flown at an altitude of 152 m (500 ft) and at a speed of about 240 km/h (150 mph) in a Cessna 337. Two observers in the back seat each counted on one side of the aircraft over a 400 m wide strip. Data recorded on each transect were partitioned at 2-min intervals, which we use as sample periods, allowing for geographical referencing. All beluga sightings, on and off-strip, were counted and ice concentration was also noted.

From 1975 to 1977, navigation was by dead reckoning: the starting point of each transect was determined with the use of a 1:250 000 map and a directional gyro was used to fly true headings. Estimated wind speed and direction were used to correct the ground speed of the aircraft. In 1978 and 1979 an OMEGA-GNS 500 Global Navigation System was used. This navigation system used Very Low Frequency (VLF) radio signals and allowed for positional accuracy in the 1 to 2 nautical mile range (Asche 1972). In some cases, due to fog, low clouds or extensive open water, transects were cut-off pre-maturely (Fig. 2.2). A total of 1102 belugas were sighted in the five years of survey (Table 2.1).

2.3.2.2 Ice conditions

Weekly regional ice charts from the Canadian Ice Service (CIS) (available at http://ice-glaces.ec.gc.ca) were used to determine ice conditions. These charts are in a Lambert projection, based on the Clarke 1866 spheroid and NAD27 datum (Canadian Ice Service Archive Documentation Series 2006). They are prepared by experienced ice forecasters who use multiple information sources such as satellite imagery, aerial reconnaissance and surface observations (Canadian Ice Service Archive Documentation Series 2006). The charts were checked for errors and corrected by comparing the electronic charts with the paper charts and the ice observations from the CWS survey observers.

2.3.2.3 Bathymetry

The International Bathymetric Chart of the Arctic Ocean (IBCAO) version 2.23 (available at http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/, from Jakobsson et al. 2008) was used to estimate bathymetry. This dataset was produced using a combination of depth soundings from ships, contour maps and gridded sources to produce a 2 km/2 km grid in Polar Stereographic projection (Jakobsson et al. 2008).

2.3.3 GIS Methods

Using ArcGIS 9.2, the three data sources were overlaid (beluga observations, ice charts and bathymetry). All data processing and analysis completed in ArcGIS 9.2 used the North Pole Lambert Azimuthal Equal-Area projection. The first step was to convert the three data sets to this projection.

2.3.3.1 Beluga observations

Sample periods of less than 2 minutes were omitted as these mainly corresponded to the start or end of transects over fast-ice and land thus containing no beluga habitat. The 2 minute sample interval resulted in an average transect distance sampled of 8.30 km (n=6556, range 6.33-10.08 km). Beluga sightings were assigned a position corresponding to the center of the transect segment surveyed during the 2 minutes. All analyses were completed using these centre positions of the sample periods.

2.3.3.2 Ice conditions

For each aerial survey flight, the weekly regional CIS ice chart of the closest following date was used in each analysis (Table 2.1). From the electronic ice charts, separate polygon shapefiles were generated to represent two ice characteristics: concentration and dominant ice type. Following Moore et al. (2000), four ice concentration classes were created: open water/light (0/10 to 1/10), light/moderate (2/10 to 4/10), moderate/heavy (5/10 to 7/10) and heavy (8/10 to 10/10) (Fig. 2.3). Dominant ice type was defined for the purposes of this research as 50% or more of the ice within the polygon (Fig. 2.4) which resulted in three classes (first year, old and open water). The region covered in fast-ice was excluded from the analysis as belugas are not visible when beneath it. However, in order to account for the low spatial resolution of the 2 minute sample interval (detailed in the previous section), and include beluga observations that fell within sample segments centered over fast-ice, the border of the fast-ice was retained in the analysis. This border was created as a 4.15 km wide band along the fast-ice edge and corresponds to 0.5 times the average distance of the 2 minute segments.

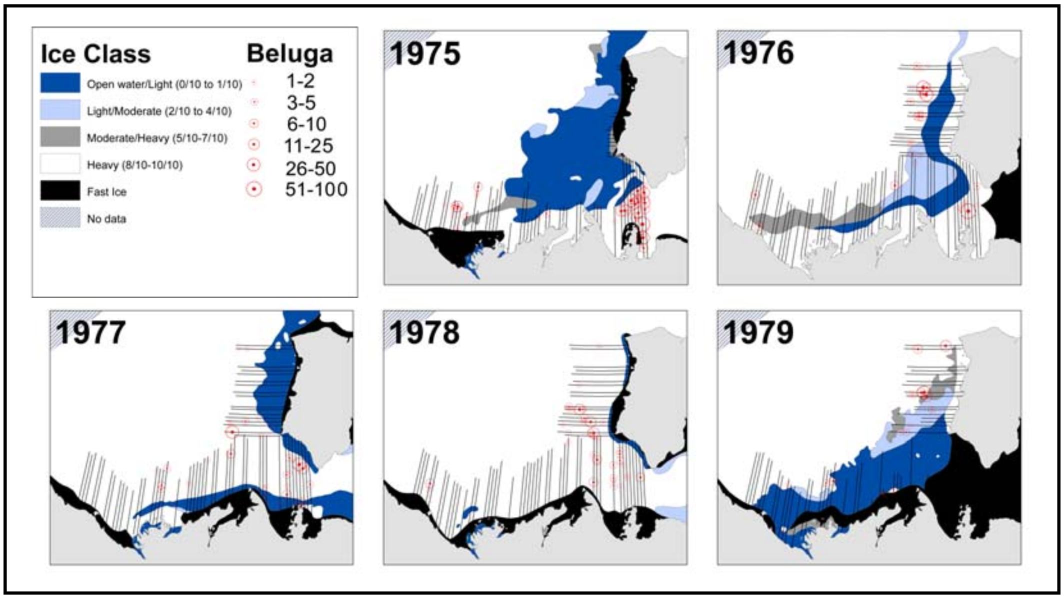

Fig 2.3 Maps of ice classes (CIS charts) and beluga sightings for each survey year *Note*: maps were produced using one chart per survey year to show general ice concentrations while the analysis was completed using multiple charts (see Table 2.1).

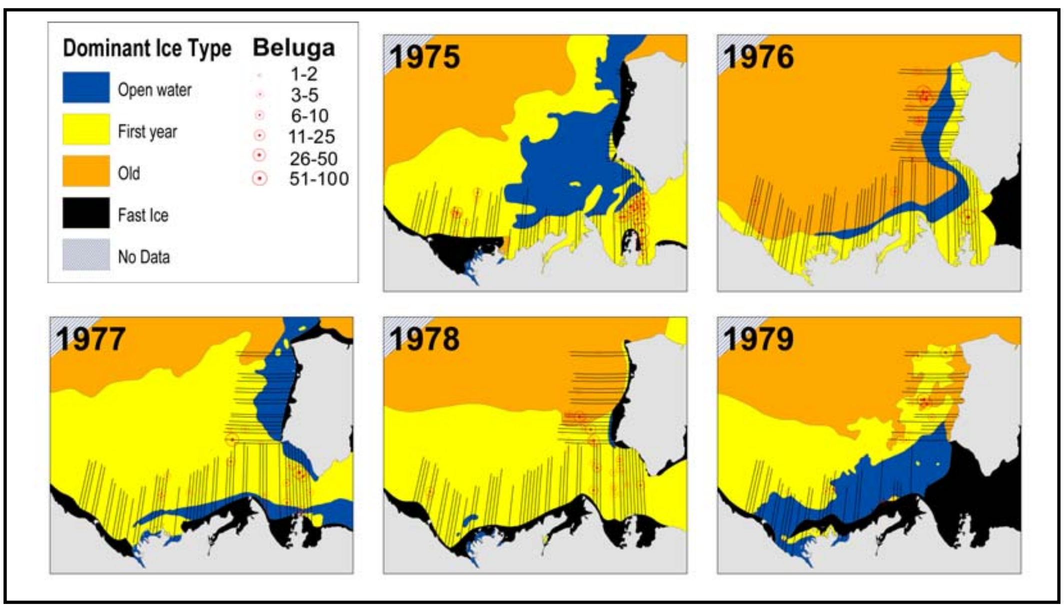

Fig 2.4 Maps of dominant ice type (CIS charts) and beluga sightings for each survey year *Note*: maps were produced using one chart per survey year to show general ice type distributions while the analysis was completed using multiple charts (see Table 2.1).

2.3.3.3 Bathymetry

Four depth classes were created: 0-50 m, 50-200 m, 200-500 m and 500-2400 m (Fig. 2.5). The first two classes correspond to the inner and outer shelf bathymetric blocks used by Moore et al. (2000) in the Alaskan Beaufort Sea while the 200-500 m depth class is over the continental slope and extends into the center of Amundsen Gulf. To test for an association with bottom gradient, the slope of the seafloor was calculated using a pixel size of 2 km X 2 km (Fig. 2.6). The study area was then divided into two zones: <0.5° (9 m drop per km) and ≥0.5° (Fig. 2.6). The threshold of 0.5° was used as this represents relatively high seafloor slope in the EBS including regions such as the continental slope and Mackenzie Canyon. Also, most of the sample points were in areas with less than 0.5° seafloor slope (median=0.279°, n=4918, range=0.002-5.412°).

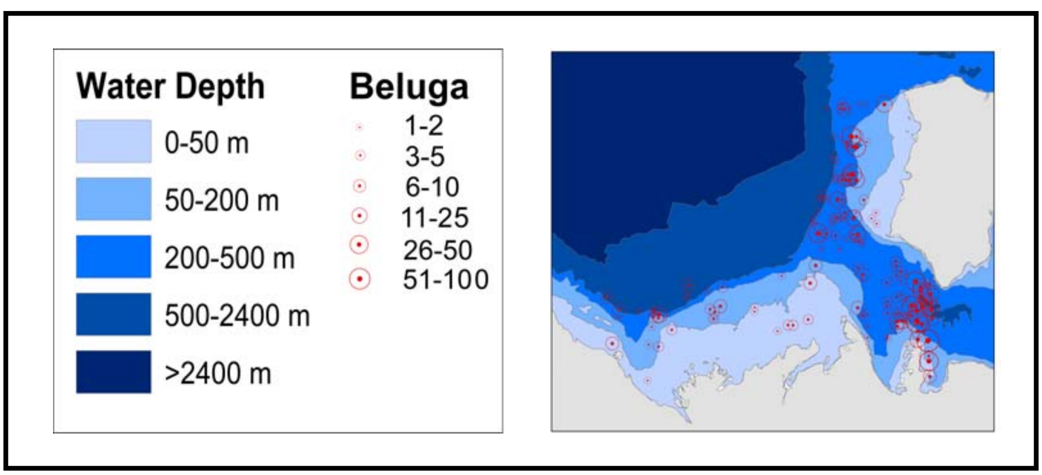

Fig 2.5 Map of depth classes and beluga observations from 5 years of surveys

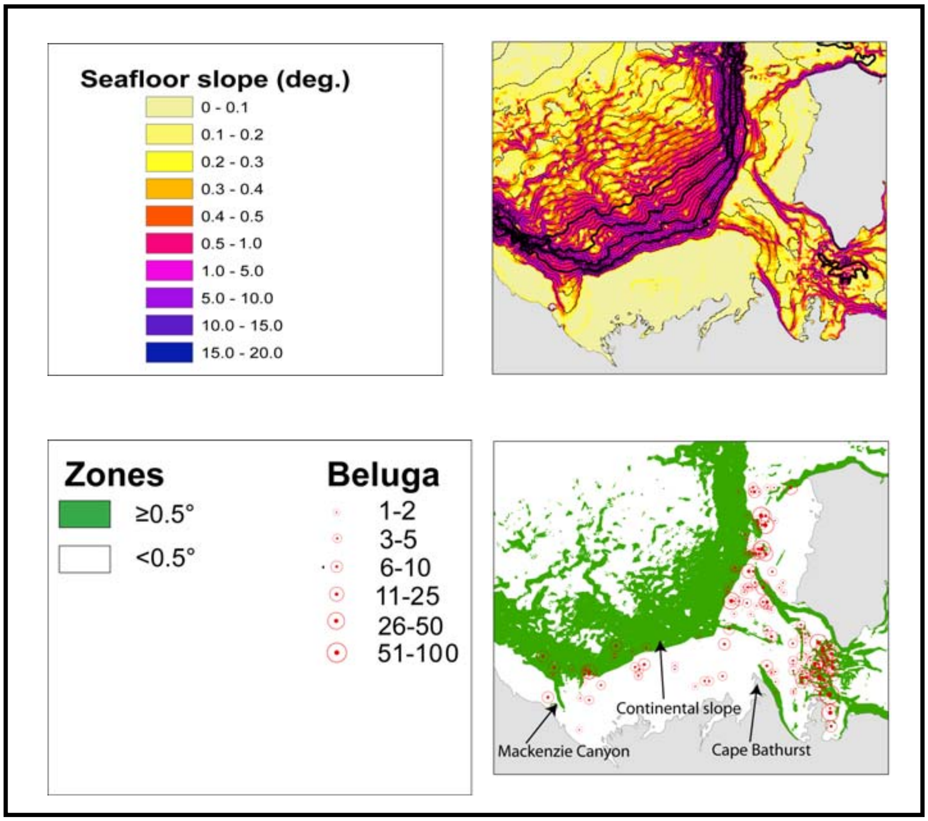

Fig 2.6 Seafloor slope in degrees (top) and seafloor slope zones and beluga sightings (bottom)

2.3.3.4 Ice/Depth

Lastly, the possibility of bathymetry and ice concentration jointly explaining the distribution of beluga in the EBS in spring was tested. The areal extent of the 200-500 m depth class was combined with that of the heavy ice class (8/10 to 10/10) to produce four spatial classes: Heavy ice concentrations in 200-500 m of water (Category 1), Other ice concentrations in 200-500 m (Category 2), Heavy ice concentrations in Other depth classes (Category 3) and all Other areas (Category 4) (Fig. 2.7).

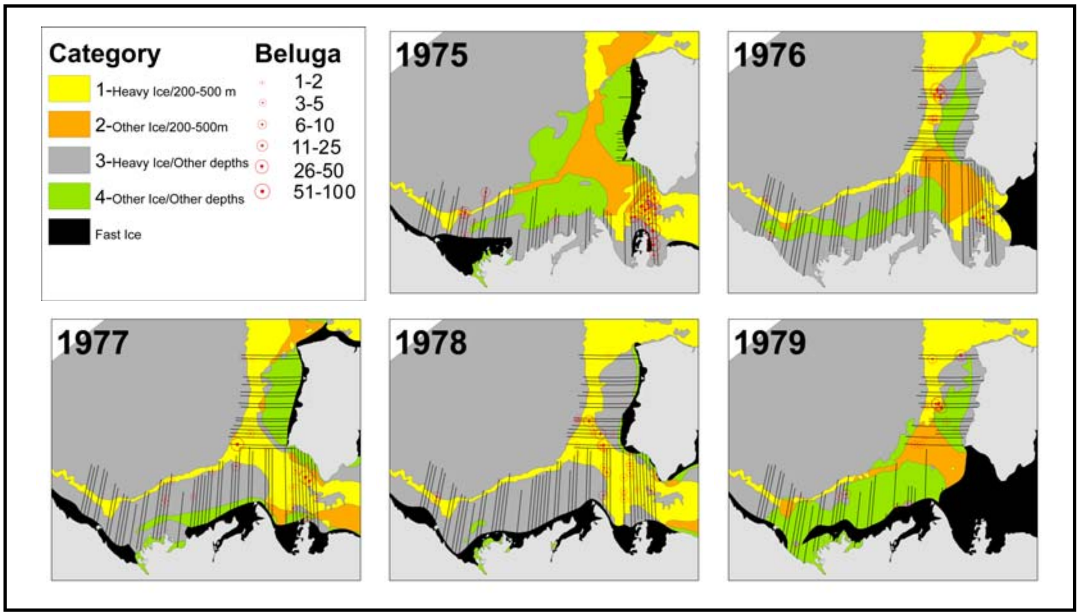

Fig 2.7 Maps of ice/depth categories and beluga sightings for each survey year *Note*: maps were produced using one chart per survey year to show general ice concentrations while the analysis was completed using multiple charts (see Table 2.1)

2.3.4 Analytical Methods

The habitat selection analysis was completed using two statistical techniques: Pearson's chi-square (Neu et al. 1974) and Euclidean distance analysis (Conner and Plowman 2001).

The chi-square technique, from Neu et al. (1974), was used to test the null hypothesis that observed beluga habitat use is equal to the expected habitat use as determined by habitat availability [1].

$$x^2 = \sum \frac{(O_i - E_i)^2}{E_i} \qquad [1]$$

i. where: O_i = Observed habitat use in the *i*th category

E_i = Expected habitat use in the *i*th category

The observed and expected habitat use were determined in ArcGIS 9.2 by assigning the ice characteristics (concentration, dominant type), depth class and depth/ice concentration category to the beluga observations (observed) and to the 2 minute sample units (expected). When chi-square analysis demonstrated that the overall observed distribution of belugas differed significantly ($p<0.05$) from the expected distribution, Bonferroni's inequality (Byers et al. 1984) was used to test whether habitat use was significantly ($p<0.05$) more or less than expected for each habitat descriptor [2].

$$\overline{p}_i - Z_{\alpha/2k}\sqrt{\frac{\overline{p}_i(1-\overline{p}_i)}{n}} \le p_i \le \overline{p}_i + Z_{\alpha/2k}\sqrt{\frac{\overline{p}_i(1-\overline{p}_i)}{n}} \qquad [2]$$

ii. where $\overline{p}_i$ = the proportion of beluga in the *i*th category

n=sample size

k= number of categories

The observed distribution is considered to be significantly higher or lower than the expected distribution if the latter does not fall within the 95% confidence limits of the observed distribution as calculated by Bonferonni's inequality statistic.

To further describe the distribution of belugas within the EBS, the relationships between beluga locations and fast-ice edges and shore were also analyzed. Conner and Plowman (2001) describe a distance based approach useful for both linear features (e.g. ice edges, shore) and non-linear features (e.g. habitat patches) that has been found to be resilient to Type 1 errors (Bingham and Brennan 2004). While their technique is described using telemetry data, point count data, such as this beluga dataset, are analogous to the extreme case of telemetry data with one location per animal. Provided the number of locations is sufficient, the same analytical techniques can be used for both (Aebischer et al. 1993).

The technique described by Conner and Plowman (2001) was used to test the null hypothesis that the proximity of beluga to the fast-ice edge and to shore is equal to that of random points. Using ArcGIS 9.2, the same technique was used for both the fast-ice edge and land. First, a raster file (100 m X 100 m pixels) of Euclidean distance to each feature was created. Then, 1000 random points were generated for each year that fell within the portion of transects surveyed and within possible beluga habitat (i.e. no land or fast-ice). These random points were then assigned to the nearest 2 minute sample point to mimic the sampling protocol of the actual observations. The values from the Euclidean distance raster files of the fast-ice edge and the land were then assigned to both the random points and the observation points.

Following Conner and Plowman (2001), the average distances of the random points to the fast-ice edge and to the shore were calculated. The ratios of the observed (actual) distances to the average random distance were then calculated. Systat 11 was used to run a student's t-test of the null hypothesis that the ratios averaged 1 (95% confidence interval) indicating that there is no significant difference between the distance of the actual points and the distance of the random points.

This same technique was used to test the null hypothesis that the distance from beluga locations to zones of seafloor slope $\geq 0.5°$ was not significantly different from random. Due to the 2 km by 2 km pixel size of the IBCAO data, a 1 km by 1 km pixel size was used for the Euclidean distance raster in this case without loss of spatial resolution.

2.4 RESULTS

2.4.1 Ice concentration

As shown by chi-square analysis, belugas were not uniformly distributed throughout the ice concentration classes in 1975, 1976 and 1979 (Fig. 2.3, Table 2.2). In 1977 and 1978, the difference between the observed distribution and the expected distribution was not significant. In all years, belugas were observed in heavy ice (8/10 to 10/10) more than expected, significantly so in 1975, 1976 and 1979. In 1979, belugas were also observed more than expected in moderate/heavy ice (5/10 to 7/10). Belugas were observed significantly less frequently than expected in light/moderate ice (2/10 to 4/10) in 1976. In all survey years, belugas were observed less frequently than expected in open water/light ice (0/10 to 1/10), significantly so in 1979.

2.4.2 Dominant ice type

Belugas were also not distributed uniformly within the areas of different ice types in 1975, 1976 and 1979 (Fig. 2.4, Table 2.2). In 1977 and 1978, the difference between the observed distribution and the expected distribution was not significant. In 1975, belugas were observed significantly more than expected in first year ice while in 1976, the same was true of old ice. In 1979, belugas were observed significantly more than expected in first year ice and in old ice and observed significantly less than expected in open water.

Table 2.2 Results of chi-square analyses of beluga sightings and ice class, dominant ice type, depth and ice/depth

	1975			1976			1977			1978			1979		
Ice Class	Effort	O	E	Effort	O	E	Effort	O	E	Effort	O	E	Effort	O	E
Open water/Light (0/10-1/10)	90	2	53	167	0	40	360	41	52	36	0	5	317	**18(-)**	54
Light/Moderate (2/10-4/10)	2	0	1	113	**14(-)**	27	37	4	5	-	-	-	42	6	7
Moderate/Heavy (5/10-7/10)	33	0	20	53	1	13	8	0	1	4	0	1	47	**23(+)**	8
Heavy (8/10-10/10)	485	**360 (+)**	288	847	**268(+)**	203	809	131	117	1049	141	136	419	**93(+)**	71
Total	610	362	362	1180	283	283	1214	176	176	1089	141	141	825	140	140
			x^2=88 p<0.001			x^2=78 p<0.001			x^2=6 p<0.250			x^2=5 p<0.250			x^2=59 p<0.001
Dominant Ice Type	Effort	O	E	Effort	O	E	Effort	O	E	Effort	O	E	Effort	O	E
First year	516	**360 (+)**	306	380	110	91	835	134	121	859	114	111	434	**89 (+)**	74
Old	4	0	2	633	**173 (+)**	152	19	1	3	194	27	25	74	**33 (+)**	13
Open water	90	2	53	167	0	40	360	41	52	36	0	5	317	**18(-)**	54
Total	610	362	362	1180	283	283	1214	176	176	1089	141	141	825	140	140
			x^2=61 p<0.001			x^2=47 p<0.001			x^2=5 p<0.100			x^2=5 p<0.100			x^2=60 p<0.001
Depth	Effort	O	E	Effort	O	E	Effort	O	E	Effort	O	E	Effort	O	E
0-50 m	251	**48 (-)**	149	387	**16 (-)**	93	401	**5 (-)**	58	341	1	44	281	**12 (-)**	48
50-200 m	162	101	96	333	**53 (-)**	80	333	49	48	297	**9 (-)**	38	247	**28 (-)**	42
200-500 m	147	**200 (+)**	87	369	**201 (+)**	88	385	**119 (+)**	56	359	**107 (+)**	46	222	**99 (+)**	38
500-2400 m	50	**13 (-)**	30	91	13	22	95	3	14	92	**24 (+)**	12	75	1	13
Total	610	362	362	1180	283	283	1214	176	176	1089	141	141	825	140	140
			x^2=224 p<0.001			x^2=219 p<0.001			x^2=128 p<0.001			x^2=156 p<0.001			x^2=142 p<0.001
Ice/Depth	Effort	O	E	Effort	O	E	Effort	O	E	Effort	O	E	Effort	O	E
Category 1	117	**198 (+)**	69	229	**196 (+)**	55	258	**105 (+)**	37	356	**113 (+)**	46	161	**68 (+)**	27
Category 2	31	2	18	139	**5 (-)**	33	128	14	19	7	0	1	61	**31 (+)**	10
Category 3	368	**162 (-)**	218	618	**72 (-)**	148	551	**26 (-)**	80	693	**28 (-)**	90	258	**25 (-)**	44
Category 4	94	0	56	194	**10 (-)**	47	277	31	40	33	0	4	345	**16 (-)**	59
Total	610	362	362	1180	283	283	1214	176	176	1089	141	141	825	140	140
			x^2=323 p<0.001			x^2=454 p<0.001			x^2=162 p<0.001			x^2=145 p<0.001			x^2=141 p<0.001

Notes: In shading are analyses for which the overall observed (O) distribution was significantly different (p<0.05) from the expected (E) distribution as calculated by the chi-square analysis. In bold are ice classes for which the number of beluga observed (O) was significantly (95% conf. limits) more (+) or less (-) than expected as calculated by Bonferonni's inequality statistic.

2.4.3 Distance to fast-ice edge and shore

Euclidean distance analysis showed that in 1975, belugas were significantly closer than random points to fast-ice edges while the opposite was true in 1977, 1978, 1979 and the difference between belugas and random points was not significant in 1976 (Table 2.3). In 1975, belugas were also significantly closer to shore than random points. In 1976, 1977, 1978 and 1979, belugas were observed farther from shore than random points, significantly so in all but 1977.

Table 2.3 Results of distance of beluga sightings to fast-ice edge, shore and zones ≥ 0.5° seafloor slope analyses

Year	n	Fast-ice edge		Shore		Zones of ≥0.5° seafloor slope	
		$\bar{X}$ [a]±*SE*	t[b](*p*)	$\bar{X}$ [a]±*SE*	t[b](*p*[*])	$\bar{X}$ [a]±*SE*	t[b](*p*)
1975	362	**0.77±0.03**	**-8.116 (0.000)**	**0.91±0.03**	**-2.668 (0.008)**	**0.12±0.02**	**-39.130 (0.000)**
1976	283	1.04±0.04	0.971 (0.332)	**1.20±0.03**	**6.124 (0.000)**	**0.29±0.02**	**-33.477 (0.000)**
1977	176	**1.33±0.04**	**7.640 (0.000)**	1.07±0.06	1.243 (0.215)	**0.29±0.03**	**-23.132 (0.000)**
1978	141	**1.16±0.04**	**4.522 (0.000)**	**1.17±0.04**	**4.494 (0.000)**	**0.25±0.02**	**-38.489 (0.000)**
1979	140	**1.34±0.06**	**5.340 (0.000)**	**1.31±0.03**	**9.790 (0.000)**	**0.64±0.08**	**-4.271 (0.000)**

Notes: Results in bold indicate significantly (p<0.05) closer or farther than random
[a]*mean of ratio of beluga distances to the mean distance of the random points (closer than random < 1 > farther than random).*
[b]*t-statistic testing the null hypothesis that (mean beluga distance/mean random distance) = 1*

2.4.4 Bathymetry

In all survey years, belugas were not distributed uniformly relative to water depth. For all five years, belugas were observed significantly more than expected in the 200-500 m depth class (Fig. 2.5, Table 2.2). In 0-50 m of water, belugas were observed significantly less than expected in all years other than 1978 when statistical significance could not be established due to a small sample size (n=1). In the 50-200 m depth class, belugas were observed significantly less than expected in 1976, 1978 and 1979. In 1975 and 1977, belugas were not observed significantly more or less than expected in this depth class. In 500-2400 m of water, belugas were observed significantly less than expected in 1975 while the opposite was true in 1978. In other years, the difference was not significant. Also, in all years, belugas were observed significantly closer than random points to zones of seafloor slope ≥ 0.5° (Fig. 2.6, Table 2.3). Furthermore, belugas were closest to zones of seafloor slope ≥ 0.5° in 1975 and furthest in 1979 (Table 2.3).

2.4.5 Ice/depth

In all years, the overall observed beluga distributions in respect to the ice/depth categories were significantly different from the expected distributions (Fig. 2.7, Table 2.2). Furthermore, in all years, significantly more belugas were observed in Category 1 waters (Heavy ice in 200-500 m of water) than expected. Another consistency in the results is that significantly fewer belugas were observed than expected in Category 3 waters (Heavy ice not in 200-500 m) in all years. In 1979, belugas were observed significantly more than expected in Category 2 waters (Other ice classes in 200-500 m of water). The opposite was true in 1976. In Category 4 waters (Other ice classes in other water depths), belugas were observed significantly less than expected in 1976 and 1979.

2.5 DISCUSSION

The dataset used in this analysis is particularly valuable as it includes five consecutive years of surveys, 1975 to 1979. The five years provide a range of spring ice conditions in the EBS including two years with heavy ice (1977 and

1978), one year with light ice (1975) and two years with intermediate ice conditions (1976 and 1979). Ice extent has been shown to influence the distribution of nutrients (MacDonald et al. 1987; Carmack and Chapman 2003) and the intensity of phytoplankton blooms (Arrigo and van Dijken 2004) within the EBS, thus influencing overall biological productivity. By using a range of ice conditions, we determined that beluga patterns of habitat selection were relatively consistent despite large inter-annual variability in ice concentrations and extent.

The key factors found to influence the distribution of belugas in the EBS in spring from 1975 to 1979 were sea ice concentration, bathymetry and seafloor slope while no pattern emerged for ice type (first year or old). First, our results indicate a preference by EBS belugas for heavy ice (8/10 to 10/10) in spring. While this preference was not statistically significant for the two heavy ice years (1977 and 1978), the majority of beluga observed in these two years of surveys, 131 of 176 in 1977 and 141 of 141 in 1978, were in heavy ice concentrations. In comparison, during the open-water (summer-fall) season, EBS belugas were found to primarily select offshore open-water (0/10 to 1/10), followed by closed ice (9/10 to 10/10) (Loseto et al. 2006). Second, we found belugas consistently selected a region characterized by 200-500 m depths. This concurs with the selection by EBS belugas of offshore water over 200 m in depth found by Loseto et al. (2006) for the open-water season (summer-fall). The region of 200-500 m depth includes the Mackenzie shelf slope area, the slope along the west side of Banks Island and extends into Amundsen Gulf. Similarly, in the Alaskan Beaufort Sea, belugas showed a preference for water depths corresponding to the continental slope in summer (Moore et al. 2000). Third, the combination of the preferred ice concentration class (heavy ice) and the preferred depth class (200-500 m) lead to the strongest and most consistent habitat relationships for beluga distribution suggesting that the combination of these two habitat characteristics has a greater influence on the distribution of belugas in the spring in the EBS than either factor independently. This analysis further indicated that depth is likely of greater influence on beluga distribution as areas with heavy ice concentrations not in 200-500 m of water were avoided in all years while there was no clear pattern for areas without heavy ice concentrations in 200-500 m of water. Notably, the distribution of sea ice is not independent of bathymetry. For example, the seaward extent of the fast-ice correlates with bathymetry in the Alaskan Beaufort Sea (Mahoney et al. 2007) while the general location of the Cape Bathurst polynya and Circumpolar Flaw Lead system in the western Amundsen Gulf (Galley et al. 2008) is in water depths of around 200-500 m. Last, belugas were in proximity to areas with higher seafloor slope ($\geq$0.5°). While correlations between beluga distribution and bottom topography have not been previously studied, seafloor slope has been shown to influence the distribution of cetaceans in Mexico (Davis et al. 1998).

Why would belugas select these habitat characteristics in spring? Habitat selection is the result of inter-related factors such as mating, feeding and predator avoidance. As belugas are believed to mate in April and May and calves are born from late June to early August (Department of Fisheries and Oceans 2002), the observed spring distribution in the EBS is likely due to a combination of predator avoidance and foraging success. Although we examine each habitat variable independently to determine its relative importance, it is critical to note that none is mutually exclusive and consistent between years in its spatial extent or in its selectability for belugas. Rather, it is the collective influence of these factors that determines how belugas select habitat.

Sea-ice extent and concentration impact the hunting success of the two main beluga predators: killer whales (*Orcinus orca*) and polar bears (*Ursus maritimus*). In the Bering Sea, belugas may use the pack-ice as protection from killer whales (Fay 1974) that penetrate only into its edge (up to 10 km from open water) (Lowry et al. 1987). Although killer whales are rarely reported in the EBS (Harwood and Smith 2002; Higdon et al. 2010), predator-avoidance behaviour could partially explain the preference for heavy ice concentrations. In contrast, polar bears (*Ursus maritimus*) hunt belugas from the ice (Lowry et al. 1987) but, as Beaufort Sea polar bears mainly consume ringed seal (*Phoca hispida*) and bearded seal (*Erignathus barbatus*) (Thiemann et al. 2008), it is unlikely that their predation has a large impact on beluga movement.

Prey distributions may also contribute to the association between belugas and heavy ice concentrations. Arctic cod (*Boreogadus saida*) has been identified as the main prey of belugas in multiple Arctic regions (Kleinenberg et al. 1964, Heide-Jørgensen and Teilmann 1994, Dahl et al. 2000) and for EBS belugas during the open-water season (Loseto et al. 2009). Arctic cod likely makes up a large part of the diet of EBS belugas in spring; although this has yet to be conclusively investigated. While the distribution of Arctic cod in the EBS in the spring is not known, they are generally associated with sea ice (Sekerak and Richardson 1978) and are often reported within (in cracks and crevices) or beneath it (e.g. Bradstreet 1982; Percy et al. 1985; Lønne and Gulliksen 1989; Crawford and Jorgenson 1990, 1993; Grandinger and Bluhm 2004). Through suction-feeding (Kane and Marshall 2009), belugas may be foraging on Arctic cod hiding in cracks and crevices at the bottom of sea ice partially explaining their preference for heavy ice concentrations.

Furthermore, prey distributions may largely explain the association between EBS belugas and the 200-500 m depth class in spring. While Arctic cod are likely the main prey (discussed above), belugas are known to forage on a large variety of fish species and invertebrates (Kleinenberg et al. 1964; Seaman et al. 1982). In Alaska in spring, in addition to Arctic cod, belugas consume saffron cod (*Eleginus gracilis*), stickleback (*Pungitius pungitus*) and sculpins (cottidea) (Seaman et al. 1982), while in the EBS in summer Arctic cisco (*Coregonus autumnalis*) is eaten (Harwood and Smith 2002). All of these species are found in the southeastern Beaufort Sea (Percy et al. 1985). Shrimp, squid and octopus are also consumed in spring in Alaska (Seaman et al. 1982). Additionally, while Arctic cod are associated with ice, they are considered semi-pelagic; being found both in the water column and at depth (Bradstreet et al. 1986). Notably, in Franklin Bay, in March and April, Benoit et al. (2008) found dense aggregations of Arctic cod near the bottom (at <250 m) where they note that the temperature and salinity coincide with that of the deep waters along the Mackenzie Shelf slope and the eastern and western slopes of Amundsen Gulf; regions which largely overlap with the 200-500 m depth class used in our study. Furthermore, belugas are known to dive to the seabed, presumably to forage (Martin et al. 1998; Richard et al. 1998; Martin and Smith 1999). Based on the collective strength of these observations, we speculate that the selection of the 200-500 m depth class may be due to the presence of aggregations of Arctic cod at depth on which beluga are feeding.

Bottom topography combined with favourable winds leads to increased upwelling at the Mackenzie Canyon, along the continental slope and near Cape Bathurst (MacDonald et al. 1987; Williams et al. 2006; Williams and Carmack 2008); all found within the region with higher seafloor slope used (≥0.5°) in our analysis. Near Cape Bathurst, upwelling leads to increased primary productivity and biological activity throughout the water column (Williams and Carmack 2008). Furthermore, upwelling contributes to the formation of flaw leads and polynyas (Stirling 1997) allowing belugas to access the surface. Emphasizing the importance of these regions is the identification of Cape Bathurst as an important feeding ground for bowhead whales (Harwood and Smith 2002). We consequently hypothesize that the proximity of beluga to regions of higher seafloor slope (≥0.5°) may be due to a combination of access to the surface for breathing and the increased biological productivity throughout the food-chain caused by upwelling of nutrient rich waters to the surface. Furthermore, Carmack and Chapman (2003) identified increased upwelling along the shelf-break when the pack ice is farther offshore and Arrigo and van Dijken (2004) documented a larger spring phytoplankton bloom in the Cape Bathurst polynya during a light ice year. This could explain why belugas were closest to regions with higher seafloor slope during the survey year with the lightest ice conditions (1975).

Our findings also indicate that belugas were not drawn to the fast-ice edge habitat or coastal areas in spring, particularly when pack-ice was present in the region. This is in contrast to the reports of belugas at numerous fast-ice edges in June and/or early July (Bradstreet and Finley 1977; Bradstreet 1982; Crawford and Jorgenson 1990; Cosens and Dueck 1991; Harwood and Smith 2002) and observations of belugas diving under the edge (Bradstreet 1982). While belugas are present at fast-ice edges, particularly while migrating from winter range, fast-ice habitat is not selected by belugas in spring (e.g. Bradstreet and Finley 1977). It is likely that fast-ice is a barrier to belugas moving towards summering grounds due to its unbroken nature that does not provide whales with access to air (Bradstreet 1982). Supporting this conclusion is the finding that migrating belugas off the coast of Alaska do not appear to feed unless their movements are blocked by ice (Seaman et al. 1982). In the EBS, as the migration route is not blocked by fast-ice, its edge may not be an important habitat for belugas in the spring.

Only in 1975, the study year with the largest expanse of open water, did belugas appear to select the fast-ice edge and coastal habitats. However, due to the lighter ice conditions, transects did not go as far offshore as in other years and stopped short of the offshore pack-ice. It is therefore unknown whether the distribution had shifted inshore or if the individuals in the offshore were missed due to the smaller survey extent. However, 1975 also had the largest sample size (n=362), suggesting that the majority of belugas likely remained within or near the survey area. Consequently, the results suggest that belugas may use fast-ice and coastal regions in the spring in years with unusually early loss of sea ice resulting in less available pack-ice.

The correlation between sea ice concentrations and beluga observations is of particular importance in the context of climate change which the Intergovernmental Panel on Climate Change predicts will have greater impacts overall in polar regions (IPCC 2007). A significant decline in the spring ice extent in the Arctic Ocean has already been reported (Parkinson and Cavalieri 2008) and sea ice concentrations and extent are both expected to decline in the future (Barber et al. 2008). While predicting the impacts of these changes in sea ice cover is complicated, the correlation we found between beluga and heavy ice concentrations indicates a potential vulnerability. Notably, the slight inter-annual variability in distribution we found in the spring supports the assessment by Laidre et al. (2008) that belugas, in comparison with other Arctic and subarctic marine mammals, are moderately sensitive to climate-induced habitat change as their wide distribution and relative flexibility in habitat and prey contribute to their resilience. The changes in beluga distribution found for the lightest ice year (1975) testify to this relative flexibility in habitat.

The predicted decline in sea ice concentrations and extent (Barber et al. 2008) associated with climate change will result in an increase in the areas of open water in the Arctic. However, areas with open water/light ice concentrations were used less than expected in every study year despite large inter-annual variability in ice extent and concentration. For EBS belugas, Amundsen Gulf, which encompasses the Cape Bathurst polynya (Stirling 1997), is believed to be the main destination of migrating belugas in spring (Fraker 1979). Polynyas are noted for having a greater abundance of life than surrounding ice covered areas due to multiple factors such as calmer waters than open seas, a temporary barrier or aid to navigation, access to air and increased productivity near the ice-water interface (Stirling 1997). While this research indicates that belugas do not select open water/light ice concentrations, the factors that cause polynyas, such as wind, tidal fluctuations, currents and upwellings (Stirling 1997), also lead to openings in the surrounding pack ice. In this way, it is possible that the biological importance of seasonal polynyas extends beyond the area of open water to the surrounding ice. Notably, Dunbar (1981) indicated it was the ice edge, as opposed to the open water, that was responsible for much of the biological productivity associated with polynyas. This may explain the lack of selection of open-water observed for belugas in the EBS in spring.

Some caution should be used in interpreting our results. First, the surveys on which these data were recorded were designed for ringed seals and targeted a relatively narrow window of time during which the seals were molting. Consequently, as beluga habitat selection changes seasonally, the patterns identified are only for the time period mid to late June. However, mid to late June represents a key period when belugas have mainly migrated back from their wintering grounds in the Bering Sea (Fraker 1979) but have yet to continue on to one of their main summering grounds in the Mackenzie estuary (Harwood and Smith 2002). Consequently, as information was lacking for this season, our research thus fills in some of the knowledge gaps regarding spring beluga habitat requirements. Second, there are also biases inherent to marine mammal aerial surveys: perception bias (animals that are visible but missed) and availability bias (animals that are in the survey area but not visible) (Marsh and Sinclair 1989). For perception bias, belugas are large and white in comparison to ringed seals and thus more visible. Furthermore, all observers on the seal surveys were keen on seeing whales of any species so their sensitivity to sighting them was high. While we cannot quantitatively assess the number of missed animals, we consider the number was small and relatively similar across habitat types and thus would have little impact on results. Availability bias is more difficult to assess as the proportion of time belugas spend at the surface is impacted by size, presence of calves, season and habitat (Heide-Jørgensen et al. 2001). It has been hypothesized that belugas spend less time at the surface in deeper waters (Barber et al. 2001) and in the presence of pack ice (Heide-Jørgensen et al. 2001). If these patterns are accurate, the preference found here, for 200 to 500 m of water with heavy ice concentrations (8/10 to 10/10), would be conservative. On a technical note, the navigation methods used for these surveys in the 1970s have since been replaced with the use of Global Positioning Systems (GPS) (e.g. Kingsley and Reeves 1998; Richard et al. 2010) while the production of CIS charts now makes greater use of satellite imagery (Canadian Ice Service Archive Documentation Series 2006) which have improved the accuracy and spatial resolution of the animal sightings and of the ice conditions respectively. Notably, these limitations impact the resolution of the datasets in their entireties but do not bias the results.

Most importantly, our research does not address the current spring distribution or habitat selection of EBS belugas. Since 1979, there have only been limited ringed seal surveys in the EBS (see Kingsley 1984) and no dedicated systematic spring beluga or cetacean surveys beyond the Mackenzie estuary. Furthermore, due to technical and logistical limitations, research using satellite-linked transmitters has not provided information on the spring distribution. Re-surveying the region, we would not only assess the present-day distribution but also possibly identify sea ice and ecosystem changes in the last 30 years, during which time it is clear there have been significant ecological changes. A reduction in spring ice extent has already been observed in the Arctic (Parkinson and Cavalieri 2008) and notably, belugas in Baffin Bay have altered their distribution in response to changes in ice extent (Heide-Jørgensen et al. 2010). As sea ice is the main determinant of beluga movements from the Bering Sea in spring (Fraker 1979; Huntington et al. 1999; Mymrin et al. 1999), we hypothesize that an earlier break-up likely results in an earlier spring migration. An earlier migration of belugas from the Bering sea could result in their arrival in the EBS in early to mid-May as opposed to late May and early June as has been the case in the past (see Fraker 1979). Supporting this hypothesis is the observation of one beluga west of Banks Island on 8 May 2008, four belugas south of Banks Island on 19 May 2008 and 20 belugas south of Banks Island on 21 May 2008 (Natalie Asselin, unpublished data). This early arrival could lead to belugas being distributed within the EBS in late May and early June in ways similar to what occurred for mid to late June, 1975-1979. In addition, more information is required on prey distribution and predator-prey relations to explain beluga movement and distribution in the EBS. While it is possible belugas transition early to their summer distribution pattern, as described by Richard et al. (1997; 2001b) and Loseto et al. (2006), the interactions of belugas and their prey are likely more complex than can be addressed by a matching temporal shift (i.e. match/mismatch hypothesis; Cushing 1990). Consequently, more research on the distribution of the most important prey species as well as research on the current spring beluga migration and subsequent distribution is needed to assess the impacts of climatic changes. For these reasons, the value of retrospective research that provides a time reference of beluga habitat selection in relation to specific ecological conditions cannot be underestimated.

From the observations of belugas collected in June 1975-1979, we conclude that despite a large degree of inter-annual variation in sea ice cover, belugas showed a preference for heavy ice concentrations (8/10 to 10/10) and water depths of 200-500 m while areas with open water to light ice concentrations (0/10 to 1/10) were not selected. Regions with higher seafloor slope (≥0.5°) were also selected. In average to heavy ice years, fast-ice edges and coastal areas were not selected while in light ice years, belugas may be more dispersed or shift their distribution shoreward to take advantage of these habitats. While the factors determining the distribution could not be ascertained with the data available, we hypothesize that the preference for 200-500 m and heavy ice concentrations is most likely to have been influenced by under-ice and deep water foraging, mainly on Arctic cod. The selection of areas with higher seafloor slope (≥0.5°) can be linked to regions where upwelling increases biological productivity and brings nutrients and prey closer to the surface. During light ice years, belugas may also be exploiting various coastal fish species and fast-ice edge resources. Furthermore, we suggest that the observed choice of sea ice habitat in spring by belugas may be reinforced by a need to avoid predators. Future research is required to further test the robustness of the observed patterns of distribution and habitat preferences and to test hypotheses about possible changes in spring distribution in the last thirty years in relation to a progressive reduction in sea ice linked to climate change.

2.6 ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance of several field assistants in conducting the aerial surveys by Canadian Wildlife Service for seals and related sightings of other marine mammals in the eastern Beaufort Sea from 1975-1979, and Douglas DeMaster and Michael C.S. Kingsley for data tabulation and statistical analyses related to those surveys. Subsequent analyses of habitat selection by the belugas recorded on these surveys was supported by the Natural Sciences and Engineering Research Council (NSERC) of Canada, the Canada Research Chairs (CRC) program, the Department of Fisheries and Oceans and ArcticNet. This is a contribution arising from the International Polar Year (IPY) Circumpolar Flaw Lead (CFL) System Study project.

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CHAPTER 3: OCCURRENCE, DISTRIBUTION AND BEHAVIOUR OF BELUGA (*DELPHINAPTERUS LEUCAS*) AND BOWHEAD WHALES (*BALAENA MYSTICETUS*) AT THE FRANKLIN BAY ICE EDGE IN JUNE 2008

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3.1 ABSTRACT

Ice edges and polynyas have long been noted for their high biological productivity within the Arctic environment. In June 2008, an aggregation of belugas and bowheads was identified at the Franklin Bay ice edge in the eastern Beaufort Sea, adjacent to the Cape Bathurst polynya. Using a helicopter, five ice edge surveys were conducted to study the distribution and behaviour of the whales. Bowheads were found to be in significantly shallower water and farther from the mouth of the Horton River than belugas. Additionally, the helicopter was used to observe behaviour in detail. Belugas and bowheads were engaged in directed travel as well as diving near and under the ice. Five beluga dives were timed and found to have an average duration of 106±27 sec ($\bar{x}$±SE) and a range of 30-197 sec. The under-ice dives observed are consistent with feeding behaviour observed in other locations for belugas and bowheads which leads us to conclude that foraging was the main purpose of diving near and under the ice. While we could not conclusively explain the importance of the Franklin Bay ice edge, we hypothesize that prey densities higher than adjacent open water may draw belugas and bowheads to the ice edge in June. Further research is needed to identify prey species consumed and to describe the beluga and bowhead distributions within the whole of the eastern Beaufort Sea in spring.

3.2 INTRODUCTION

The Arctic environment is a world of climatic extremes with large seasonal fluxes in temperature, light and sea ice extent. Arctic animals have evolved and adapted to survive these large environmental variations by feeding opportunistically within ephemeral areas offering a high density of food items. As in other extreme climates, such as deserts and alpine areas, certain areas have relatively low faunal and floral densities while other areas serve as oases with much higher species abundances. Within the polar oceanic environment, polynyas and ice edges have long been recognized as habitats with higher species abundance than the surrounding ice covered regions (Stirling 1980; Dunbar 1981; Stirling 1997). From marine mammals to birds and plankton, these areas of open water adjacent to ice covered waters support a large variety of life, especially in spring as migrating animals return to the Arctic (Stirling 1997).

Belugas and bowhead whales are two of the Arctic marine mammals that are often reported along ice edges and in polynyas (Fay 1974; Johnson et al. 1976; Bradstreet and Finley 1977; Sekerak and Richardson 1978; Fraker 1979; Carroll and Smithhisler 1980; Stirling 1980; Bradstreet 1982; Fraker and Fraker 1982; Reeves et al. 1983; Norton and Harwood 1986; Carroll et al. 1987; Crawford and Jorgenson 1990; Cosens and Dueck 1991; Richard et al. 1998; Stewart 2001; Harwood and Smith 2002). Beluga behaviour at fast-ice edges is impacted by the location of the edge in relation to the migration route (i.e. whether or not the ice is blocking their travel) and includes directed movement (Bradstreet 1982; Cosens and Dueck 1991; Huntington et al. 1999), back and forth movement (Cosens and Dueck 1991), circling (Cosens and Dueck 1991), diving under the ice (Bradstreet 1982) and under-ice feeding (Huntington et al. 1999). Bowhead whales also engage in under-ice feeding (Carroll et al. 1987).

Within the Arctic, belugas and bowheads follow a migration pattern largely dictated by sea ice conditions (Department of Fisheries and Oceans 2002; Ainley et al. 2003). They migrate into seasonally ice-covered regions in spring, following break-up, and migrate out in fall, prior to freeze-up. The eastern Beaufort Sea (EBS) populations of bowheads and belugas over winter in the Bering Sea (Fraker 1979). The timing and direction of the spring migration of both whales is influenced by ice conditions (Fraker 1979; Carroll and Smithhisler 1980; Huntington et al. 1999; Mymrin et al. 1999; Moore and Reeves 1993). Generally by late April and early May the whales are travelling through the waters of northwestern Alaska (Fraker 1979). Travelling through leads far offshore, bowheads reach the EBS in early to mid-May (Braham et al. 1980) while belugas arrive in mid to late May (Fraker 1979). Their first destination is the Amundsen Gulf and the Cape Bathurst polynya and flaw lead system (Fraker 1979); regions that are also used throughout the summer (Stirling 1980). Belugas are believed to feed for four to six weeks in Amundsen Gulf (Fraker 1979; Stirling 1980) before part of the population migrates west to the Mackenzie estuary (Fraker 1979; Richard et al. 2001). Similarly, bowheads also occupy the area near Cape Bathurst earlier in the year than the region of the Mackenzie Delta (Fraker and Bockstoce 1980). The Cape Bathurst polynya is believed to be an important feeding ground for both belugas and bowheads in the spring (Stirling 1980).

In 2007 and 2008, the EBS was the target of extensive scientific research during the International Polar Year (IPY) Circumpolar Flaw Lead (CFL) System Study (Barber et al. 2010). As part of the CFL study, beluga and bowhead ice edge use was to be investigated using the CCGS Amundsen Research Icebreaker and aerial surveys. Due to relatively low ice concentrations and ice extent in the spring of 2008 (Fig. 3.1), we focused our investigation on Franklin Bay. We documented the occurrence, behaviour, and habitat use of an aggregation of belugas and bowheads at the Franklin Bay fast-ice edge in June 2008.

3.3 MATERIALS AND METHODS

3.3.1 Study area

The study area is in Franklin Bay, Northwest Territories, Canada. This bay is situated in the south-eastern Beaufort Sea, on the east side of Cape Bathurst (Fig. 3.2). Oceanic water masses in the Beaufort Sea include a surface layer of Pacific origin (McLaughlin et al. 1996) that circulates in a clockwise direction (Coachman and Aagaard 1974), a region, below the top 40 to 60 m, where circulation is reversed and known as the Beaufort undercurrent (Aagaard et al. 1989). Waters of Atlantic origin are found between 200 and 600 m (McLaughlin et al. 1996). Franklin Bay, reaches maximum depths of 220 m and a major river, the Horton River, drains into its west side (Fig. 3.2). On average, freeze-up in Franklin Bay begins in September while break-up starts in late June or early July (Galley et al. 2008). Until 21 June 2008, a fast-ice edge was present in the bay, extending to the mouth of the Horton River. On 21 June, large fractures formed in the ice and, by 22 June, those fractures widened to the point where there was considerable open water in the bay (Fig. 3.3).

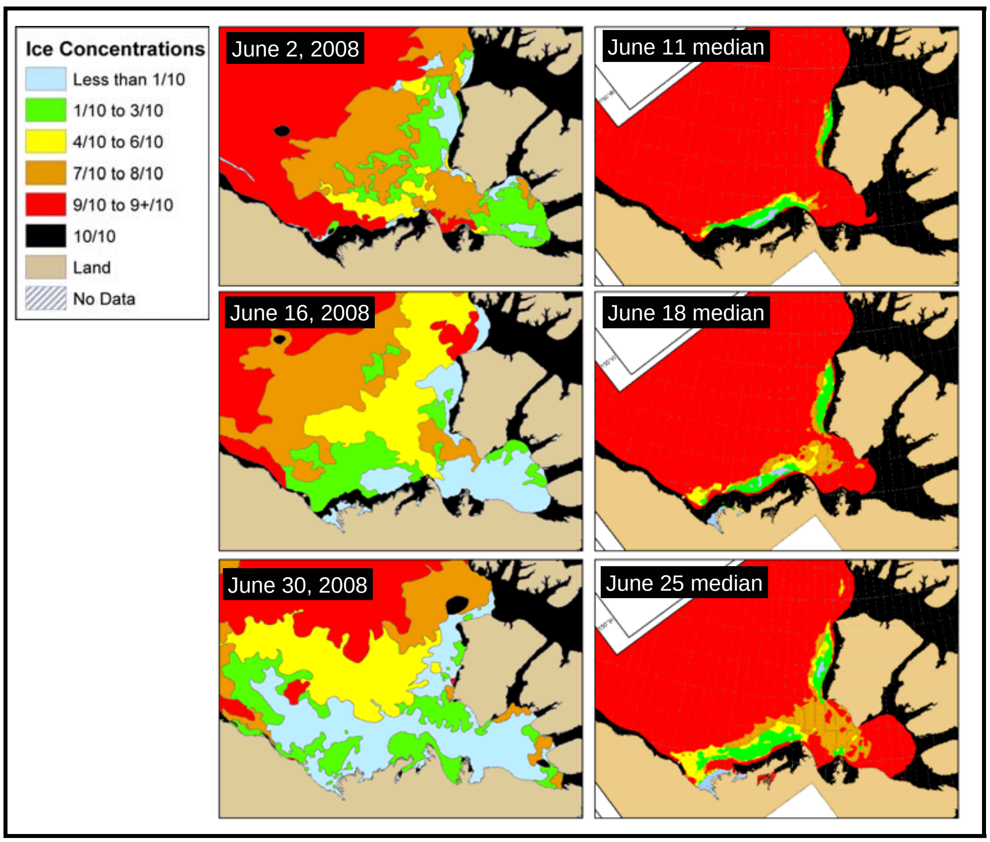

Fig 3.1 Ice concentrations for June 2, 16 and 30, 2008 (left and created in ArcGIS 9.2 with .e00 files from Canadian Ice Service, Environment Canada) and 30-year median ice concentrations from 1971 to 2000 for June 11, 18 and 25 (right and from Canadian Ice Service, Environment Canada - http://www.ec.gc.ca/glaces-ice/default.asp?lang=En&n=E4B3AD2B-1- accessed September 17 2010)

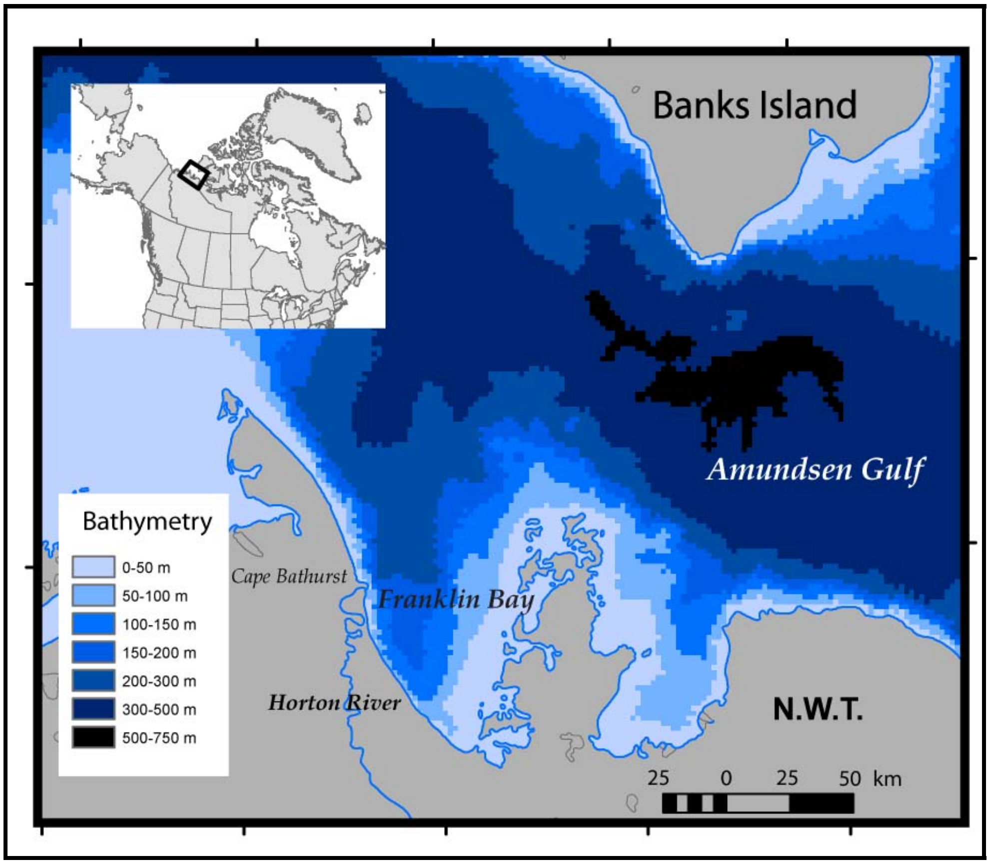

Fig 3.2 Study area (bathymetry from Jakobsson et al. 2008)

3.3.2 Aerial Surveys

A helicopter (Messerschmidt BO 105) was used to conduct aerial surveys and to record beluga and bowhead behaviour at the Franklin Bay fast-ice edge. Ice edge surveys were conducted on June 11, June 15, June 16, June 18 and June 21 (Fig. 3.3). On June 24, a final survey was flown through the survey area after the fast-ice had broken up (Fig. 3.3). In all cases, the helicopter flew along the fast-ice edge at 305 m (1000 ft.) from west to east at 185 km/hr. The position of the helicopter was logged every 2 seconds on a Global Positioning System (GPS) unit. An experienced whale observer (NA), sat in the front left seat and counted

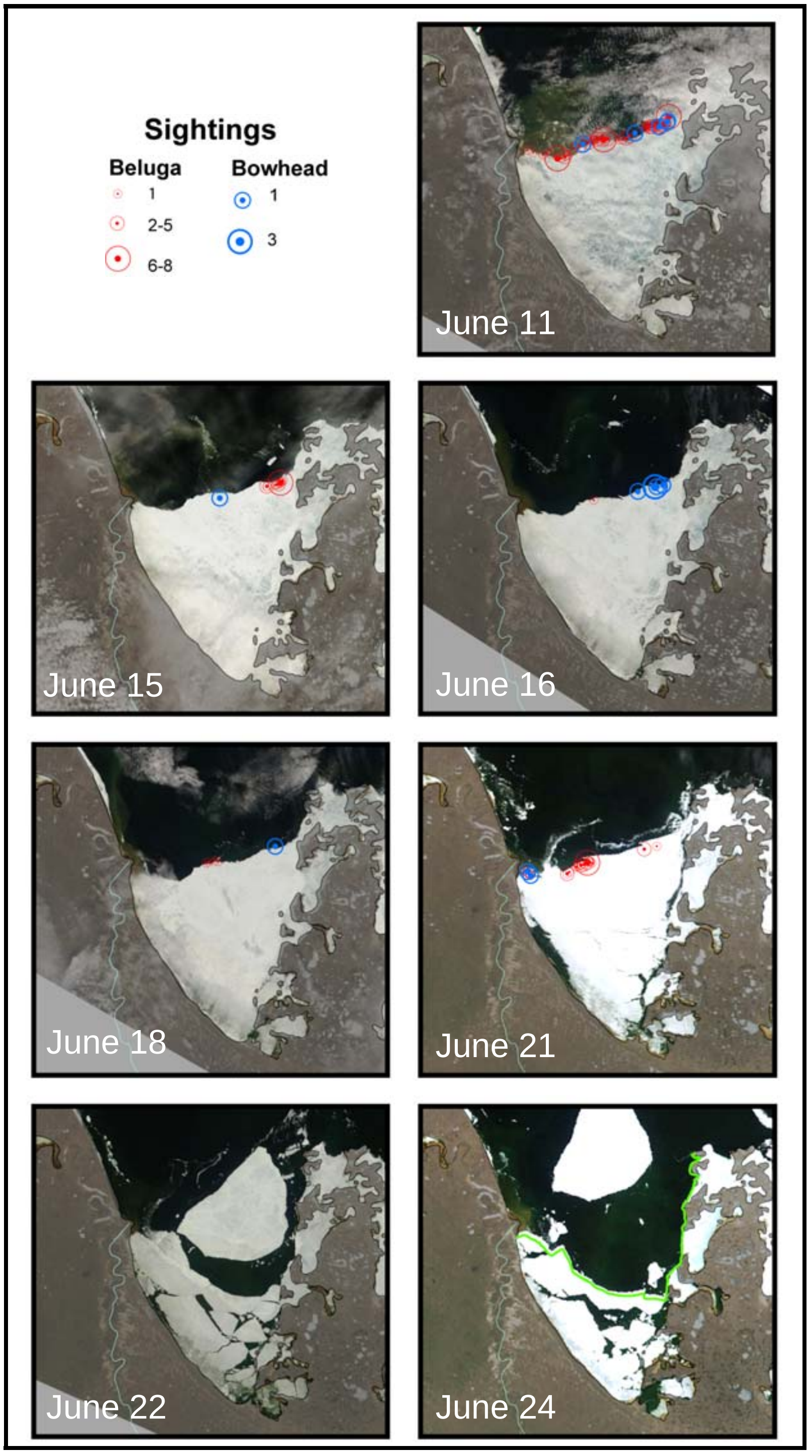

Fig 3.3 Beluga and bowhead sightings from the five surveys conducted along the Franklin Bay ice edge (June 11-21), June 22 ice conditions and June 24 survey track (in green). The Horton River is shown in blue and MODIS Terra images (NASA/GSFC, MODIS Rapid Response, available at http://rapidfire.sci.gsfc.nasa.gov/realtime) are used in all of the maps to show ice conditions.

all sightings of belugas and bowheads. Direction of travel was also noted when possible. When sightings were very numerous, the helicopter slowed down to allow for complete counts of visible animals prior to continuing along the ice edge.

Two additional flights were conducted on June 15 and June 21 to study behaviour at the floe edge. During these flights, the helicopter flew at an altitude of 305 m (1000 ft.) along the fast-ice edge until a group of animals was encountered. The aircraft then slowed or hovered and a Sony HDR-HC3 handheld video camera was used to film activity. Whales were monitored to ensure that their behaviour was not impacted by the presence of the helicopter. Following Patenaude et al. (2002), a disturbance response was defined as unusual behaviour such as vigorous swimming, abrupt dives, tail slapping or animals orienting away from the aircraft.

3.3.3 Data processing

Using the GPS log track, sightings were geo-referenced by using the location of the helicopter as an approximation of the location of the sightings. The videos from the behavioural flights were viewed to time complete dives and surface intervals (i.e. time spent at the surface between dives). For groups, the start and end of a dive were determined by the first animal diving or surfacing. Surfacing times for groups were calculated in the same way. For the purpose of our research, a group was defined as individuals within one body length of each other and behaving cohesively. When possible, dives were classified as shallow or deep based on the angle of descent of the animals (Fig. 3.4).

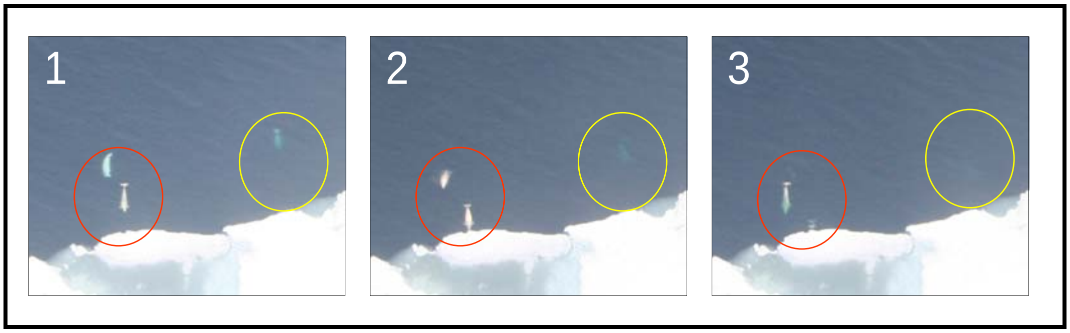

Fig 3.4 Examples of shallow dives (circled in red) and a deep dive (circled in yellow)

3.3.4 GIS Methods and Analytical Methods

Using ArcGIS 9.2, locations of beluga and bowhead sightings were overlaid on a bathymetric raster layer of the region and a vector layer of the Northwest Territories (Geogratis http://geogratis.cgdi.gc.ca/). The bathymetric layer was generated from the International Bathymetric Chart of the Arctic Ocean (IBCAO ver 2.23 http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/). This dataset was produced using a combination of depth soundings from ships, contour maps and gridded sources to produce a 2 km/2 km grid in Polar Stereographic projection (Jakobsson et al. 2008). We calculated the seafloor slope in ArcGIS 9.2 from the IBCAO dataset using a pixel size of 2 km X 2 km.

Following Davis et al. (1998), a Kruskal-Wallis one-way analysis of variance was run in Systat 11 to test whether beluga and bowhead locations differed with respect to depth, seafloor slope and distance to the mouth of the Horton River. We used ArcGIS 9.2 to determine the values of these three environmental descriptors at each sighting location. Water depth and seafloor slope were used as explanatory variables because these two factors have been found to correlate with the distribution of belugas in the eastern Beaufort Sea in June (Asselin et al. 2010). The choice of distance to the mouth of the Horton River as a third explanatory variable reflected the fact that belugas enter estuaries in large numbers after break-up in late-spring/early-summer (Norton and Harwood 1985; Caron and Smith 1990; Frost and Lowry 1990; Harwood et al. 1996; Martin et al. 2001; Innes et al. 2002; Hobbs et al. 2005; Lewis et al. 2009) and we wanted to test if the location of the river correlated with their distribution in spring.

3.4 RESULTS AND DISCUSSION

During the five surveys along the Franklin Bay fast-ice edge, a total of 192 belugas and 15 bowheads were spotted (Table 3.1). Juveniles of both species were also present including at least one neonate beluga sighted on June 15. Numbers of belugas sighted in one survey ranged from 1 (June 16) to 100 (June 11) while the numbers of bowheads sighted ranged from 1 (June 15 and June 18) to 6 (June 16) (Table 3.1, Fig. 3.3). On June 24, following break-up of the fast-ice, no belugas or bowheads were observed in the bay during the survey (Fig. 3.3). The aggregation of a hundred or so belugas identified on June 11 along the fast-ice edge was notably larger than any other groups seen in the region that spring. Multiple helicopter and fixed-wing flights had been conducted since early May and failed to identify any large aggregations in the region (Fig. 3.5). These flights included dedicated ice edge/polynyas surveys, conducted by NA in a DeHavilland Twin Otter aircraft (Fig. 3.5, Fixed-wing surveys), one helicopter survey (Fig. 3.5, Helicopter survey), also conducted by NA, as well as reconnaissance flights conducted by the captain of the CCGS Amundsen to help plan out routes for the ship. NA accompanied the captain on five of these reconnaissance flights to observe for marine mammals (Fig. 3.5, Helicopter reconnaissance).

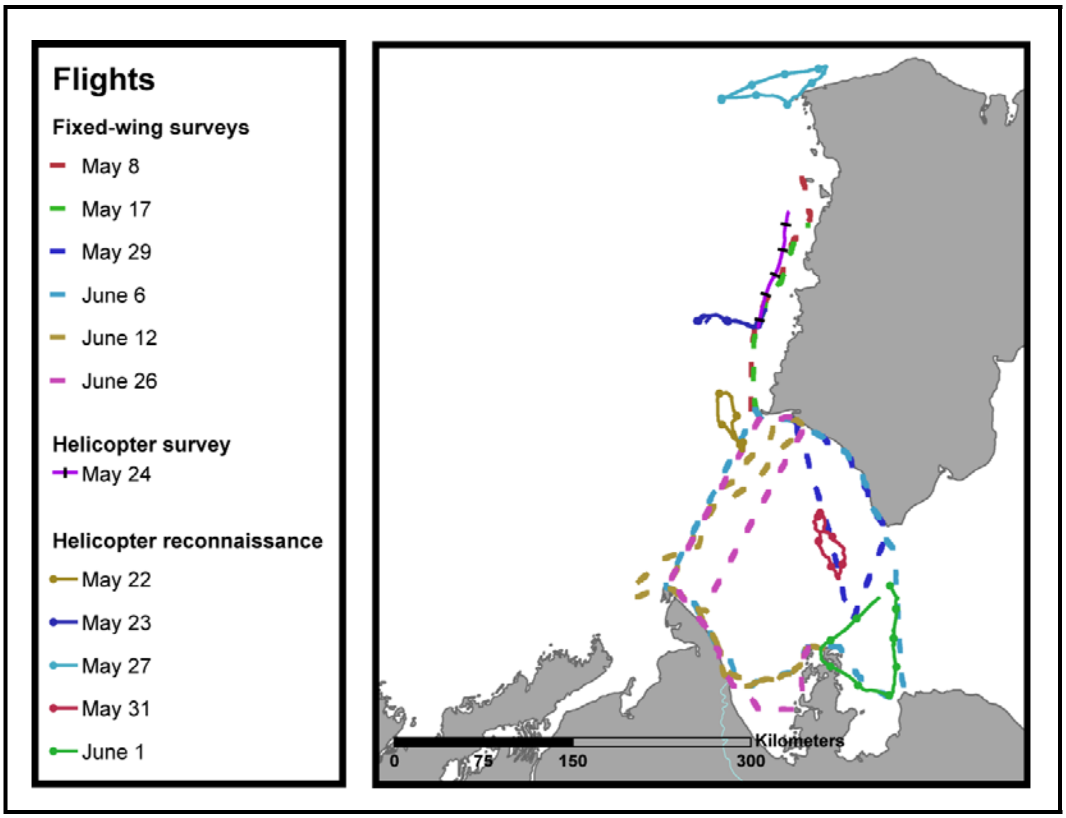

Fig 3.5 Flights in study region

As the Franklin Bay ice edge did not block their migration path, which is generally east-west (Department of Fisheries and Oceans 2000), we hypothesize that this floe edge habitat must have been a bigger draw for belugas than the surrounding open-water areas. While Asselin et al. (2010) concluded that EBS belugas preferred pack ice covered regions (8/10 to 10/10 ice concentrations) in June; they noted that in light ice years belugas may also use fast-ice edges. In the spring of 2008, the relatively low ice concentrations in the EBS may have lead belugas to exploit this fast-ice edge environment. During the June 24 survey, after break-up, belugas and bowheads were no longer observed in the survey area (Fig. 3.3).

Table 3.1 Summary of survey observations

Date	Survey Length (km)	Beluga count	Bowhead count
June 11	85	100	5
June 15	88	24	1
June 16	80	1	6
June 18	87	4	1
June 21	75	63	2
June 24	133	0	0

3.4.1 Behaviour at fast-ice edge

Generally, belugas and bowheads were engaged in traveling or diving behaviours. Not many animals were observed resting at the surface. Much of the traveling was parallel to the ice edge, in a general westerly or easterly direction, while some individuals were observed swimming towards or away from the ice edge. Both shallow and deep dives (based on the body angle) were observed for belugas travelling and for belugas diving in proximity to or under the ice. On June 15, of 18 beluga dives that were classified for depth, 10 were shallow while 8 were deep. Bowheads were observed resting at the surface, travelling and diving. The orientation of the belugas and bowheads was noted for 83 and 8 individuals respectively. Of these sightings, belugas were oriented west (n=47, 56.6%), east (n=22, 26.5%), towards the ice (n=10, 12.0%) and away from the ice (n=4, 4.8%). In the case of bowheads, they were oriented west (n=3, 37.5%), towards the ice (n=4, 50.0%) and away from the ice (n=1, 12.5%). On June 15, 25 belugas were observed and videotaped during a 20 minute period. The results presented are for dive durations and surface intervals of groups. Group size was found to be dynamic, with animals joining and leaving groups, and ranged from 1 to 5 individuals. While some animals swam along the edge in an easterly or westerly heading, we focussed on animals that interacted with the ice edge. Notably, some belugas were observed to first swim along the ice-edge and then turn abruptly to dive under the ice. We were able to time five of these under-ice dives and they had an average duration of 106±27 sec ($\bar{x}$±SE) and a range of 30-197 sec. Four surface intervals were also timed and found to have an average duration of 52±12 sec ($\bar{x}$±SE) and a range of 23-77 sec. On June 21, one bowhead under-ice dive was timed and had a duration of 297 seconds (0:04:57).

While average dive and surface-interval duration can provide information on general beluga activity, the detailed activities of individuals or beluga groups can help elucidate the potential role of the ice edge. Two examples of behaviour observed on June 15 follow.

3.4.1.1 Example 1

One beluga, observed for 130 seconds, came out from under the ice as it surfaced from depth. After a 23 second surface-interval, it executed a 30 second deep dive in the same region as its initial surfacing. The beluga then spent 77 seconds at the surface and swam back and forth along the ice edge prior to diving once again in the same spot.

3.4.1.2 Example 2

A group of three belugas, observed for 452 seconds, was first seen swimming along the ice edge heading east. They then turned and dove under the ice edge in succession. They emerged from the ice 121 seconds later with a fourth individual. The group of four belugas then spent 43 seconds at the surface swimming along the ice edge and doing small dives before diving under the edge, at a shallow angle, once again in succession. After 197 seconds, the group of four belugas re-emerged (Fig. 3.6.1) with a fifth whale close behind (Fig. 3.6.2). The group of four then appeared to chase the fifth beluga (Fig. 3.6.3). After 64 seconds at the surface, the group of four dove under the ice edge once again at a shallow angle while the fifth whale dove deeper (Fig. 3.6.4, 3.6.5 and 3.6.6).

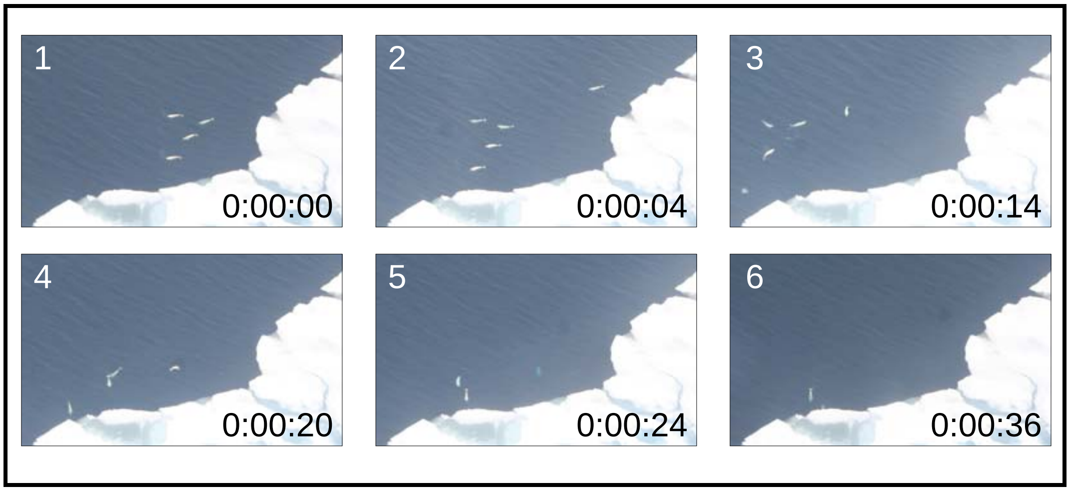

Fig 3.6 Sequence of movements of a group of 4 belugas interacting with a lone beluga. Time stamps indicate elapsed time from image 1 (0:00:00).

Diving under fast-ice has also been reported in the spring in Norton Bay, Alaska where belugas feed first on herring and later on tomcod under the ice (Huntington et al. 1999). Mymrin et al. (1999) indicate that when belugas are feeding at the ice edge in the Northern Bering Sea they dive under the ice as a group and re-surface to breathe in the same place. In contrast, they report that, when migrating, belugas swim in one direction and move rapidly out of sight (Mymrin et al. 1999). The similarities in the behaviours described by Huntington et al. (1999), Mymrin et al. (1999) and those of the belugas we observed in Franklin Bay in June 2008 suggest that they were feeding under the ice.

Beluga forage on a large variety of fish species and invertebrates (Kleinenberg et al. 1964; Seaman et al. 1982) but Arctic cod (*Boreogadus saida*) has been identified as their main prey throughout the Arctic (e.g. Kleinenberg et al. 1964; Heide-Jørgensen and Teilmann 1994; Dahl et al. 2000; Loseto et al. 2009). Arctic cod is considered ice associated and has been observed beneath sea ice as well as within its cracks and crevices (e.g. Bradstreet 1982; Percy et al. 1985; Lønne and Gulliksen 1989; Crawford and Jorgenson 1990, 1993; Gradinger and Bluhm 2004). Arctic cod have also been found at depth in Admiralty Inlet (Crawford and Jorgenson 1990) and, notably, in Franklin Bay, in March and April (Benoit et al. 2008). However, Craig et al. (1982) indicate that Arctic cod are not numerous in near shore habitats during the start of the open-water season. It is possible that belugas at the Franklin Bay ice edge were under-ice feeding (for shallow dives) and benthic foraging (for deep dives) on Arctic cod, but other prey items may have also contributed to the attraction of the floe edge at that time.

Belugas, with their wide feeding spectrum (Kleinenberg et al. 1964), may have been exploiting a variety of prey. In coastal waters of western Alaska in summer, belugas consume saffron cod (*Eleginus gracilis*), sculpins (Family Cottidae) and various salmon species (Seaman et al. 1982) while belugas in the Mackenzie River estuary consume Arctic cisco, burbot and whitefish (Harwood and Smith 2002). In Norton Bay Alaska in spring, belugas feed under the ice on herring and tomcod (Huntington et al. 1999). Pacific herring (*Clupea palasii*) is the main fish caught in Franklin Bay (Percy et al. 1985) and they are known to aggregate for spawning in sub-tidal waters in spring (Hay 1985). Ruben Ruben, an Inuvialuit fisherman and hunter from Paulatuk, NWT, stated that belugas would have been feeding on herring at the Franklin Bay ice edge in June 2008 (R. Ruben, personal communication, November 2009). We consequently hypothesize that Pacific herring may have been the main prey of belugas observed diving along and under the ice in Franklin Bay in June 2008.

The behaviour of the group of four belugas in example 2 (above and Fig. 3.6) first resembled feeding behaviour, as described by Mymrin et al. (1999). They also displayed aggressive behaviour towards the fifth whale which matches the description of a chase and possibly a charge given in the beluga ethogram (developed with belugas in captivity) in DiPaola and Akai (2007). In other odontocetes, instances of aggression are often related to male-male competition (Norris 1967; MacCleod 1998; Scott et al. 2005). Loseto et al. (2006) hypothesized that smaller male belugas in the EBS in summer may be segregating from large males partly to avoid aggression. We consequently hypothesize that this may have been an instance of male-male competition, possibly related to foraging success.

We also observed bowheads diving repeatedly under the ice and swimming along the fast-ice edge in very close proximity to it. Near Pt. Barrow Alaska, bowheads have been observed feeding under the fast-ice in the spring (Carroll et al. 1987). Based on prey items, it was determined that the whales were mainly feeding pelagically, on copepods and euphausiids, but some near-bottom feeding was also identified (Carrol et al. 1987). Similarly, Lowry et al. (2004) identified copepods and euphausiids as the main prey of bowheads in the spring in the Alaskan Beaufort Sea. While bowheads engage in three types of feeding in the Beaufort

Sea in summer (skim-feeding at or near the surface, in the water column and at or near the bottom) (Würsig et al. 1989), stomach contents from one whale taken in August in the Mackenzie Delta contained mainly pelagic prey (Pomerleau et al. 2010). Notably, copepods make up 90% of bowhead prey biomass in the Canadian Beaufort Sea (Schell and Saupe 1993) and two copepods, *Calanus hyperboreus* and *C. glacialis,* are present in Franklin Bay in winter (Benoit et al. 2010). In Franklin Bay in May and June 2008, the three copepods *Calanus glacialis*, *Metridia longa* and *C. hyperboreus* dominated the large class of zooplankton (>1000 µm) with *C. hyperboreus* contributing the most to biomass (Gérald Darnis, unpublished data). Large copepods are most common in bowhead stomach contents (Lowry 1993). Based on these findings, we conclude that bowheads observed diving under the ice in Franklin Bay were mainly engaged in pelagic feeding on copepods. Those observed swimming along the ice edge were either skim-feeding, also on copepods, or traveling. While we did not see any indication of bottom feeding, such as mud emanating from the mouths of bowheads (Würsig et al. 1989), we cannot exclude this possibility.

3.4.2 Differences in the distribution of beluga and bowhead

The distribution of water depths of beluga sightings differed significantly from that of bowhead sightings (KW=6.018, df=1, p=0.014) with belugas on average being in deeper waters (Fig. 3.7, Table 3.2). Also, belugas were significantly closer on average to the mouth of the Horton River than bowheads (KW= 4.058, df=1, p=0.044) (Fig. 3.7, Table 3.2). Beluga and bowhead sighting locations did not differ significantly with respect to seafloor slope (KW=0.742, df=1, p=0.389) (Fig. 3.7, Table 3.2).

Table 3.2 Beluga and bowhead descriptive statistics for environmental characteristics

Species	*n*	Statistic	Seafloor slope (deg.)	Depth (m)	Distance to Horton River (km)
Beluga	192	mean (SE)	0.44 (0.02)	129 (4.3)	33.7 (1.1)
		median	0.35	162	30.1
		minimum	0.09	34	4.3
		maximum	1.20	194	56.8
Bowhead	15	mean (SE)	0.50 (0.08)	86 (11.3)	42.3 (4.4)
		median	0.43	72	50.7
		minimum	0.18	36	5.5
		maximum	1.19	194	56.2

In the Alaskan Arctic, in summer and fall, belugas were also found to use deeper waters than bowheads, reflecting the differences in their feeding modes and prey items (Moore and DeMaster 1998). The differences in distribution we found for belugas and bowheads (water depth and distance to the Horton River) are also likely due to the different feeding ecology of belugas and bowheads. While EBS bowheads consume fairly specific prey, eating mainly copepods in the EBS (Lowry 1993), belugas are able to exploit a variety of prey species (Kleinenberg et al. 1964; Seaman et al. 1982). Consequently, while the range in depth distributions for belugas and bowheads are similar (Table 3.2) the 50th percentiles of those values is narrower for bowheads than it is for belugas (Fig. 3.7). This may indicate that belugas are foraging on a variety of prey, distributed at various depths; while bowheads are restricted to a few species associated with a narrower depth range. Similarly, the relative proximity of belugas to the Horton River may indicate they are also exploiting nearshore or riverine resources. In the Mackenzie

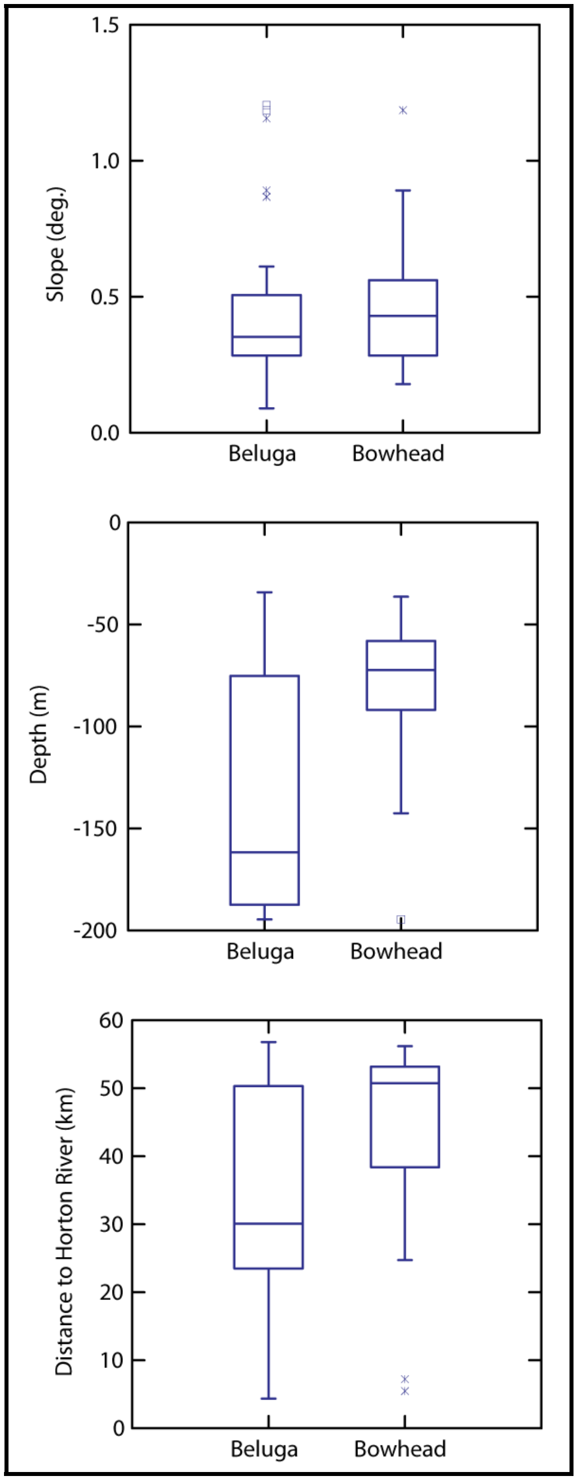

Fig 3.7 Box plots of the seafloor slope (top), the water depth (middle) and the distance to the Horton River (bottom) for beluga and bowhead sightings. The box encompasses the middle 50% of values with the mid-line indicating the median. The whiskers extend to 1.5 X the interquartile range while x's indicate near outliers and o's indicate far outliers.

estuary, belugas consume Arctic cisco (*Coregonus autumnalis*), burbot (*Lota lota*), and whitefish (*Coregonus* spp.) (Harwood and Smith 2002) and we hypothesize that they may be doing the same in the plume of the Horton River. The lack of difference in the seafloor slope distribution between bowhead and beluga sightings may indicate that this variable does not vary sufficiently in Franklin Bay to measure a significant difference, or that belugas and bowhead relate to seafloor slope similarly.

These results must be interpreted cautiously as the data were not collected through a systematic survey to compare the presence at the ice edge to offshore regions. Consequently, further research is needed to conclusively ascertain why belugas and bowheads were at the Franklin Bay ice edge. A larger sample size, especially for bowhead whales, would assist in understanding the differences in habitat selection for these two species. Large-scale, systematic surveys could better explain the importance of fast-ice edges to both whale species and determine their respective overall spring distributions within the EBS. However, this is the first description of beluga and bowhead activity at a fast-ice edge in the EBS. The presence of belugas and bowheads, along with the probable feeding behaviour, identified at the Franklin Bay ice edge underlines the importance, noted by others (Stirling 1980; Dunbar 1981; Stirling 1997) of ice edges and polynyas to Arctic marine mammals. Notably, belugas have been found to select areas with heavy ice concentrations in spring (Asselin et al. 2010) while the same has been found for bowheads in summer (Ferguson et al. 2010). Dunbar (1981) emphasized that it was the ice edge, as opposed to the open water, that appeared to be key to the biological importance of polynyas. For cetaceans in the Arctic, which rely on dense aggregations of prey (Moore and DeMaster 1998), the selection of ice covered habitat is likely linked to foraging success. We consequently hypothesize that the Franklin Bay fast-ice edge may provide higher than average concentrations of zooplankton, needed by bowheads to meet their energetic needs (Lowry 1993), and the presence of one or many fish prey species on which beluga are foraging.

In the context of climate change, our results support the conclusion of Laidre et al. (2008) that Arctic cetaceans have some resilience to climate change, partly due to their lower sensitivity to sea ice changes than other Arctic marine mammals. This is particularly important as a significant decline in the spring ice extent in the Arctic Ocean has already been reported (Parkinson and Cavalieri 2008). Although Asselin et al. (2010) found belugas preferred heavy ice cover and water depths of 200-500 m in spring, which they attributed to prey distributions; our results confirm that belugas also exploit fast-ice edges. Notably, belugas in west Greenland have been found to shift their distribution in response to changes in sea ice extent (Heide Jorgensen et al. 2010). Bowheads have been found to have improved body condition during low ice years; possibly due to increased primary productivity (George et al. *unpublished manuscript*). Belugas in the EBS may adapt to a loss of sea ice by concentrating their foraging effort in areas with dependable concentrations of prey, such as ice edges, while bowheads may thrive in an environment with less sea-ice extent. However, due to the springtime coupling of sea ice extent and phytoplankton (Heide Jorgensen et al. 2007) it is likely the spring feeding habitat of bowheads will be altered by climate change. Further research is needed to conclusively assess the impacts of a changing climate on these two cetaceans in the EBS.

The identification of an aggregation of belugas and bowheads at the Franklin Bay ice edge underlines the importance of this habitat to whales in the spring in the EBS. The respective distributions of belugas and bowheads differed in terms of water depth and proximity to the Horton River with belugas being both in deeper water and closer to the Horton River mouth. While belugas and bowheads were observed travelling along the ice edge, both species also engaged in repeated dives under the ice. These dives are consistent with feeding behaviour observed in other locations and provide further evidence of the biological importance of ice edges and polynyas to marine mammals. While we could not conclusively identify prey species with the data available, we hypothesize that belugas and bowheads may find higher than average concentrations of prey at the Franklin Bay ice edge in the form of a variety of fish species (for belugas) and abundant zooplankton (for bowheads). Further research is needed to fully examine the distribution of belugas and bowheads in spring in the EBS and to investigate the prey species being targeted by foraging dives.

3.5 ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance in the field of the officers and crew of the CCGS Amundsen and particularly of the helicopter pilots Guillaume Carpentier and Serge Arsenault. Klaus Hochheim also provided field support and the photos used in figures 3.4 and 3.6. This work was supported by the Natural Sciences and Engineering Research Council (NSERC) of Canada, the Canada Research Chairs (CRC) program, the Department of Fisheries and Oceans and ArcticNet. This is a contribution arising from the International Polar Year (IPY) Circumpolar Flaw Lead (CFL) System Study project.

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CHAPTER 4: CONCLUSION

4.1 FINDINGS

In order to understand the importance of the circumpolar flaw lead to belugas, as well as their distribution and habitat selection in the eastern Beaufort Sea (EBS) in spring, two techniques were used. First, chapter 2 looked at the overall distribution of belugas within the study region and addressed large-scale habitat associations using a historical dataset from 1975 to 1979. This chapter established a general distribution pattern and a baseline from which to study changes over time. Second, chapter 3 looked at a specific area, the Franklin Bay ice edge, to further explain the finer-scale habitat selection and behaviour of belugas and bowheads within one type of habitat found in the EBS in spring: fast-ice edges.

Evaluating the distribution of belugas throughout the EBS lead to the determination that belugas mainly select areas with 200-500 m of water depth and heavy ice concentrations (8/10 to 10/10) in spring (chapter 2). In the lightest ice year for which distribution was analyzed (1975), I found that belugas may also select fast-ice edges and coastal regions (chapter 2). The selection of fast-ice edge habitat is particularly interesting as this is a region where fast-ice is not hindering the movement of belugas to summer feeding grounds. By examining the behaviour of belugas and bowheads at the Franklin Bay ice edge in June of 2008, it was established that both of these animals were likely engaged in feeding (chapter 3). These findings indicate that fast-ice edges may provide a persistent and concentrated supply of prey in spring, particularly when the offshore pack is either distant or lacking.

This research provides the first description of the distribution of belugas in spring in the EBS. These results can be used both to better understand the habitat selection of belugas in spring but also as a baseline from which to study the impacts on belugas of climate change and the associated decrease in ice extent and concentrations. Furthermore, this research is the first extensive description of beluga habitat selection in spring anywhere within the circumpolar Arctic. While belugas had been observed in spring throughout the Arctic (ex. Bradstreet and Finley 1977; Bradstreet 1982; Cosens and Dueck 1991; Crawford and Jorgenson 1990; Harwood and Smith 2002) this is the first systematic study of their distribution throughout a region. Consequently, while fast-ice edges were previously considered an important feeding habitat for belugas in spring, my findings indicate that in years with average to heavy ice years, belugas do not select fast-ice edges.

However, in light ice years, such as 1975 (chapter 2) and 2008 (chapter 3), I found that belugas possibly shift or expand their distribution to take advantage of fast-ice edges and coastal regions. I hypothesize that ice-edges may provide a higher concentration of prey than adjacent open water. This is the first description of beluga and bowhead behaviour at a fast-ice edge in the EBS in spring. My research identified that feeding may occur at fast-ice edges and that this habitat can be of importance to belugas and bowheads in the spring.

4.2 DISCUSSION

Environmental factors leading to the observed distribution in the study area could not be determined conclusively with the data available. Habitat selection is generally the result of inter-related factors such as mating, feeding and predator avoidance. As belugas are believed to mate in April-May, and calves are born from late June to early August (Department of Fisheries and Oceans 2002), the observed distribution in the EBS spring is likely due to a combination of predator avoidance and foraging success.

Belugas are preyed upon by killer whales (*Orcinus orca*) and polar bears (*Ursus maritimus*). In the Bering Sea, belugas may seek protection from killer whales by staying within the pack ice (Fay 1974) as this predator is known to penetrate into the pack ice edge up to about 10 km from open water (Lowry et al. 1987). While killer whales are rarely reported in the EBS (Harwood and Smith 2002, Higdon et al. 2010), the preference for an ice shelter, shown by belugas in the Bering Sea, may endure in other regions used by these same animals. This could partially explain their preference for heavy ice concentrations (8/10-10/10) described in chapter 2. Polar bears are known to hunt belugas when they surface in holes in the ice and along leads (Lowry et al. 1987). However, Beaufort Sea polar bears mainly consume ringed seal (*Phoca hispida*) and bearded seal (*Erignathus barbatus*) (Thiemann et al. 2008) making it unlikely that their predation has a large impact on beluga movement or habitat choice.

A more likely explanation for the observed beluga distribution, as discussed in chapters 2 and 3, is that it is due to prey distributions. While Arctic cod (*Boreogadus saida*) is their main prey in many regions (Kleinenberg et al. 1964, Heide-Jørgensen and Teilmann 1994, Dahl et al. 2000, Loseto et al. 2009), belugas feed on a large variety of fish species and invertebrates (Kleinenberg et al. 1964, Seaman et al. 1982). This generalist feeding strategy enables belugas to exploit a range of habitats. Consequently, while belugas may show a preference for areas with heavy ice concentrations in spring when these are available (chapter 2) they also have the ability to exploit fast-ice edge resources (chapter 2 and chapter 3). As noted in chapters 2 and 3, further research is needed to understand the EBS spring distribution of beluga prey, particularly Arctic cod. More research is also needed to determine the beluga spring diet composition. Specifically, the associations between prey species, sea ice and bathymetry need to be examined to understand the cause of the beluga distribution described in chapter 2. Also, work in both fast-ice and pack-ice habitats is needed to determine whether age and sex classes of ESB belugas are found in each habitat and what activities are taking place (e.g. feeding, traveling or resting).

My findings support the conclusion by Laidre et al. (2008) that belugas are moderately-sensitive to climate change. Their wide distribution and flexibility in habitat selection contributes to their resilience (Laidre et al. 2008). However, it is also possible that different age and sex classes of EBS belugas are segregating between the available spring habitats, as they are known to do during the open-water season (Loseto et al. 2006). Sex, age and reproductive status of belugas have been show to affect the habitat selection of belugas in the western and eastern Arctic (Barber et al. 2001; Richard et al. 2001, Loseto et al. 2006). The survey dataset used in chapter 2 did not contain information on these factors, but calves were observed along the fast ice-edge in Franklin Bay in June 2008 (chapter 3). Females and calves select open water habitats near mainland during the open-water season (July to freeze-up) (Loseto et al. 2006).

The question of whether belugas use a variety of habitats due to sex and age class segregation is of particular importance in the context of climate change. While the Intergovernmental Panel on Climate Change (IPCC 2007) anticipates climate change will have greater impacts overall in Polar Regions, Parkinson and Cavalieri (2008) reported a significant decline in the spring ice extent in the Arctic Ocean from 1979 to 2006. Sea ice concentrations and extent are both expected to decline in the future (Barber et al. 2008). These changes in sea ice extent and concentrations will alter habitats available to belugas. Offshore regions may become more accessible, resulting in belugas expanding their ranges into them. In west Greenland, belugas surveyed in March and April dispersed more widely and shifted their distribution northward and westward (offshore) when the pack ice extent was reduced (Heide-Jørgensen et al. 2010). As belugas are already found in offshore regions with heavy ice cover in the EBS (Chapter 2, Barber et al. 2001, Richard et al. 2001), a reduction in ice extent may not lead to an increase in their range. Furthermore, if only some sex and age classes of belugas utilize these offshore regions, decreased ice extent may not benefit the population as a whole.

I also found that EBS beluga select against open water in the spring, regardless of the extent of sea ice cover (chapter 2). In June 2008, no aggregations of beluga were seen in open water. Consequently, if sea ice extent in the Arctic declines in the future as predicted (Barber et al. 2008) belugas may have to contract their spring distribution to remain within the pack ice. If belugas do concentrate within remnant ice-covered areas, their sensitivity to climate change would effectively increase. Notably, Dunbar (1981) indicated it was the ice edge, as opposed to the open water, that was responsible for much of the biological productivity associated with polynyas. This may explain the lack of selection for open-water observed by EBS belugas in spring.

Beyond the reductions in sea ice extent and concentrations associated with climate change, Comiso (2003) reports that the Beaufort Sea experienced a warming in surface temperature from 1981 to 2001. Ocean temperature is thought to be critical to the distribution of cetaceans elsewhere in the world, having both direct impacts (i.e. on the animal itself) and indirect impacts (i.e. on the distribution of their prey) (Martin and Reeves 2002). Consequently, belugas could be further impacted by climate change if the distribution of their prey changes. This is of particular importance in the Arctic where cetaceans depend on areas with higher than average concentrations of prey to meet their caloric needs (Moore and DeMaster 1998).

4.3 FUTURE RESEARCH AND CONCLUSIONS

Further research is needed to document the present spring distribution of belugas in the EBS and to identify changes that have happened over the last 30 years as well as the impacts of the reported changes in ice extent (Parkinson and Cavalieri 2008) and surface temperature (Comiso 2003). By repeating the extensive surveys completed by the Canadian Wildlife Service in the 1970s, the impacts of climate change and other human-induced habitat changes could be studied not only for belugas but also for other EBS marine mammals (e.g. ringed seals, polar bears and bowhead whales). Specific to belugas, by using the spring beluga distribution from the 1970s (chapter 2), changes in distribution could be measured. Such research would enable us to improve predictions on future impacts of climate change on the distribution and viability of the EBS beluga population.

Determining if habitat segregation observed during the open-water season (Loseto et al. 2006) occurs in other seasons would help determine the sensitivity of belugas to environmental changes. Techniques could include equipping belugas with satellite-linked transmitters during their spring migration through coastal

Alaskan waters which would provide detailed information about movements and habitat use. Biopsy samples could also be collected to determine the sex and reproductive status of the animals. Unfortunately, research using satellite-linked transmitters and/or biopsy samples often relies on a few individuals to draw conclusions about an entire population. Another approach would be to combine the use of satellite-linked transmitters with extensive visual aerial surveys, such as those conducted in the 1970s by the Canadian Wildlife Service (see chapter 2). By combining these techniques, the shortcomings of each can be overcome. Aerial surveys provide large sample sizes while satellite-linked transmitters provide detailed movement data and biopsy samples allow for the determination of sex.

From the observations of belugas collected in June 1975-1979, I concluded that despite a large degree of inter-annual variation in sea ice concentrations and extent, belugas consistently showed a preference for heavy ice concentrations (8/10 to 10/10) and water depths of 200-500 m while areas with open water to light ice concentrations (0/10 to 1/10) were not selected. Regions with higher seafloor slope (≥0.5°) were also selected. In average to heavy ice years, fast-ice edges and coastal areas were not selected while in light ice years, belugas may be more dispersed or shift their distribution shoreward to take advantage of these habitats. The presence of a large aggregation of belugas and bowheads at the Franklin Bay fast-ice edge in June 2008 emphasized the importance of this habitat to whales in the spring in the EBS. Both species were engaged in dives consistent with foraging behaviour observed in other locations providing further evidence of the biological importance of ice edges and polynyas to marine mammals. While the factors determining the distributions could not be conclusively ascertained with the data available, I hypothesize that the preference for 200-500 m and heavy ice concentrations in the 1970s is most likely to have been influenced by under-ice and deep water foraging, mainly on Arctic cod. At the Franklin Bay ice edge, I hypothesize that belugas and bowheads found higher than average concentrations of prey in the form of a variety of fish species (for belugas) and abundant zooplankton (for bowheads). Additional research is required to further test the robustness of the observed patterns of distribution and habitat preferences and to test hypotheses about possible changes in spring distribution since the 1970s in relation to the progressive reduction in sea ice that has been linked to climate change.

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APPENDIX 1: EASTERN BEAUFORT SEA BELUGA AND BOWHEAD SIGHTINGS FROM MAY AND JUNE 2008

Date: date of sighting

Latitude and Longitude: location of observation platform (used as an approximation for the location of the animals)

Group size: number of individuals in the group. For the purposes of the helicopter surveys, the visual surveys and the aerial photographs, a group was defined as individuals within one body length of each other. Other data collection methods did not have a precise definition of a 'group'.

Method: data collection method

Aerial Photograph: observations from aerial photographs taken from a DeHavilland Twin Otter aircraft equipped with a camera hatch that flew at an altitude of 914 m and a speed of 222 km/h. Photographs were viewed in Adobe Photoshop CS3.

Visual (305 m): visual observation from a dedicated beluga survey flight flown in a DeHavilland Twin Otter aircraft at an altitude of 305 m and a speed of 204 km/h.

Visual (914 m): visual observations from dedicated beluga survey flights flown in a DeHavilland Twin Otter aircraft at an altitude of 914 m and a speed of 222 km/h. The primary purpose of these flights was to conduct a photographic aerial survey, hence the higher altitude.

Helicopter-Other: other sightings of belugas and bowheads made by various observers during flights in a Messerschmidt BO 105 helicopter at various altitudes

Helicopter-Survey: visual observations from dedicated beluga survey flights flown in a Messerschmidt BO 105 helicopter at an altitude of 305 m

Ship: visual observations made from the bridge of the CCGS Amundsen

Date	Latitude	Longitude	Group size	Species	Method
7-May-2008	70.902	-127.110	1	Bowhead	Ship
7-May-2008	70.881	-127.074	2	Bowhead	Ship
7-May-2008	70.814	-126.764	1	Bowhead	Ship
7-May-2008	70.484	-125.183	4	Bowhead	Ship
7-May-2008	70.412	-124.901	2	Bowhead	Ship
7-May-2008	70.406	-124.822	1	Bowhead	Ship

Date	Latitude	Longitude	Group size	Species	Method
7-May-2008	70.419	-124.671	1	Bowhead	Ship
7-May-2008	70.423	-124.620	2	Bowhead	Ship
7-May-2008	70.417	-124.611	2	Bowhead	Ship
7-May-2008	70.385	-124.602	2	Bowhead	Ship
8-May-2008	73.334	-124.756	1	Beluga	Visual (305 m)
18-May-2008	70.321	-125.898	1	Bowhead	Ship
18-May-2008	70.411	-124.449	1	Bowhead	Ship
18-May-2008	70.516	-123.835	7	Bowhead	Ship
18-May-2008	70.742	-122.756	1	Bowhead	Ship
18-May-2008	70.754	-122.728	2	Bowhead	Ship
18-May-2008	70.811	-122.589	2	Bowhead	Ship
19-May-2008	70.652	-122.886	4	Beluga	Ship
19-May-2008	70.666	-122.841	1	Bowhead	Ship
19-May-2008	70.674	-121.919	1	Bowhead	Ship
19-May-2008	70.677	-121.707	1	Bowhead	Ship
21-May-2008	70.877	-122.083	15	Beluga	Helicopter-Other
21-May-2008	70.567	-121.365	1	Bowhead	Ship
21-May-2008	70.569	-121.391	2	Bowhead	Ship
21-May-2008	70.572	-121.412	1	Bowhead	Ship
21-May-2008	70.590	-121.650	1	Bowhead	Ship
21-May-2008	70.615	-122.050	2	Bowhead	Ship
21-May-2008	70.618	-122.102	1	Bowhead	Ship
21-May-2008	70.608	-123.806	2	Bowhead	Ship
22-May-2008	71.627	-126.413	2	Beluga	Helicopter-Other
22-May-2008	71.650	-126.467	12	Beluga	Helicopter-Other
22-May-2008	71.988	-126.681	1	Beluga	Helicopter-Other
22-May-2008	71.935	-127.057	2	Beluga	Helicopter-Other
22-May-2008	71.000	-124.598	1	Bowhead	Ship
22-May-2008	71.060	-124.818	1	Bowhead	Ship
22-May-2008	71.170	-125.460	1	Bowhead	Ship
22-May-2008	71.227	-125.542	3	Bowhead	Ship
22-May-2008	71.321	-125.856	1	Bowhead	Ship
22-May-2008	71.324	-125.938	2	Bowhead	Ship
24-May-2008	72.992	-125.633	1	Beluga	Helicopter-Survey
29-May-2008	70.846	-124.356	2	Beluga	Visual (914 m)
29-May-2008	70.948	-124.413	1	Beluga	Visual (914 m)
29-May-2008	71.000	-124.437	2	Beluga	Visual (914 m)
29-May-2008	71.024	-124.450	2	Beluga	Visual (914 m)
29-May-2008	71.269	-123.537	2	Bowhead	Visual (914 m)
29-May-2008	71.364	-124.723	1	Bowhead	Visual (914 m)
29-May-2008	71.802	-125.545	1	Bowhead	Ship
29-May-2008	71.713	-125.473	1	Bowhead	Ship
30-May-2008	71.378	-125.117	1	Bowhead	Helicopter-Other
30-May-2008	71.308	-125.025	1	Bowhead	Helicopter-Other
30-May-2008	71.220	-124.947	2	Bowhead	Helicopter-Other

Date	Latitude	Longitude	Group size	Species	Method
30-May-2008	71.175	-124.733	1	Bowhead	Helicopter-Other
30-May-2008	71.274	-124.964	1	Bowhead	Ship
31-May-2008	70.937	-124.682	1	Beluga	Helicopter-Other
31-May-2008	70.802	-124.456	2	Beluga	Helicopter-Other
31-May-2008	70.788	-124.446	2	Beluga	Helicopter-Other
31-May-2008	70.808	-124.482	2	Beluga	Helicopter-Other
31-May-2008	70.802	-124.465	2	Beluga	Helicopter-Other
31-May-2008	70.744	-124.359	1	Beluga	Helicopter-Other
1-Jun-2008	70.617	-123.250	2	Bowhead	Helicopter-Other
1-Jun-2008	70.193	-123.163	1	Bowhead	Helicopter-Other
1-Jun-2008	70.196	-123.135	1	Bowhead	Helicopter-Other
1-Jun-2008	70.024	-123.140	1	Bowhead	Helicopter-Other
1-Jun-2008	70.644	-123.220	1	Bowhead	Ship
1-Jun-2008	70.358	-123.090	3	Bowhead	Ship
1-Jun-2008	70.283	-123.111	1	Bowhead	Ship
6-Jun-2008	71.774	-126.499	2	Beluga	Aerial Photograph
6-Jun-2008	71.770	-126.506	1	Bowhead	Aerial Photograph
6-Jun-2008	71.699	-126.622	1	Beluga	Aerial Photograph
6-Jun-2008	71.699	-126.622	1	Bowhead	Aerial Photograph
6-Jun-2008	71.647	-126.708	1	Beluga	Aerial Photograph
6-Jun-2008	71.643	-126.715	1	Beluga	Aerial Photograph
6-Jun-2008	71.639	-126.721	1	Beluga	Aerial Photograph
6-Jun-2008	71.615	-126.762	1	Beluga	Aerial Photograph
6-Jun-2008	71.615	-126.762	1	Beluga	Aerial Photograph
6-Jun-2008	69.963	-126.644	1	Beluga	Aerial Photograph
6-Jun-2008	69.963	-126.644	1	Beluga	Aerial Photograph
6-Jun-2008	69.951	-126.626	1	Beluga	Aerial Photograph
6-Jun-2008	69.937	-126.590	1	Beluga	Aerial Photograph
6-Jun-2008	69.984	-125.693	1	Beluga	Aerial Photograph
6-Jun-2008	69.986	-125.682	1	Beluga	Aerial Photograph
6-Jun-2008	70.015	-125.406	1	Beluga	Aerial Photograph
6-Jun-2008	71.778	-126.492	3	Beluga	Visual (914 m)
6-Jun-2008	71.662	-126.682	1	Beluga	Visual (914 m)
6-Jun-2008	71.610	-126.770	2	Beluga	Visual (914 m)
6-Jun-2008	71.346	-127.202	2	Beluga	Visual (914 m)
6-Jun-2008	71.068	-127.650	4	Beluga	Visual (914 m)
6-Jun-2008	71.054	-127.671	1	Beluga	Visual (914 m)
6-Jun-2008	71.346	-127.202	1	Bowhead	Visual (914 m)
10-Jun-2008	70.072	-123.433	2	Bowhead	Ship
10-Jun-2008	70.072	-123.433	1	Bowhead	Ship
10-Jun-2008	70.072	-123.433	3	Bowhead	Ship
10-Jun-2008	70.072	-123.433	1	Bowhead	Ship
10-Jun-2008	70.101	-123.414	3	Bowhead	Ship
10-Jun-2008	70.174	-123.693	2	Bowhead	Ship
10-Jun-2008	70.241	-123.322	10	Bowhead	Ship

Date	Latitude	Longitude	Group size	Species	Method
11-Jun-2008	69.918	-126.461	1	Beluga	Helicopter-Survey
11-Jun-2008	69.934	-126.686	1	Beluga	Helicopter-Survey
11-Jun-2008	69.926	-126.635	1	Beluga	Helicopter-Survey
11-Jun-2008	69.918	-126.540	1	Beluga	Helicopter-Survey
11-Jun-2008	69.918	-126.539	1	Beluga	Helicopter-Survey
11-Jun-2008	69.905	-126.404	7	Beluga	Helicopter-Survey
11-Jun-2008	69.906	-126.365	1	Beluga	Helicopter-Survey
11-Jun-2008	69.906	-126.364	1	Beluga	Helicopter-Survey
11-Jun-2008	69.911	-126.330	2	Beluga	Helicopter-Survey
11-Jun-2008	69.911	-126.327	1	Beluga	Helicopter-Survey
11-Jun-2008	69.913	-126.317	1	Beluga	Helicopter-Survey
11-Jun-2008	69.916	-126.301	1	Beluga	Helicopter-Survey
11-Jun-2008	69.917	-126.300	1	Beluga	Helicopter-Survey
11-Jun-2008	69.939	-126.238	1	Beluga	Helicopter-Survey
11-Jun-2008	69.945	-126.187	2	Beluga	Helicopter-Survey
11-Jun-2008	69.956	-126.103	3	Beluga	Helicopter-Survey
11-Jun-2008	69.957	-126.093	1	Beluga	Helicopter-Survey
11-Jun-2008	69.962	-126.064	1	Beluga	Helicopter-Survey
11-Jun-2008	69.964	-126.049	1	Beluga	Helicopter-Survey
11-Jun-2008	69.965	-126.044	1	Beluga	Helicopter-Survey
11-Jun-2008	69.965	-126.040	1	Beluga	Helicopter-Survey
11-Jun-2008	69.966	-126.016	5	Beluga	Helicopter-Survey
11-Jun-2008	69.966	-126.015	1	Beluga	Helicopter-Survey
11-Jun-2008	69.965	-125.978	1	Beluga	Helicopter-Survey
11-Jun-2008	69.965	-125.965	3	Beluga	Helicopter-Survey
11-Jun-2008	69.965	-125.959	8	Beluga	Helicopter-Survey
11-Jun-2008	69.965	-125.958	1	Beluga	Helicopter-Survey
11-Jun-2008	69.967	-125.932	1	Beluga	Helicopter-Survey
11-Jun-2008	69.966	-125.923	3	Beluga	Helicopter-Survey
11-Jun-2008	69.963	-125.812	1	Beluga	Helicopter-Survey
11-Jun-2008	69.963	-125.783	1	Beluga	Helicopter-Survey
11-Jun-2008	69.968	-125.744	3	Beluga	Helicopter-Survey
11-Jun-2008	69.974	-125.710	2	Beluga	Helicopter-Survey
11-Jun-2008	70.003	-125.586	1	Beluga	Helicopter-Survey
11-Jun-2008	70.005	-125.545	1	Beluga	Helicopter-Survey
11-Jun-2008	70.005	-125.544	1	Beluga	Helicopter-Survey
11-Jun-2008	70.004	-125.524	1	Beluga	Helicopter-Survey
11-Jun-2008	70.004	-125.512	1	Beluga	Helicopter-Survey
11-Jun-2008	70.004	-125.511	2	Beluga	Helicopter-Survey
11-Jun-2008	70.004	-125.510	1	Beluga	Helicopter-Survey
11-Jun-2008	70.003	-125.503	3	Beluga	Helicopter-Survey
11-Jun-2008	70.003	-125.501	1	Beluga	Helicopter-Survey
11-Jun-2008	70.003	-125.499	1	Beluga	Helicopter-Survey
11-Jun-2008	70.003	-125.497	1	Beluga	Helicopter-Survey
11-Jun-2008	70.003	-125.494	1	Beluga	Helicopter-Survey

Date	Latitude	Longitude	Group size	Species	Method
11-Jun-2008	70.003	-125.492	1	Beluga	Helicopter-Survey
11-Jun-2008	70.003	-125.490	3	Beluga	Helicopter-Survey
11-Jun-2008	70.003	-125.485	1	Beluga	Helicopter-Survey
11-Jun-2008	70.000	-125.442	1	Beluga	Helicopter-Survey
11-Jun-2008	70.002	-125.433	2	Beluga	Helicopter-Survey
11-Jun-2008	70.004	-125.417	1	Beluga	Helicopter-Survey
11-Jun-2008	70.004	-125.407	2	Beluga	Helicopter-Survey
11-Jun-2008	70.006	-125.385	2	Beluga	Helicopter-Survey
11-Jun-2008	70.008	-125.370	2	Beluga	Helicopter-Survey
11-Jun-2008	70.010	-125.363	1	Beluga	Helicopter-Survey
11-Jun-2008	70.014	-125.355	1	Beluga	Helicopter-Survey
11-Jun-2008	70.035	-125.331	6	Beluga	Helicopter-Survey
11-Jun-2008	70.040	-125.333	1	Beluga	Helicopter-Survey
11-Jun-2008	69.951	-126.157	1	Bowhead	Helicopter-Survey
11-Jun-2008	69.984	-125.658	1	Bowhead	Helicopter-Survey
11-Jun-2008	70.003	-125.426	1	Bowhead	Helicopter-Survey
11-Jun-2008	70.018	-125.346	1	Bowhead	Helicopter-Survey
11-Jun-2008	70.020	-125.342	1	Bowhead	Helicopter-Survey
12-Jun-2008	70.188	-124.787	1	Beluga	Aerial Photograph
12-Jun-2008	70.111	-125.186	1	Bowhead	Aerial Photograph
12-Jun-2008	70.105	-125.191	1	Bowhead	Aerial Photograph
12-Jun-2008	70.042	-125.338	1	Bowhead	Aerial Photograph
12-Jun-2008	70.042	-125.338	1	Bowhead	Aerial Photograph
12-Jun-2008	70.011	-125.411	2	Bowhead	Aerial Photograph
12-Jun-2008	70.011	-125.411	1	Bowhead	Aerial Photograph
12-Jun-2008	70.008	-125.426	2	Bowhead	Aerial Photograph
12-Jun-2008	70.006	-125.459	3	Beluga	Aerial Photograph
12-Jun-2008	70.006	-125.459	2	Beluga	Aerial Photograph
12-Jun-2008	70.005	-125.476	2	Beluga	Aerial Photograph
12-Jun-2008	70.005	-125.476	1	Beluga	Aerial Photograph
12-Jun-2008	70.005	-125.476	1	Beluga	Aerial Photograph
12-Jun-2008	70.005	-125.476	1	Beluga	Aerial Photograph
12-Jun-2008	70.004	-125.492	2	Beluga	Aerial Photograph
12-Jun-2008	70.004	-125.492	1	Beluga	Aerial Photograph
12-Jun-2008	70.003	-125.509	1	Beluga	Aerial Photograph
12-Jun-2008	70.003	-125.509	1	Beluga	Aerial Photograph
12-Jun-2008	70.003	-125.509	1	Beluga	Aerial Photograph
12-Jun-2008	70.003	-125.509	1	Beluga	Aerial Photograph
12-Jun-2008	70.002	-125.525	1	Beluga	Aerial Photograph
12-Jun-2008	69.999	-125.591	1	Beluga	Aerial Photograph
12-Jun-2008	69.999	-125.591	4	Beluga	Aerial Photograph
12-Jun-2008	69.999	-125.591	2	Beluga	Aerial Photograph
12-Jun-2008	69.999	-125.591	3	Beluga	Aerial Photograph
12-Jun-2008	69.999	-125.591	1	Beluga	Aerial Photograph
12-Jun-2008	69.999	-125.591	1	Beluga	Aerial Photograph

Date	Latitude	Longitude	Group size	Species	Method
12-Jun-2008	69.999	-125.591	1	Beluga	Aerial Photograph
12-Jun-2008	69.999	-125.591	1	Beluga	Aerial Photograph
12-Jun-2008	69.999	-125.591	1	Beluga	Aerial Photograph
12-Jun-2008	69.997	-125.607	1	Beluga	Aerial Photograph
12-Jun-2008	69.997	-125.607	1	Beluga	Aerial Photograph
12-Jun-2008	69.997	-125.607	1	Beluga	Aerial Photograph
12-Jun-2008	69.997	-125.607	1	Beluga	Aerial Photograph
12-Jun-2008	69.994	-125.621	3	Beluga	Aerial Photograph
12-Jun-2008	69.990	-125.634	1	Beluga	Aerial Photograph
12-Jun-2008	69.990	-125.634	1	Beluga	Aerial Photograph
12-Jun-2008	69.987	-125.648	1	Beluga	Aerial Photograph
12-Jun-2008	69.987	-125.648	1	Beluga	Aerial Photograph
12-Jun-2008	69.987	-125.648	2	Beluga	Aerial Photograph
12-Jun-2008	69.987	-125.648	1	Beluga	Aerial Photograph
12-Jun-2008	69.987	-125.648	2	Beluga	Aerial Photograph
12-Jun-2008	69.959	-126.128	1	Beluga	Aerial Photograph
12-Jun-2008	69.959	-126.128	1	Beluga	Aerial Photograph
12-Jun-2008	69.964	-126.067	1	Beluga	Aerial Photograph
12-Jun-2008	69.965	-126.051	1	Beluga	Aerial Photograph
12-Jun-2008	69.965	-126.051	1	Beluga	Aerial Photograph
12-Jun-2008	69.965	-126.051	1	Beluga	Aerial Photograph
12-Jun-2008	69.965	-126.051	1	Beluga	Aerial Photograph
12-Jun-2008	69.965	-126.051	1	Beluga	Aerial Photograph
12-Jun-2008	69.965	-126.051	1	Beluga	Aerial Photograph
12-Jun-2008	69.967	-126.003	1	Beluga	Aerial Photograph
12-Jun-2008	69.967	-126.003	1	Beluga	Aerial Photograph
12-Jun-2008	69.967	-126.003	1	Beluga	Aerial Photograph
12-Jun-2008	69.968	-125.987	1	Beluga	Aerial Photograph
12-Jun-2008	69.978	-125.707	1	Beluga	Aerial Photograph
12-Jun-2008	69.987	-125.668	1	Beluga	Aerial Photograph
12-Jun-2008	69.989	-125.655	1	Beluga	Aerial Photograph
12-Jun-2008	69.989	-125.655	1	Beluga	Aerial Photograph
12-Jun-2008	69.989	-125.655	2	Beluga	Aerial Photograph
12-Jun-2008	69.992	-125.642	2	Beluga	Aerial Photograph
12-Jun-2008	69.992	-125.642	2	Beluga	Aerial Photograph
12-Jun-2008	69.999	-125.600	1	Beluga	Aerial Photograph
12-Jun-2008	70.002	-125.504	2	Beluga	Aerial Photograph
12-Jun-2008	70.002	-125.504	1	Beluga	Aerial Photograph
12-Jun-2008	70.002	-125.488	1	Beluga	Aerial Photograph
12-Jun-2008	70.002	-125.488	1	Beluga	Aerial Photograph
12-Jun-2008	70.002	-125.488	1	Beluga	Aerial Photograph
12-Jun-2008	70.002	-125.488	1	Beluga	Aerial Photograph
12-Jun-2008	70.003	-125.472	1	Beluga	Aerial Photograph
12-Jun-2008	70.003	-125.456	1	Beluga	Aerial Photograph
12-Jun-2008	70.003	-125.456	1	Beluga	Aerial Photograph

Date	Latitude	Longitude	Group size	Species	Method
12-Jun-2008	70.003	-125.456	1	Beluga	Aerial Photograph
12-Jun-2008	70.003	-125.456	1	Beluga	Aerial Photograph
12-Jun-2008	70.004	-125.440	1	Beluga	Aerial Photograph
12-Jun-2008	70.004	-125.440	1	Beluga	Aerial Photograph
12-Jun-2008	70.004	-125.440	1	Beluga	Aerial Photograph
12-Jun-2008	70.005	-125.425	1	Beluga	Aerial Photograph
12-Jun-2008	70.005	-125.425	4	Beluga	Aerial Photograph
12-Jun-2008	70.010	-125.398	1	Beluga	Aerial Photograph
12-Jun-2008	70.010	-125.398	1	Beluga	Aerial Photograph
12-Jun-2008	70.010	-125.398	2	Beluga	Aerial Photograph
12-Jun-2008	70.014	-125.387	1	Beluga	Aerial Photograph
12-Jun-2008	70.014	-125.387	2	Beluga	Aerial Photograph
12-Jun-2008	70.014	-125.387	1	Beluga	Aerial Photograph
12-Jun-2008	70.014	-125.387	1	Beluga	Aerial Photograph
12-Jun-2008	70.018	-125.378	2	Beluga	Aerial Photograph
12-Jun-2008	70.203	-124.984	1	Beluga	Aerial Photograph
15-Jun-2008	70.000	-125.490	2	Beluga	Helicopter-Survey
15-Jun-2008	70.000	-125.489	1	Beluga	Helicopter-Survey
15-Jun-2008	70.000	-125.488	1	Beluga	Helicopter-Survey
15-Jun-2008	70.004	-125.408	1	Beluga	Helicopter-Survey
15-Jun-2008	70.006	-125.393	1	Beluga	Helicopter-Survey
15-Jun-2008	70.007	-125.378	1	Beluga	Helicopter-Survey
15-Jun-2008	70.007	-125.378	1	Beluga	Helicopter-Survey
15-Jun-2008	70.007	-125.378	1	Beluga	Helicopter-Survey
15-Jun-2008	70.007	-125.378	1	Beluga	Helicopter-Survey
15-Jun-2008	70.007	-125.378	1	Beluga	Helicopter-Survey
15-Jun-2008	70.007	-125.378	2	Beluga	Helicopter-Survey
15-Jun-2008	70.010	-125.365	1	Beluga	Helicopter-Survey
15-Jun-2008	70.011	-125.358	1	Beluga	Helicopter-Survey
15-Jun-2008	70.012	-125.357	7	Beluga	Helicopter-Survey
15-Jun-2008	70.015	-125.346	1	Beluga	Helicopter-Survey
15-Jun-2008	70.019	-125.334	1	Beluga	Helicopter-Survey
15-Jun-2008	69.966	-125.940	1	Bowhead	Helicopter-Survey
16-Jun-2008	69.960	-126.065	1	Beluga	Helicopter-Survey
16-Jun-2008	69.986	-125.642	1	Bowhead	Helicopter-Survey
16-Jun-2008	70.000	-125.480	3	Bowhead	Helicopter-Survey
16-Jun-2008	70.000	-125.463	1	Bowhead	Helicopter-Survey
16-Jun-2008	70.004	-125.403	1	Bowhead	Helicopter-Survey
18-Jun-2008	69.955	-126.072	1	Beluga	Helicopter-Survey
18-Jun-2008	69.959	-126.051	1	Beluga	Helicopter-Survey
18-Jun-2008	69.962	-125.990	1	Beluga	Helicopter-Survey
18-Jun-2008	69.959	-125.958	1	Beluga	Helicopter-Survey
18-Jun-2008	70.005	-125.408	1	Bowhead	Helicopter-Survey
21-Jun-2008	69.932	-126.730	1	Beluga	Helicopter-Survey
21-Jun-2008	69.933	-126.720	1	Beluga	Helicopter-Survey

Date	Latitude	Longitude	Group size	Species	Method
21-Jun-2008	69.922	-126.691	1	Beluga	Helicopter-Survey
21-Jun-2008	69.920	-126.678	1	Beluga	Helicopter-Survey
21-Jun-2008	69.919	-126.673	1	Beluga	Helicopter-Survey
21-Jun-2008	69.925	-126.697	1	Beluga	Helicopter-Survey
21-Jun-2008	69.925	-126.697	1	Beluga	Helicopter-Survey
21-Jun-2008	69.925	-126.696	1	Beluga	Helicopter-Survey
21-Jun-2008	69.924	-126.695	1	Beluga	Helicopter-Survey
21-Jun-2008	69.924	-126.694	1	Beluga	Helicopter-Survey
21-Jun-2008	69.919	-126.680	1	Beluga	Helicopter-Survey
21-Jun-2008	69.919	-126.679	1	Beluga	Helicopter-Survey
21-Jun-2008	69.919	-126.678	1	Beluga	Helicopter-Survey
21-Jun-2008	69.918	-126.675	1	Beluga	Helicopter-Survey
21-Jun-2008	69.916	-126.670	1	Beluga	Helicopter-Survey
21-Jun-2008	69.921	-126.321	1	Beluga	Helicopter-Survey
21-Jun-2008	69.921	-126.320	2	Beluga	Helicopter-Survey
21-Jun-2008	69.926	-126.300	1	Beluga	Helicopter-Survey
21-Jun-2008	69.927	-126.299	1	Beluga	Helicopter-Survey
21-Jun-2008	69.942	-126.241	1	Beluga	Helicopter-Survey
21-Jun-2008	69.943	-126.228	1	Beluga	Helicopter-Survey
21-Jun-2008	69.943	-126.227	1	Beluga	Helicopter-Survey
21-Jun-2008	69.948	-126.190	1	Beluga	Helicopter-Survey
21-Jun-2008	69.948	-126.190	1	Beluga	Helicopter-Survey
21-Jun-2008	69.948	-126.190	1	Beluga	Helicopter-Survey
21-Jun-2008	69.948	-126.189	3	Beluga	Helicopter-Survey
21-Jun-2008	69.948	-126.189	1	Beluga	Helicopter-Survey
21-Jun-2008	69.948	-126.189	1	Beluga	Helicopter-Survey
21-Jun-2008	69.948	-126.189	1	Beluga	Helicopter-Survey
21-Jun-2008	69.948	-126.189	1	Beluga	Helicopter-Survey
21-Jun-2008	69.949	-126.181	1	Beluga	Helicopter-Survey
21-Jun-2008	69.951	-126.157	1	Beluga	Helicopter-Survey
21-Jun-2008	69.951	-126.157	2	Beluga	Helicopter-Survey
21-Jun-2008	69.956	-126.126	7	Beluga	Helicopter-Survey
21-Jun-2008	69.956	-126.127	5	Beluga	Helicopter-Survey
21-Jun-2008	69.956	-126.127	4	Beluga	Helicopter-Survey
21-Jun-2008	69.960	-126.113	1	Beluga	Helicopter-Survey
21-Jun-2008	69.959	-126.106	1	Beluga	Helicopter-Survey
21-Jun-2008	69.959	-126.105	1	Beluga	Helicopter-Survey
21-Jun-2008	69.959	-126.104	1	Beluga	Helicopter-Survey
21-Jun-2008	69.959	-126.102	1	Beluga	Helicopter-Survey
21-Jun-2008	69.956	-126.083	1	Beluga	Helicopter-Survey
21-Jun-2008	69.996	-125.583	3	Beluga	Helicopter-Survey
21-Jun-2008	70.006	-125.462	1	Beluga	Helicopter-Survey
21-Jun-2008	69.929	-126.697	1	Bowhead	Helicopter-Survey
21-Jun-2008	69.916	-126.668	1	Bowhead	Helicopter-Survey
23-Jun-2008	70.420	-126.530	1	Bowhead	Ship

Date	Latitude	Longitude	Group size	Species	Method
23-Jun-2008	70.470	-126.771	2	Bowhead	Ship
23-Jun-2008	70.543	-127.193	1	Bowhead	Ship
23-Jun-2008	70.552	-127.244	1	Bowhead	Ship
24-Jun-2008	70.694	-126.709	1	Bowhead	Ship
24-Jun-2008	70.652	-126.529	2	Bowhead	Ship
26-Jun-2008	71.612	-126.620	1	Beluga	Aerial Photograph
26-Jun-2008	71.616	-126.613	1	Beluga	Aerial Photograph
26-Jun-2008	71.640	-126.574	1	Beluga	Aerial Photograph
26-Jun-2008	71.643	-126.567	1	Beluga	Aerial Photograph
26-Jun-2008	71.643	-126.567	2	Beluga	Aerial Photograph
26-Jun-2008	70.268	-125.165	8	Bowhead	Ship
27-Jun-2008	70.998	-126.338	1	Bowhead	Ship
27-Jun-2008	71.239	-126.445	3	Bowhead	Ship
27-Jun-2008	71.266	-125.347	1	Bowhead	Ship
28-Jun-2008	71.106	-125.927	1	Bowhead	Ship
29-Jun-2008	70.871	-128.816	1	Bowhead	Ship
29-Jun-2008	70.894	-129.881	1	Bowhead	Ship