

Understanding ringed seal foraging ecology through Inuit knowledge and stomach content analysis

by

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Abstract

Ringed seals (*Pusa hispida*) are opportunistic predators but primarily feed on Arctic cod (*Boreogadus saida*) and lipid-rich pelagic crustaceans. Recently, shifts in diet have been observed. We used semi-structured interviews and stomach contents analysis to describe ringed seal diet and foraging ecology. Interviews (n=23) were conducted with hunters from Arctic Bay, Pangnirtung, and Pond Inlet, Nunavut. Ringed seal stomach samples (n=201) were harvested from Admiralty Inlet, Cumberland Sound, and Eclipse Sound and samples containing prey contents (n=166) were analysed.

Hunters observed *ugak* (cod) and *kinguk* (amphipods) in the stomachs of ringed seals, year-round, across spatial scales, and within all age classes. The flavour of ringed seal meat was variable across space and time, with some associating the flavour with ringed seal prey. Some participants identified specific areas where ringed seals foraged, for example, the floe edge, polynyas and in areas of current, while most responses pointed to widespread feeding. Ringed seals were described as feeding year-round, except for the moulting and basking period when their stomachs were typically empty or had fewer contents. Some age-related differences in diet were observed by interviewees, specifically that juveniles consumed more *kinguk* than other prey types when they were first weaned.

Stomach contents revealed Arctic cod and Hyperiididae were most abundant and frequently occurring of fishes and invertebrates, respectively. Multivariate tests found a significant effect for region, year of harvest, month of harvest, age class, and the

interaction between age class and region. Univariate tests indicated significant differences between regions in the prey counts of Arctic cod and Euphausiacea. Arctic cod had higher abundance and biomass in both northern regions than in Cumberland Sound, whereas Euphausiacea was not present in either of the northern regions. Temporal differences were driven by Euphausiacea among years and Amphipoda among months. Amphipoda differed significantly among age classes with young of the year consuming the highest abundance and biomass, followed by subadults, and adults. Understanding the foraging ecology of ringed seals will help wildlife managers better understand the evolving dynamics of the Arctic food web and determine potential impacts on species at higher trophic levels.

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Chapter 1: General Introduction

1.1 Background

Anthropogenic greenhouse gas emissions have driven global increases in oceanic and atmospheric temperature, contributing to glacial retreat, global sea level rise, sea ice loss, and changing precipitation (IPCC, 2014). However, temperature changes are not uniform. Higher latitudes have been experiencing greater increases in temperature, at nearly twice that of the global average (Dai et al., 2019; IPCC, 2014; NSIDC, 2020). Surface temperature is expected to continue to rise throughout the 21st century and it is projected that the Arctic Ocean will be seasonally ice free by mid-century (Notz & Stroeve, 2018).

Many species face serious risks related to the rapid onset of climate change. Some terrestrial, marine, and freshwater species with the ability to shift their distribution, seasonal activities, and migration patterns have already begun to do so (IPCC, 2014). Distributional shifts of marine fishes, invertebrates, and phytoplankton poleward and into deeper, colder waters have occurred in all ocean basins as a result of ocean surface warming (IPCC, 2014), which has altered ecosystem composition. Arctic sea ice retreat is increasing primary production at high latitudes, and altering diversity and species richness (IPCC, 2014).

In the Arctic, ice-obligate and ice-associated species face climate change challenges associated with habitat modifications, ecosystem alterations, stresses to body condition and health, and human interactions (Moore & Huntington, 2008). Habitat loss is the largest threat to

Arctic species, but alterations to prey could be a major threat as well (Moore & Huntington, 2008).

Foraging ecology

Arctic marine mammals are inherently difficult to study because their distributions at remote high latitudes and ice-covered environment, and foraging activity is difficult to observe because feeding occurs underwater (Pierce & Boyle, 1991). However, a study of foraging ecology is essential to understanding the biology of marine mammals and their role in marine ecosystems (Van Langevelde & Prins, 2008).

Study species

Ringed seals (*Pusa hispida*) are widely distributed through Arctic and subarctic waters, and are strongly ice-adapted (COSEWIC, 2019; McLaren, 1958). Adults establish territories during ice freeze-up in late fall, and females give birth in subnivean lairs in the spring (Furgal et al., 2002; McLaren, 1958). Pups are weaned after 5-8 weeks, and mating between adults occurs near the end of the lactation period (Smith, 1987; Smith & Hammill, 1981). In late spring and early summer ringed seals bask on the surface of the ice where they begin their moult (Young & Ferguson, 2013). Ringed seals are opportunistic predators (Chambellant et al., 2013; Holst et al., 2001; Wathne et al., 2000), feeding in the benthic and pelagic zones on a variety of fish and invertebrates (Siegstad et al., 1998; Young & Ferguson, 2013). The most common prey include Arctic cod (*Boreogadus saida*) and the lipid-rich pelagic crustaceans *Themisto libellula* (Chambellant et al., 2013; Holst et al., 2001; Young & Ferguson, 2013).

There is evidence of shifting diets in the Arctic due to changing sea ice conditions. For instance, Hamilton et al. (2015) recorded several behavioural changes in ringed seals following a major collapse of sea ice in the Svalbard region in 2006, resulting in the reduced body condition of the seals. Hamilton et al. hypothesized that these behavioural changes were due to greater foraging effort, increasing the energy costs of acquiring food (Hamilton et al., 2015).

Chambellant et al. (2013) found that in south-western Hudson Bay Arctic cod declined in the diet of ringed seals in the 1990s, which shifted to include more capelin (*Mallotus villosus*) by the 2000s. This shift was also observed in the diets of thick-billed murre (*Uria lomvia*) in northern Hudson Bay (Gaston et al., 2003). A later study looking at thick-billed murre collected from 2007-2009 in the same region found a correlation between the length of the open water season and the incidence of Arctic cod in the diet (Gaston et al., 2012). The prevalence of Arctic cod went from 100% when there were less than 110 open water days to almost 0% when the open water season exceeded 175 days (Gaston et al., 2012). The observed changes in diet composition is thought to be a result of warming waters in Hudson Bay (Gaston et al., 2003, 2012). A change in the structure of the Arctic food web to incorporate more temperate species has also been observed in the Barents Sea, and is expected to continue throughout the Arctic as ocean temperatures increase and become more hospitable for southern species (Fossheim et al., 2015; Hamilton et al., 2015; Kortsch et al., 2015). Given ringed seals are ubiquitous throughout the Arctic and have a generalist feeding strategy they are interesting as a sentinel species and changes in diet may be indicative of broader environmental changes.

Stomach contents analysis

In the marine environment it is difficult to directly observe what marine mammals eat, and so indirect methods are used to describe prey and make diet estimations (Pierce & Boyle, 1991). Stomach contents analysis allows for the identification of prey taxa from identifiable food remains such as otoliths, fish bones, squid beaks, and invertebrate exoskeletons. A possible limitation of this method is the differential passage rates of taxa, differences in degradation of prey, the effects of partial digestion (Pierce & Boyle, 1991) and anomalous feeding events. Nonetheless, it remains the most common and oldest method in use (Bowen & Iverson, 2012; Hyslop, 1980).

Inuit Knowledge

Inuit Knowledge (IK) is a valuable source of information and knowledge that has contributed greatly to our understanding of the foraging ecology of Arctic marine mammals (e.g., Breton-Honeyman et al., 2016; Furgal et al., 2002; Gryba et al., 2021). In Nunavut, harvesting is essential to the lives of the people, both culturally and nutritionally (Kenny & Chan, 2017). Hunting practices sustain traditional sharing customs, support a special knowledge of wildlife resources and ecosystems, and reinforce intergenerational links when knowledge of the environment and hunting skills are taught to young hunters by their elders (Reeves et al., 1998; Wenzel, 1996). The result is a strong connection to the land and ocean, and a lifetime of observations on animal behaviour, distribution, and other life history traits (Karetak et al., 2017). The information collected by Inuit hunters about their environment is a rich source of insights and knowledge (Karetak et al., 2017; Wenzel, 2004). Observations by local hunters of species and

the environment are complementary to the information collected through western scientific pursuits and can help paint a more complete picture of a species' ecology (Wenzel, 1999).

Care must be taken when collecting and using IK. The aspects of IK that are considered 'useful' along science are those typically described as environmental knowledge (McGregor, 2004; Usher, 2000; Wenzel, 2004). This compartmentalized view of IK is removed from the context in which it is shared (Huntington, 2005) and its use within scientific, co-management, and governmental systems is inherently colonial due to these systems being rooted in western ideology (Agrawal, 1995; Nadasdy, 1999). Nonetheless, Inuit wish to see their knowledge used in policy development and alongside science so that their views and priorities are represented in the decisions that impact their lives (McGregor, 2004).

Study Area: Eastern Canadian Arctic

There are indications that Cumberland Sound, Nunavut (approximately 65°N 66°W), is a changing marine system. Residents of Pangnirtung have observed capelin presence since the early 2000s (Carscadden et al., 2013), a species that has continued to persist in the region (McKinney et al., 2012; Ogloff et al., 2019; Ulrich & Tallman, 2021). Investigations into fatty acid profiles of beluga whales from Cumberland Sound suggest a shift in summer diet from Arctic cod to capelin over time (1980 to 2010) (Watt et al., 2016). Marcoux et al. (2012) found that carbon 13 and nitrogen 15 stable isotopes declined over time, for both muscle and skin tissues gathered from beluga harvested between 1982 to 2009. The changing trend of stable isotope values may reflect changes to the Cumberland Sound marine ecosystem or a shift in beluga diet (Marcoux et al., 2012). Research into the sources of carbon implied primary production had shifted from

sympagic to pelagic carbon sources, for beluga harvested between 1982 to 2009 in Cumberland Sound (Brown et al., 2017).

For both Admiralty Inlet (approximately 73°N 86°W) and Eclipse Sound (approximately 72.8°N 79°W) there does not exist the same body of published knowledge on changes that may be occurring in these areas. Nonetheless, there is a latitudinal gradient of sea-ice phenology, where higher latitudes have a shorter ice-free season than regions at lower latitudes (Yurkowski et al., 2016) and as sea ice declines and the Arctic ocean warms there is potential for changes to the marine food web (Fosshiem et al., 2015; Frainer et al., 2021; Møller & Nielsen, 2019). These three study sites make a nice comparison between a lower Arctic site where changes to the marine ecosystem have been observed and the northern regions where although there have been changes in sea ice (Galley et al., 2012; Howell et al., 2008, 2009), there is a lack of observations of marine food web changes. Therefore, I was interested in investigating ringed seal foraging in these three areas.

1.2 Thesis objectives

My primary research question is: are there differences in ringed seal diet and foraging between the high Arctic (Arctic Bay and Pond Inlet, Nunavut) and the low Arctic (Pangnirtung)? I employed two approaches to investigate ringed seal foraging ecology in these three regions: the first uses semi-structured interviews to collect information from Inuit hunters and knowledge holders from Arctic Bay, Pangnirtung, and Pond Inlet, Nunavut on ringed seal foraging ecology; the second investigates and compares the diet of ringed seals harvested from the marine areas of Admiralty Inlet, Cumberland Sound, and Eclipse Sound using stomach contents analysis.

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Chapter 2. Inuit knowledge of ringed seal foraging ecology from hunters in Arctic Bay, Pangnirtung, and Pond Inlet, Nunavut

2.1 Abstract

Foraging ecology is necessary to understand the biology of marine mammals and their role in marine ecosystems. This is especially important to understand the potential impact of climate change to species of particular interest to Inuit. Ringed seals (*Pusa hispida, nattiq*) are important culturally, economically, and as a food source for Inuit in Nunavut. Yet few studies have been carried out using Inuit Knowledge to understand ringed seal foraging ecology. In this study I documented hunter's Inuit Knowledge with the aim of improving our knowledge of ringed seal foraging ecology in the eastern Canadian Arctic and increasing published documentation of hunters' knowledge. I conducted interviews with twenty-three individuals from Pangnirtung (n=8), Pond Inlet (n=8) and Arctic Bay (n=7), Nunavut, in September and October 2016 and March 2017, respectively. Participants from all three communities identified *ugak* (cod) and *kinguk* (amphipods) as being the main prey items for ringed seals. Both Pond Inlet and Pangnirtung had relatively high prey diversity described by interviewees (n=15 and n = 10, respectively) compared to Arctic Bay (n=4). The flavour of ringed seal meat was variable across space and time, with some associating the flavour with what seals had fed on. Some participants identified specific areas where ringed seals foraged, for example the floe edge, polynyas and in areas of current, while most responses pointed to widespread feeding. Ringed seals were described as feeding year-round, except for the moulting and basking period when their

stomachs were typically empty or had fewer contents than the rest of the year. This is when seals were also their skinniest. Some age-related differences in diet were observed by interviewees, specifically that juveniles consumed more *kinguk* than other prey types when they were first weaned. There were some observations of inter-species interactions during foraging activities. Seabirds were observed feeding in proximity to feeding ringed seals, while one person observed that narwhals would herd Arctic cod towards shore, where ringed seals would feed on the available prey. The knowledge presented here provides information on ringed seal diet and foraging that can be an important resource for management and monitoring of this species.

2.2 Introduction

Foraging ecology is essential to understanding the biology of marine mammals and their role in marine ecosystems (Van Langevelde & Prins, 2008). This is especially true in the Arctic where the impacts of climate change are disproportionately great compared to the global average (Cohen, 2014; Huang, 2017; IPCC, 2014; Polyakov et al., 2012). The increase in ocean temperature, and associated sea ice cover decline (Box et al., 2019; Dai et al., 2019), are both causing changes in the distribution of ice-related biota (Bluhm et al., 2011; Eamer et al., 2013; Pecuchet et al., 2020). Changes in the food web can affect species that are of particular importance to northerners.

Ringed seals (*Pusa hispida, nattiq*) are an ice-dependent species distributed widely throughout the circumpolar Arctic and subarctic waters (COSEWIC, 2019). They have a high trophic status and are considered an important link within Arctic and subarctic food webs (Kovacs, 2014). Inuit and others have relied on ringed seals for millennia (Boas, 1889; Kelly & Quakenbush, 1987; McGhee, 1996; Pelly, 2001; Ukkonen et al., 2014; Wenzel et al., 2016), and despite changing from nomadic to settled, wage-reliant lifestyles, Inuit continue to rely on ringed seals due to their cultural importance and nutritional value (Borré, 1994; Pars et al., 2001; Pelly, 2001; Wenzel, 2000). Ringed seals are expected to be impacted negatively by reduced sea ice, and the altered distribution and abundance of their prey (COSEWIC, 2019). In the Amundsen Gulf, ringed seal body condition declined over three decades (1992 to 2019) and although the influencing factors are complex it may be a result of changing diets, reduced sea ice habitat, or changes in weather conditions (Harwood et al., 2020). In contrast, ringed seals in western Svalbard have had relatively stable body condition over time despite a major decline of sea ice

habitat that has occurred over recent decades (Andersen et al., 2021). The pronounced differences in ringed seal body condition between these two areas highlights how important consistent monitoring is to understand the possible impacts of climate change on ringed seals.

Foraging ecology studies of ringed seals include stomach content analysis, stable isotope analysis, and fatty acid composition (Dehn et al., 2007; Holst et al., 2001; Matley et al., 2015; Thiemann et al., 2007; Young & Ferguson, 2013, 2014). Some constraints of these methods include limited samples, greater representation of hard parts over soft-bodied prey in stomach content analysis, which is generally under-represented (Pierce & Boyle, 1991), and that fatty acid and stable isotopes analyses provide proxy dietary measures that are integrated across all prey items, and therefore do not provide resolution at the level of individual prey (Budge et al., 2006; Iverson et al., 2004; Newsome et al., 2010). Increasing the diversity of evidence can improve our understanding of ringed seal foraging and how climate induced changes are impacting this endemic Arctic species. Particularly in the eastern Canadian Arctic, where there are documented changes to the marine system in the low Arctic, specifically Cumberland Sound (e.g., Brown et al., 2017; Carscadden et al., 2013; Marcoux et al., 2012; Ogloff et al., 2019; Watt et al., 2016), and a lack of published information in the high Arctic, specifically Admiralty Inlet and Eclipse Sound, Inuit knowledge (IK) is a valuable source of information and can be used to document and understand the changes occurring to Arctic species and the environment due to climate change (Cuerrier et al., 2015; Falardeau & Bennett, 2020).

Ringed seals are well researched in the Canadian Arctic, with many researchers benefitting from the knowledge imparted by Inuit guides and community members (Kelly & Quakenbush, 1987; McLaren, 1958). There has been a small but growing number of studies that

focus on IK to understand and document ringed seal ecology (Cleator, 2001; Furgal et al., 2002; Gadamus et al., 2015; Gryba et al., 2021; Huntington et al., 2015, 2016a, 2016b, 2017).

There are many terms used to describe Indigenous peoples' knowledge (Houde, 2007) which captures the local, traditional and unique understanding of the state of and experience within a geographic region (Grenier, 1998). In Inuit Nunangat, Inuit Qaujimajatuqangit is the term used to describe the body of knowledge which includes all aspects of Inuit life, including the physical, spiritual, and cultural (Wenzel, 2004), of which traditional ecological knowledge (TEK) is an aspect (Wenzel, 2004). IK accumulated through generations, peers, and personal experience spans large spatial and temporal scales, continues to be essential for individuals and communities (Huntington et al., 2017), and reflects a rich understanding of the environment and wildlife (Karetak et al., 2017, p. 41; Wenzel, 1999). In this paper, IK denotes the described knowledge and understanding of ringed seal biology and foraging ecology provided by Inuit hunters.

The meaningful inclusion of IK in decision making, policy development, and wildlife management builds trust and enhances governance (Fazey et al., 2006; Tengö et al., 2014) and ensures local perspectives are considered in what is typically centralized, outside decision making (Alessa et al., 2016). In Nunavut, IK was mandated to be used in decision making when the Nunavut Agreement was finalized and co-management boards established, and in the most recent amendments to the Fisheries Act Indigenous and community knowledge is to be considered in decision making alongside other forms of information when available (*Fisheries Act, RSC 1985, c. F-14*, 2019; Tunngavik Federation of Nunavut & Indian Affairs and Northern Development, 1993).

Most studies that include IK of ringed seal ecology have been conducted in Alaska. Those from Canada included published transcripts from interviews with hunters in Chesterfield Inlet, Nunavut (Cleator, 2001), and a description of ringed seal biology and behaviour synthesized from interviews with Ikpiarjuk (Arctic Bay) hunters (Furgal et al., 2002). These resources describe the shared knowledge of hunters concerning ringed seal prey, and characteristics of meat flavour that may be an indicator of prey consumed (Cleator, 2001; Furgal et al., 2002). For instance, in Chesterfield Inlet, interview participants described *kinguk* (amphipods), Arctic cod (*Boreogadus saida*), Greenland cod (*Gadus ogac*), sculpins (Cottidae), as well as sand lance (Ammodytidae) and capelin (*Mallotus villosus*) as ringed seal prey (Cleator, 2001). In Arctic Bay, hunters described the flavour of ringed seal meat, differentiating between geographic areas and what the seals fed on, for example noting that in some areas they tasted and smelled like Arctic cod (Furgal et al., 2002).

These two publications provide a glimpse of the prey that ringed seals consume across their latitudinal range. In the southern part of ringed seal range, fishes like capelin and sand lance (*Ammodytes sp.*) were observed to be dominant in prey studies after the year 2000 (Chambellant et al., 2013; Young & Ferguson, 2014), both species with limited distribution in cold Arctic waters (McNicholl et al., 2018; Pedro et al., 2020; Rose, 2005). Whereas in higher latitudes, species like Arctic cod and *Themisto libellula* dominate ringed seal diet (Gjertz & Lydersen, 1986; Matley et al., 2015; Weslawski et al., 1994)

It is possible that changes to prey distribution are occurring in the high Arctic as well, but most diet studies in the area are not recent. Some work in Lancaster Sound between 2000-2003 found that thick-billed murre (*Uria lomvia*) fed their chicks capelin, but it is unknown if this has

continued since (Carscadden et al., 2013). In other parts of the Arctic, there have been poleward shifts in fish and invertebrate distributions because of warming waters, increasing open-water period, and shrinking and thinning sea ice (e.g., Frainer et al., 2021; Møller & Nielsen, 2019; Pecuchet et al., 2020).

This study is part of a larger project, called the Ringed Seal Inuit Qaujimagatunqangit (RSIQ) study conducted by the Government of Nunavut (GN), to collect and document information on ringed seal ecology, environmental changes, and hunting practices from an IK perspective. After hearing from hunters who attended the Ringed Seal Monitoring and Planning Workshop held in Iqaluit, Nunavut from March 6-7, 2014, the GN conceived the RSIQ study to help address the underrepresentation of IK of ringed seals in research (McCarney et al., 2016).

Cumberland Sound, the main body of water adjacent to Pangnirtung, has been had documented changes to the marine system, including observations of capelin (*Mallotus villosus*) by residents since the early 2000s (Carscadden et al., 2013), changes to stable isotopes in beluga (*Delphinapterus leucas*) blubber indicating a diet shift or underlying ecosystem change (Marcoux et al., 2012), changes in fatty acid profiles for beluga since the 2000s that also point to a shift in diet, specifically towards capelin from Arctic cod (*Boreogadus saida*) (Watt et al., 2016), and changes in the primary sources of carbon production from sympagic to pelagic (Brown et al., 2017). There is not the same body of published evidence suggesting changes to the marine food web in areas near Arctic Bay and Pond Inlet, but there is evidence that the open water period has increased in the high Arctic as a result of warming (Galley et al., 2012; Howell et al., 2008, 2009) which may be a trigger for changes to the marine food web as a result of northward migrations of temperate fish and invertebrate species (Fossheim et al., 2015b; Frainer et al.,

2021; Møller & Nielsen, 2019). I focused on the eastern Canadian Arctic for this study to have broad coverage of the Baffin region and describe ringed seal foraging ecology between low Arctic, Pangnirtung) where changes have been documented and the high Arctic (Arctic Bay and Pond Inlet) where little is known. This study ran in parallel to a diet study based on stomach content analysis of ringed seals harvested from the same communities.

The purpose of our project is to improve our understanding of ringed seal foraging ecology for the eastern Canadian Arctic and increase published documentation of hunters' IK. Below I describe prey, flavour of ringed seal meat, foraging location, seasonal differences, differences among age classes, and other observations related to foraging from interviews conducted in Arctic Bay, Pond Inlet, and Pangnirtung, Nunavut.

2.3 Methods

Study Area

Our study focused on the areas near three Baffin Island communities, Arctic Bay, Pond Inlet, and Pangnirtung (Figure 2.1). All three communities have Inuit populations who relocated voluntarily or forcibly from traditional hunting areas and camps. The community settlements predominantly occurred in the 1950s and 1960s, when the Government of Canada began housing initiatives in these and other locations throughout the Canadian Arctic, but some individuals and families were moved earlier in the century. Prior to settlement in these communities, Inuit travelled by dog team to access hunting, fishing, and gathering areas and to visit other encampments, resulting in in-depth knowledge of broad geographic regions. This

continues to be the case, but Inuit now travel by boat in the open water season, and snowmobile in the winter and spring.

Arctic Bay (Ikpiarjuk) is located on the north shore of Adams Sound within Admiralty Inlet (73.0376° N, 85.1480° W). The small hamlet was established as a trading post for the Hudson's Bay Company in 1936. At that time, some Inuit were moved from regions around Cape Dorset, Pangnirtung, and Pond Inlet to the area near Arctic Bay (QIA, 2013a). The settlement was predominantly made up of *Qallunaat* (southern Canadians or people of European descent) until the Government of Canada began efforts in the 1950s to bring modern amenities to entice Inuit of the area to settle there. By the late 1960s most Inuit from the Admiralty Inlet region had relocated to Arctic Bay, which became a hamlet in 1976 (QIA, 2013a). Arctic Bay now has a population of 868, predominantly Inuit (>95%) (Statistics Canada, 2016a). Hunting and fishing continue to be important parts of Inuit life. Inuit diet is made up of a diverse array of mammals, fish, birds and plants, including caribou (*Rangifer tarandus*), ringed seals, narwhals (*Monodon monoceros*), Arctic foxes (*Vulpes lagopus*), Arctic wolves (*Canis lupus arctos*), polar bears (*Ursus maritimus*), Arctic char (*Salvelinus alpinus*), wildfowl, Arctic hares (*Lepus arcticus*), eggs, and berries (Furgal et al., 2002; QIA, 2013a). Many of these wild resources are harvested locally around Admiralty Inlet, but are also harvested in areas farther away during trips expressly made for the purpose of hunting, for example to Bylot Island for inland caribou hunting, or on overland journeys to other communities, for example to Pond Inlet (QIA, 2013a).

The region around Pond Inlet (Mittimatalik) has been occupied by the pre-Dorset, Dorset, Thule, and modern Inuit peoples for approximately 4000 years (QIA, 2013c). The modern community is located along the south-eastern shore of Eclipse Sound (72.7001° N, 77.9585° W)

on northern Baffin Island. The first trading establishment was set up east of where Pond Inlet is today, by Scottish whalers in 1903 (QIA, 2013c). As contact with outsiders continued and Inuit life shifted to rely more and more on wages and trade, some moved to eventually settle in or near Pond Inlet. As a result of infrastructure investments by the Government of Canada and a policy of compulsory school attendance between 1963 and 1968, over 90% of Inuit people in the region had moved to live in the community by the end of the 1960s (QIA, 2013c). Pond Inlet now has a population of 1,617, of whom most are Inuit (>90%) (Statistics Canada, 2016c). Some of the most important species in the diet of the people of this region include ringed seals, narwhals, and other marine mammals (QIA, 2013c). Inuit hunters of this area harvest some species locally but must travel great distances to access other wild resource (QIA, 2013c). For example, ringed seals are widely available, narwhals can be harvested in Eclipse Sound, and trap lines for Arctic foxes branch inland from Eclipse Sound along its many inlets, sounds and fiords. On the other hand, hunters must travel to northern Foxe Basin and the southern shore of Devon Island for walrus (*Odobenus rosmarus*), and to Navy Board Inlet and Baffin Bay for polar bears (QIA, 2013c).

Pangnirtung (Panniqtuuq) is located on the south shore of Pangnirtung Fiord off the north-east side of Cumberland Sound (66.1466° N, 65.7012° W). Historically, people lived around the coastline and islands of Cumberland Sound, travelling throughout the year to access seasonally appropriate hunting opportunities (QIA, 2013b). Contact with outsiders began with whalers who came to the region in the 1800s to exploit the bowhead whale (*Balaena mysticetus*) population, which severely declined as a result (COSEWIC, 2009). The hamlet grew out of a Hudson's Bay Company trading post, an Anglican Mission, and a government hospital that were established in the 1920s. Throughout these times Inuit continued to live throughout the region

with some movement associated with the whaling camps and when the trading post was established, then travel to Pangnirtung to trade furs and oil for goods (QIA, 2013b). In 1962, nearly 80% of Inuit from Cumberland Sound were evacuated or travelled voluntarily from their camps to the community of Pangnirtung because the Government of Canada feared widespread starvation would occur as a result of a distemper epidemic that spread among the sled dogs in the region (QIA, 2013d). Although many returned to their camps within a year, the disruption to the hunting and trapping economy resulted in pressure for people to move permanently to Pangnirtung by 1970 (QIA, 2013d, 2013b). The hamlet now has a population of 1481, over 90% of which are Inuit (Statistics Canada, 2016b). Ringed seals and caribou are considered essential. Ringed seals are widely available in Cumberland Sound and the adjoining inlets and fiords, and people travel to Cumberland Peninsula and Hall Peninsula to harvest from the caribou herds that migrated through those areas (QIA, 2013b). Inuit also harvest beluga, which can be found throughout Cumberland Sound but were concentrated on the western and northern side. Historically, bowhead whales were also important, but their harvest was disrupted when their population went into decline. In recent decades Panniqtummiut (residents of Pangnirtung) have had the opportunity to harvest bowhead whales again since the population has increased. Walrus are harvested in several areas, including the mouth of Cumberland Sound (QIA, 2013b). Arctic char are the most important fish species and are fished for in Cumberland Sound and in the fiords and inlets in the summer, often using nets, using weirs during the later summer migration up-river sometimes, and in the winter through the ice at inland lakes (QIA, 2013b).

Residents of the three communities harvest ringed seals throughout the year, as they are widely available. The harvest of this species is higher in these communities, and others on Baffin Island, than in the rest of the territory (NWMB, 2004).



Figure 2.1: Map of Baffin Island denoting the communities which participated in the study, Arctic Bay, Pond Inlet, and Pangnirtung, Nunavut

Research approach

I adopted a qualitative ethnographic research approach for this project to document IK on ringed seals (Bryman, 2012, p. 469; Whitehead, 2005). Semi-structured interviews are an effective method for documenting Indigenous and local knowledge (Ferguson & Messier, 1997; Huntington, 1998; Thorpe, 2000). Participants communicate in comfortable surroundings without the rigidity of questionnaires. Interviews are open-ended and allow space for participants to expand on topics of interest (Bernard, 2006; Bryman, 2012, p. 471).

Approval and ethics

Before commencing this research, I contacted the Hunters and Trappers Organizations (HTO) in Arctic Bay, Pangnirtung, and Pond Inlet to establish whether their communities would be interested in participating in the study, and to seek approval and support for the project. Although this project was conceived of by the Government of Nunavut out of discussions and comments by Inuit participating in the Ringed Seal Monitoring and Planning Workshop (McCarney et al., 2016), their voices may not necessarily represent the community. The board of an HTO are elected by community members. The decisions of the HTO board are therefore meant to represent the community members and make decisions in the best interests of the community. I wrote a letter (provided in both English and Inuktitut) describing the project and asked to have the project added to the agenda for discussion during the HTO board meeting. I was not present for the meetings in Arctic Bay and Pond Inlet but could attend in Pangnirtung. All communities approved the project and did not have any questions or concerns. The University of Manitoba's Joint-Faculty Research Ethics Board provided ethics approval (see

supplemental documents) for this research (Protocol #J2015:029, HS17880). There was no need for approval through the Nunavut Research Institute (NRI) because the RSIQ project was conducted and facilitated by the GN which has authority to conduct research within Nunavut under the auspices that the GN maintain all ethical considerations as expected by the NRI (Personal communications, Jamal Shirley, 2015)

Design

I created a questionnaire to help standardize interviews. Questions covered a broad range of topics on ringed seal biology. The draft was reviewed by Dr. Steve Ferguson, with Dr. Chris Furgal making some adjustments, and finally Jason Etuangat, an employee of the GN who assisted with conducting the interviews, reviewed the guide and suggested changes that helped reduce redundancy. Questions related to interviewee history and ringed seal foraging ecology are included in table 1 and the results included below are related to foraging.

Table 2.1: Series of questions used for semi-structured interviews with peer-recommended experts

Subject	General questions
Personal history	<p>Where and when were you born?</p> <p>How long have you lived in this community?</p> <p>What other communities have you lived in?</p> <p>Do you hunt marine mammals?</p> <p>How old were you when you began hunting?</p> <p>Are you still actively hunting ringed seals?</p> <p>How often do you go hunting?</p>
The following questions were asked for each season (spring, summer, fall, and winter)	
Hunting	<p>Where do you hunt ringed seals and why?</p> <p>Has this changed since you first started hunting seals, and if so, how?</p> <p>Do ringed seals harvested from different areas taste different? If so, how and from where?</p> <p>Has anything about how you hunt them changed since you started hunting ringed seals?</p>
Foraging	<p>Have you observed ringed seals feeding?</p> <p>Where do ringed seals spend the most time feeding?</p> <p>Are there other places you have seen them feeding?</p> <p>Do ringed seals feed on the same kind of food in all places? Or do they feed on different things in different places?</p> <p>Where is the best food for ringed seals found?</p> <p>When you have seen a ringed seal feeding, have you seen any other species in the area?</p> <p>Do adults and juveniles feed in the same/different areas?</p> <p>Have the places where ringed seals feed changed since you started hunting ringed seals?</p> <p>What are ringed seals feeding on?</p> <p>Do adults and juveniles eat the same/different kind of food?</p> <p>Has anything changed about what they feed on since you first started hunting seals?</p>
Stomach contents	<p>Do you typically find anything in ringed seals' stomachs? If yes:</p> <p>Is there usually a lot/few food in the stomach?</p> <p>If there are stomach contents, can you identify any species?</p> <p>Do you see a difference between stomach contents in different ringed seals? If yes, do you know why?</p> <p>Has the amount of food in the stomachs of ringed seals changed since you starting hunting ringed seals? If so, how?</p> <p>Has the kind of food you see in the stomachs of ringed seals changed since you starting hunting ringed seals? If so, how?</p>

Participant recruitment

Upon approval from the HTOs, I conducted semi-structured interviews with consenting Inuit hunters. I employed peer recommendations for participant selection and recruitment (Davis & Wagner, 2003; Huntington, 2000), specifically approaching people identified as ringed seal experts by the HTO, GN Wildlife Officer, and the interpreter. None of the people who were recommended were women, likely because not many women are considered hunters, and therefore all who participated in the study were men. Other criteria that determined if a person participated in the interviews were their interest and willingness to participate, and their availability when interviews were being conducted in their community.

A consent form was provided to all participants (Grenier, 1998, p. 87), which described the project objectives, details around confidentiality, and how the information would be used. As part of informed consent, participants could remain anonymous, be included in the acknowledgements only, or be quoted directly (see consent form in supplemental materials). In reporting the results of this study, the names of two people were kept confidential, as per their request.

I conducted interviews in a variety of settings, depending on the comfort of the participants. These included the HTO office, participants' homes, the Pond Inlet Parks Canada office, and on two occasions at my home in Pangnirtung. I asked participants if they were comfortable with audio recordings of the interviews ($n = 13$), and in cases where they were not, I took handwritten notes ($n = 10$). Geographic information was recorded on printed maps of the area, created using ArcGIS 10.3.

Interviews

The interview team was led by myself, Jason Etuangat who provided support and assistance, as well as a local interpreter in the case that a participant was unilingual (Inuktitut only) or preferred to speak in Inuktitut during the interview. I conducted 23 interviews with hunters from Pangnirtung (n = 8), Pond Inlet (n = 8), and Arctic Bay (n = 7) in September 2016, October 2016, and March 2017, respectively. I took hand-written notes during the audio recordings and Jason Etuangat helped by recording information on the maps, and as a bilingual Inuktitut/English speaker he elaborated on questions that participants misunderstood and would at times expand on the translation the interpreter provided if they had missed one or more elements. I had the support of English-Inuktitut interpreters from each community to conduct the interviews. I met with the interpreters before interviews were scheduled to review the interview guide and answer any questions. Interpreters in all three communities suggested expanding the seasonal questions to include the six seasons Inuit recognize: early spring, spring, summer, early fall, fall and winter. Interpretation and translation of the interviews occurred simultaneously. Each interpreter differed in their vocabulary and method of articulating the questions and responses. Jason Etuangat's presence at all the interviews helped to mitigate this variability, although this was not our intention for his participation at the outset. There was some limitation and nuance in these contributions, in that the cultural norm is to defer to the knowledge of one's Elders, and Jason Etuangat was younger than all the interpreters. Having local interpreters working with us allowed interviews to be conducted in local dialects, improved our ability to schedule interviews and get in touch with participants, and gave us access to the

interpreter's understanding of the local context and geography from which participants' experience was derived.

I wished to minimize fatigue of both the interpreters and participants, so I followed the lead of interpreters in scheduling between two or three interviews a day, and ensured that I stopped for frequent breaks, usually every half hour to an hour. Including breaks. In some cases when interviews exceeded two or three hours, they were rescheduled to continue another day. Handwriting notes took time during the interview and may have resulted in some details being missed and prevented us from including direct quotes in the results for those interviews and more accurately representing the voices of those interviewees.

Typically, participants answered questions directly, but sometimes when related to hunting they responded through stories of trips or experiences. The interviewers tried to follow up on responses to have the participants elaborate more but I was cognizant of the cultural norm of not questioning one's Elders. If a participant seemed resistant in their responses the interviewers did not pursue those lines of questioning. As a result, there were small informational gaps in some of the interviews. As was recommended by HTOs, and as part of the GN policy, I compensated all participants with an honorarium of \$45 per hour regardless of the length of the interview.

Interviews began with a description of the project, a consent form provided in the language of choice of the participant (either English or Inuktitut), a verbal summary of the project, and an opportunity for participants to ask questions. The first interview questions concerned the participant's personal history, for example when and where he was born, where he lived before moving to the community, and when he moved to the community, using the

maps to allow the participant to record the spatial information. I then continued with questions on hunting practices, descriptions of environmental features like polynyas and the floe edge, and details around the commercial sale of seal pelts. The rest of the interview focused on the participant's personal knowledge of ringed seal biology and ecology, and all questions were repeated for each of the seasons. Participants sometimes found the length of the interviews tedious and so when I asked questions relating to spring or fall, I asked for participants to be specific as to whether their response was early or late in the season. I used the maps throughout the interviews to record geographical information or place names that participants wanted to include. I used a single aid to help with identifying ringed seal prey, *A field guide to prey of ringed seal (Pusa hispida) of the Canadian Arctic* (McLeod et al., n.d.). When participants were describing a prey type morphologically we looked through the field guide to determine the species, in most cases the interviewees could not identify the species but did narrow the fish or invertebrate to a family or class.

Data organization and analysis

Audio recordings were transcribed based on the English translations during the interviews, the maps were digitized using ArcGIS (version unknown) by a consulting firm, and I transcribed the handwritten notes. Figures of maps were created by using R version 4.0.3, map layers retrieved digitally from Statistics Canada, and details (i.e., place names) were added using Inkscape version 1.0.2.

I analyzed the interviews using NVivo (Version 11, 2016; QSR International) software. I uploaded the transcribed interviews (audio and handwritten notes) as primary source materials

and grouped documents by community. I used two approaches to systematically categorize and code the text. The first was to use content analysis (Bernard, 2006, p. 510; Bryman, 2012, p. 288) to code the material according to the subjects by which the interviews were organized. I generated subjects before coding the text based on the major topics in the interviews and while working through the transcripts, I coded blocks of text related to these subjects. In Figure 2.2 I show subjects (nodes) that I used to code the text, which are associated with the results. I made associations between separate subject groups manually after exporting coded text from NVivo. For example, I coded text related to the prey that interviewees described with a parent node as “observation type” and specified with child nodes either “stomach contents” or “observed feeding”. Secondly, I used an open-coding method (Bernard, 2006, p. 493; Corbin & Strauss, 1990) to identify subjects that emerged from the text which I did not anticipate in our questions. For example, another “observation type” was coded as “partially consumed” which referred to when participants observed part of a consumed fish floating in a ringed seal breathing hole.

I categorized responses as one of three “knowledge types”, either 1) “personal” or firsthand observations, 2) “peer” or second hand observations, or 3) “speculative” based on extrapolations from observations (Ferguson & Messier, 1997). I identified knowledge as “speculative” only when the interviewee’s response was uncertain or an assumption was articulated based on another observation, for example, observing a partially consumed fish in a ringed seal breathing hole was speculated to be ringed seal prey. I decided not to use responses that were categorized as peer-knowledge so that for this study I could focus on an interviewee’s personal experiences and observations, and included speculative knowledge, but ensured I identified them as such.

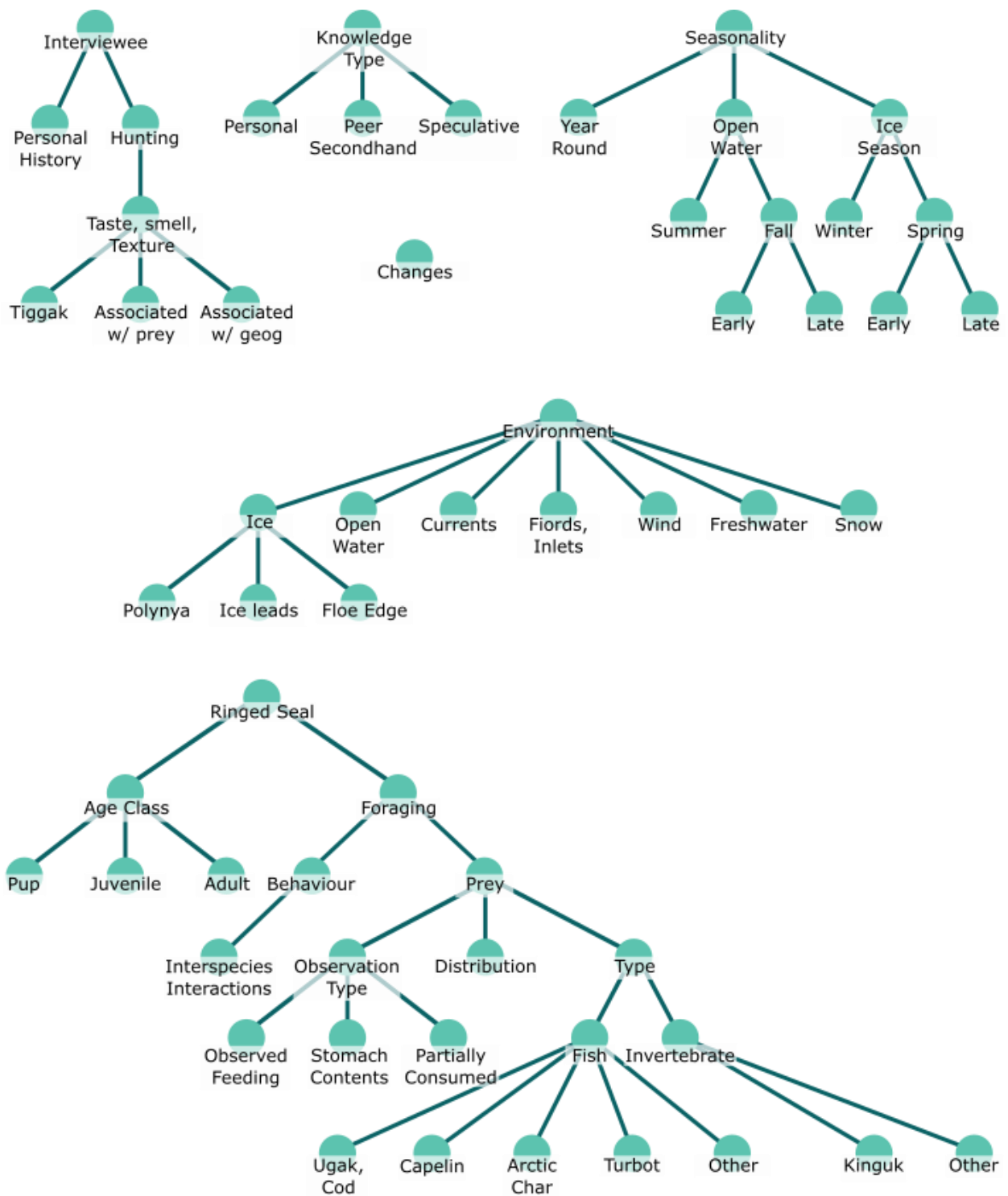


Figure 2.2: NVivo node map showing the hierarchical structure of subjects used to code the interview text.

Below I summarize interview findings and include direct quotations to explore key topics. I have mildly edited interviewee quotes to promote readability. I include a summary of ringed seal prey types identified by participants in table 1. If a participant identified a ringed seal's prey type either through direct observation or in the stomach contents at least once I denote this with an 'x' in table 1, and if the participant had observed a fish species in ringed seal breathing holes at least once I denote this with an '*' in the same table.

2.4 Results

Number and attributes of people interviewed

The interview participants were Inuit Elders and hunters considered experts by the boards of the HTOs, interpreters, or GN Wildlife Officers. All were male, ranging in age from 31 to 80 years old (mean = 65.5) at the time of the interview, and possessed substantial detailed knowledge on ringed seal ecology based on their own observations as well as inter-peer and inter-generational knowledge. Interviewees described their first hunting experiences from an early age, some with memories of hunting when they were younger than five years of age in their parents' *qamutik* (a sled pulled behind a dog team or snowmobile). Some specified that they began hunting independently between the ages of 12 and 14. All the participants were still actively hunting at the time of their interview, except for one who had stopped two years prior when his leg mobility declined (Table 2.2). Various factors impacted people's ability to participate in harvesting activities, for example access to gear (one person only had a boat and so he could not go hunting during the winter and spring), access to gas, having favourable weather conditions, or availability of time (being employed limited harvesting activities to

weekends and holidays). Three people limited their hunting to mostly the spring or summer because of their age or gear but had many previous years of experience hunting in the other seasons, whereas all others were at the time still hunting throughout the year. Harvesting frequency varied from one day a week to every day when people went on longer trips. Hunters in all communities described their hunting areas as being near their family's traditional hunting grounds and camps but the spatial extent of where they had ringed seal hunting experience was widespread (Figures 2.3, 2.4, 2.5). Interviews lasted between an hour and six hours.

Table 2.2: Summary of interviewee characteristics associated with age at the time of the interview, age when they began hunting, total number of years hunting, if they were actively still hunting at the time of the interview, and the frequency with which they went hunting

	Interview number	Age	Age at first hunt	Total years hunting	Actively hunting	Hunting frequency
Arctic Bay	1	71	6	65	Yes, but in the summer	
	2	64	14	50	Yes	3-7 days per week
	3	61	9	52	Yes	6 days a week, only day not hunting is Sunday
	4	69	Since a young age		Yes	1-7 days per week
	5	80	Approx. 12	68	No, has not hunted in 2 years, loss of mobility	up to 7 days a week
	6	75	Approx. 5	70	Spring time now only,	Simply stated that he hunts frequently
	7	74	9	65	Yes	Depending on the weather, whenever the weather is good for hunting
Pangnirtung	1	63	All his life		Yes	No response
	2	75	2		Yes	No response
	3	68	7	61	Yes	2 days per week at minimum
	4	70	Since a young age		Yes	1 day per week at minimum
	5	63	12	51	Yes	3 days per week at minimum
	6	68	14	54	Yes	Frequency depends on season, sometimes camped out for long periods
	7	66	10 or younger	56	Yes	No response
	8	77	6	71	Yes, mostly in the summer	Most days June to August
Pond Inlet	1	67	4	63	Yes	Everyday, depending on weather; prior to retirement Friday to Sunday
	2	63	3	60	Yes	1 per week while working, and all holidays and vacation
	3	61	7 or 8	53	Yes	2 days per week and holidays
	4	31	6 or 7, independently 12 or 13	24	Yes	Several days a week, goes whenever the weather allows
	5	67	Since a young age		Yes	3 days per week at minimum
	6	69	12	57	Yes	2 or 3 times per week in summer, depends on weather. Easier to hunt in winter despite it being windier
	7	37	5	32	Yes	1 day per week in winter, and couple times a month in summer
	8	68	No response		Yes	No response

74°N



Figure 2.3: Composite map of the region surrounding Arctic Bay displaying the spatial extent of all (n=7) interviewees' knowledge of ringed seal habitat, as was described during semi-structured interviews.



Figure 2.4: Composite map of the region surrounding Pond Inlet, Nunavut displaying the spatial extent of all (n=8) interviewees' knowledge of ringed seal habitat, as was described during semi-structured interviews



Figure 2.5: Composite map of the region surrounding Pangnirtung, Nunavut displaying the spatial extent of all (n=8) interviewees' knowledge of ringed seal habitat, as was described during semi-structured interviews

Below I describe interview findings by major topic: ringed seal prey, ringed seal flavour, spatial differences in foraging, seasonal differences in foraging, foraging differences by ringed seal age class, other observations associated with foraging, and then by community.

Ringed seal prey

Interview participants in all three communities described ringed seal prey by observing stomach contents, foraging behaviour, and the remnants of fish found in *agluiit* (seal breathing holes; see prey identified with '*' in Table 2.2). Common prey types were described easily using the Inuktitut names or English translation (for example *ugak* or Arctic cod), in which case I use the Inuktitut name below. In some cases, the name of the prey type being described was not known by participants and the interpreter and I was not able to identify it using the prey guide (McLeod et al., n.d.), so they used morphological descriptions to try and identify the species. I include these descriptions below.

Arctic Bay

Interviewees identified four unique prey types in Arctic Bay. All participants (7) observed, by investigating stomach contents, that ringed seals fed on both *kinguk* (amphipods, commonly refers to the carnivorous *Themisto sp.*) and *ugak* (cod; or more specifically Arctic cod, *Boreogadus saida*). One interviewee (Tommy Tatatuapik) observed that ringed seals were also feeding on shellfish or clams by investigating their feces. He stated:

you could tell that what they're eating, these seals when they're on top of the ice, the poop is more like shellfish, you could see the bones and fragments of shell[s] compared with these seals here, they mostly have cod, fragments of cod or [the feces are] black but here [they contain] more bones or fragments of shells. (Tommy Tatatuapik)

He characterized ringed seals that were feeding in more shallow areas as “*coastal seals*,” explaining that they tasted more like the bottom of the ocean:

they're mostly feeding where the polynyas are or where [the water is] shallow, along the leads or around the point ... and because they're coastal seal[s] they taste more like [the] bottom, shellfish or clams or, they taste more like bottom fish. (Tommy Tatatuapik)

Two participants noted that ringed seals prefer either *kinguk* or *ugak*: “*so they don't mix [the prey] as much ... they stay with one particular diet*” (Tommy Tatatuapik) and “*the [ringed seals] that are near kinguk ... have more kinguk in [the stomach contents] and the ones that [are near] more cod, they have more cod, small cod*” (Olayuk Naqitarvik).

Although not included in Table 2.2 one participant speculated that Arctic char were ringed seal prey. He based this on the behaviour of ringed seals going up the Saputti River, presumably to chase the fish.

Pond Inlet

Participants from Pond Inlet identified 15 prey types, the highest diversity of the three communities. All interviewees (8) identified *ugak* as a prey type for ringed seals, seven participants had observed *kinguk* in stomach contents, and three participants had observed ringed seals feeding on Arctic char (*Salvelinus alpinus*). In addition, three individuals identified a sea snail called *tulluganak*, which was described as “*some kind of butterfly*” (Caleb Sangoya) and “*kinda look[s] like a raven*” (Jaykolassie Killiktee). Based on input from the interpreter I concluded that this species would likely be the sea snail *Limacina sp.* Other prey types observed by participants included *kanayuk* (sculpin; Cottoidea), *ijituk* (a type of small sculpin), Greenland halibut (*Reinhardtius hippoglossoides*), *kingukpak* (a type of brown shrimp about 4-5 inches

long), pink shrimp (a species that is about 2 inches long), clams or shellfish, *igluunaq* (which may be Mysida or Euphausiacea), a fish resembling a snailfish (small and reddish), puffer-like fish, and a fish similar to Acadian redfish (see table 2 for the number of people who observed these prey types).

Some participants observed partially consumed fish floating in the *agluit* (table 2). The interviewees speculated that these were remnants from ringed seals feeding.

Pangnirtung

In Pangnirtung, the participants described 10 distinct prey types that ringed seals fed on near the community and in Cumberland Sound. *Kinguk* were observed by all (8) of the participants, capelin (recognized as a newer species in the area) were observed by most (5) in stomach contents, four participants observed each of *ugak* and Greenland halibut, and three people described a fish called *ijituk*, a small, jelly-like fish with a red spine, smaller than *kinguk*, which was identified as a small species of sculpin through discussions with the interpreter and others in the community. Other prey types included Arctic char, *kingautia* (an invertebrate, smaller than *kinguk*), a large eyed fish (about 1.5 inches long), shrimp, and *kanayuk*. There was a single individual who also observed prey in *agluit*, specifically Greenland halibut and Arctic cod.

Table 2.3: Prey types observed in ringed seal stomach contents by interview participants in Arctic Bay, Pangnirtung, and Pond Inlet, Nunavut. The symbol 'X' indicates the interviewee identified the fish or invertebrate as ringed seal prey, either through stomach contents or directly observing ringed seals feeding. The symbol '*' indicates the interviewee observed partially consumed fish in ringed seal breathing holes.

Prey types	Arctic Bay							Pangnirtung								Pond Inlet								
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
Kinguk (amphipods)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	
Ugak (cod)	X	X	X	X	X	X	X	X		X		X*	X			X	X	X	X	X	X	X	X	X*
Arctic char												X						X		X		X		
Clams/shellfish					X											X								
Benthic fish					X																			
Capelin								X		X		X	X	X										
Greenland halibut									X			X*	X	X					*	X*	*		*	
Kingautia (invert smaller than kinguk)									X															
Small, large eyed fish (1.5 inches long)									X															
Shrimp										X						X								
Kanayuk (sculpin)										X						X							X	
Ijituk (small type of sculpin with large eyes)											X	X		X								X		
Kingukpak (brown shrimp, 4-5 inches long)																X								
Shrimp (pink, 2 inches long)																X								
Igluunaq (small inverts, usually can only see the eyes) these may be Mysida or Euphausiacea																	X							
Tulluganak - sea snail or sea butterfly (likely Limacina sp.)																	X	X			X			
Small (2 inches), reddish, snailfish type fish																				X				
Puffer-like fish																						X		
Similar to Acadian redfish																					*	X	*	
Lumpfish																			*					

* Found part of the fish in ringed seal breathing holes.

Ringed seal flavour

Most participants described inter-individual differences in the taste of meat from ringed seals they harvested. Interviewees usually associated flavour differences with prey types, certain seasons, different geographic areas, or ringed seal age classes.

Arctic Bay

The taste of ringed seal meat was described by all participants as sometimes having a different flavour depending on various factors. Five participants associated flavour with what ringed seals were feeding on: *“Each seal doesn't taste the same because it depends on what they're feeding on, so whatever they're feeding on will affect the meat, the taste of the meat”* (Tommy Tatatuapik). Of those participants, four observed that ringed seals consuming *ugak* tasted differently from those feeding mainly on *kinguk*. All noted that the latter tasted better. Sakiasie Quanaq explained: *“[ringed seals] feeding on kinguk, taste better compared with the one[s] that are feeding on cod”*. One participant mentioned that whether a seal fed on larger or smaller *ugak* made a difference in flavour and that he could also taste if seals had been feeding at the bottom of the ocean.

Most participants (6) noted a difference in ringed seal flavour during the ice season (winter to spring), which dissipated during the other months of the year. Three participants mentioned that ice presence or type influenced ringed seal prey distribution and, therefore, the flavour of seal meat. For example, one hunter explained that *“when [ringed seals were] on thick ice they mostly fed on krill¹, but when the ice [was] thin or [the seals were] in open water, they go*

¹ The interpreter in Arctic Bay translated *kinguk* to “krill”

after codfish” (Koonoo Oyokuluk). Other hunters pointed out that *“the seals in the solid ice compared with [those in] moving ice, taste different and what they feed on also varies”* (Sakiasie Quanaq), and that *“the more active [ringed seals] are, the less taste or odour or smell, and then the ones that are inside on solid ice where they're not as active, they smell or taste stronger”* (Olayuk Naqitarvik).

One person described spatial variation in flavour of ringed seals between Lancaster Sound and Admiralty Inlet in the summer. Five participants identified the floe edge as a location where the seals tasted different than those in the rest of Admiralty Inlet, and while this difference was discernible mostly in early spring and spring, one individual stated that he could taste the difference in winter as well. Two participants identified *kinguk* as the prey type being fed on near the flow edge: *“flow edge area probably has more kinguk, so they taste better, they're feeding more on the kinguk, than the southern area they're more into cod”* (Sakiasie Quanaq). On the other hand, another interviewee stated that the difference in flavour was due to ringed seals feeding on cod near the floe edge *“the best tasting ones are here, around the flow edge because they feed on the small codfish with big eyes on it”* (Tommy Tatatuapik).

Two interview participants stated that the texture of ringed seals harvested in areas with a stronger current or from polynyas in the winter were different from other areas. One attributed the difference to the level of activity: *“because it's current it's all moving water, so [the ringed seals are] more fit, the fat is more white, and the meat is not as rich and [has a] different texture”* (Koonoo Oyokuluk), while the other stated that *“the seals that are inhabiting the current or where the polynyas are ... are mostly feeding on the codfish”* (Tommy Tatatuapik).

Pond Inlet

In Pond Inlet, all interview participants (8) spoke of spatial differences in ringed seal flavour, for example, stating that *“all the seals taste good, but we notice the difference in different areas”* (Jaykolassie Killiktee). The areas people identified where harvested ringed seals tasted different were Lancaster Sound, the floe edge, Eclipse Sound, east of the floe edge and Bylot Island, and east of Baffin Island (Figure 2.6). For example, one participant noted that *“[ringed seals are] least flavoursome down in open ocean when we come up [to] seal hunt [at] the floe edge. They're best. They're not so heavy tasting. They are not too fatty and their liver is much more tasteful”* (Caleb Sangoya). Three people attributed these flavour differences to diet, with Joshua Arreak explaining that *“they taste [like] what they eat”*, while another interviewee only speculated that this was the cause of differences in flavour. Another noted finding no difference in the stomach contents (i.e., that ringed seals were feeding on both *ugak* and *kinguk*) of ringed seals harvested from Lancaster Sound, despite noticing a difference in the taste: *“nothing different [in the stomach contents] but still taste[d] just a little different”* (Joshua Katsak). One participant noted that seals in Navy Board Inlet tasted like those harvested in Baffin Bay. Three interviewees described differences in the taste of ringed seals that extended far beyond the waters near Pond Inlet, including west and south to Admiralty Inlet and Hudson Bay, and east and southward as far as Iqaluit. For example, one interviewee stated:

The [ringed] seals taste better towards Clyde River. Clyde [River], Pang[nirtung] and Iqaluit....From that area toward the other side Baffin Island. Igloolik, Repulse Bay, uh, Chesterfield Inlet area ... [the ringed seals] taste heavier [and] goes towards Hudson Bay (Caleb Sangoya).

Another interviewee expanded along these lines by explaining:

From what I know, like, further South like Clyde and all the way to Iqaluit, the seals taste different, like same taste as in this area [east of Eclipse Sound] ... and I think it's because of what they eat. Makes a difference (James Simonee).

Most of the participants did not mention differences in taste associated with the time of year. One stated that ringed seal flavour was generally the same year-round. Two noted that winter and spring, and the ice season, were the times when taste differences were more pronounced. One participant expanded that during winter, ringed seals in open water areas (near the floe edge) and those in fiords (ice-cover) differed in flavour and that the latter had a *“different taste and the smell [was] less”* (Joshua Katsak).

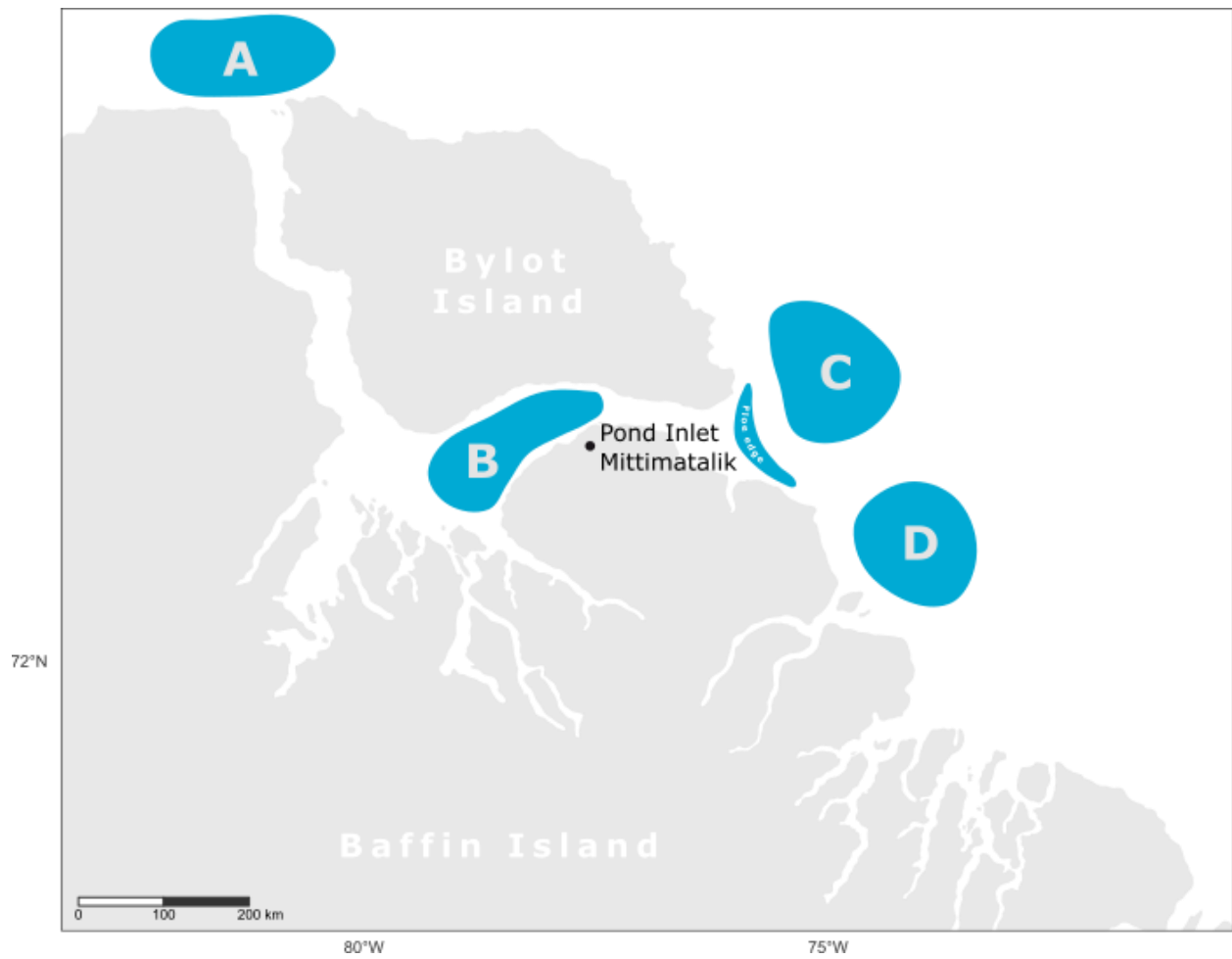


Figure 2.6: Map showing the approximate areas where interview participants from Pond Inlet, Nunavut verbally described spatial differences in the flavour of ringed seals harvested, including the floe edge, Lancaster Sound (A), Eclipse Sound (B), east of the floe edge and Bylot Island (C), and east of Baffin Island (D)

Pangnirtung

Most of the participants (7) described taste variation detected in ringed seals they harvested. Usually, this was attributable to the summer and moulting period when the ringed seals were at their skinniest, and therefore did not taste as good. Five of the interviewees stated that the ringed seals tasted best when they fattened up again in the early fall and the winter. The meat was also described by three participants as less desirable when ringed seals were feeding on *ugak*. One interviewee described Arctic char as having a negative impact on the taste of ringed seal meat and that the smell and taste was discernible as soon as the seal was cut open. Ringed seals in a certain part of Cumberland Sound fed on a type of fish called *ijituk*, which caused their meat to not taste good. One person described *kinguk* as having an impact on the taste of seal and that the meat tasted best when they fed on this prey. One interviewee described differences in taste that spanned large geographic areas; specifically, he noted that seals near Iqaluit did not taste as good as those near Pangnirtung, with the former having a more aged taste and the latter having a purer taste and speculated that this difference was associated with what was available for prey in the area.

Spatial differences in foraging

Participants described spatial variation in seal feeding locations that ranged from the small scale, with a focus on specific features such as polynyas or the floe edge, to the large scale, which covered areas far outside their communities. In many cases interviewees reflected on how feeding locations shaped seal access to specific species of prey.

Arctic Bay

Ringed seals feeding near polynyas was noted by three participants, with current as the factor that was associated with the presence of prey species, both *ugak* and *kinguk*. Paul Ejangiaq stated: *“the current helps [the prey] to get them close to the surface ... amphipods are closer to the surface, so it's easier for them”*. The floe edge was associated with feeding ringed seals by two participants who both identified *ugak* and *kinguk* as prey. One participant included that in deep-water areas ringed seals predominantly fed on *kinguk*, but another characterized deep-water areas as being associated with *ugak*. Moses Koonoo spoke of the good health of ringed seals in a certain part of Admiralty Inlet: *“Victor Point area always has healthy [ringed] seals or [that have thick] fat. Maybe they have good food there to eat, enough for them”*.

Pond Inlet

Interview participants described some spatial variation in ringed seal prey. One stated that ringed seals east of Eclipse Sound fed on *ugak* and said that he had *“never seen any kinguk in their stomach from this area”* (Joshua Katsak). The two types of shrimp (*kingukpak* and a type that is pink) described were each specific to a particular location within southern Eclipse Sound and western Navy Board Inlet, respectively. Another participant had observed that *“[ringed] seals more around fjords or inlets [were] bigger than the east side [of Eclipse Sound] ... because of what they eat”* (James Simonee) but did not state what the differences in prey would have been. A fish resembling a snailfish, small and reddish, was described by one participant as ringed seal prey found in a specific area of Eclipse Sound, and that seals near Clyde River also fed on this type of fish. Near Button Point, in Eclipse Sound, another participant observed a fish resembling an Acadian redfish in the stomachs of seals. He also observed that ringed seals fed on *ugak* in

areas with rough ice and near the floe edge. Another observed that ringed seals fed more on *kinguk* than *ugak* in Eclipse Sound but found the opposite in the inlets.

Pangnirtung

Descriptions of spatial distribution of ringed seal feeding were again variable. One individual pointed out that although ringed seals were found everywhere, there were some areas where they gathered to feed. One participant had observed that ringed seals fed more in open water areas because there would be more *kinguk*, whereas another interviewee had observed that ringed seals fed on *kinguk* anywhere. Two individuals had observed that ringed seals fed on capelin in the mouth of Pangnirtung Fiord, and one of them said that there was also an abundance of capelin on the west side of Cumberland Sound, which was perhaps why he had observed more ringed seals in that region. In a certain part of Cumberland Sound, one interviewee observed that the ringed seals were larger because they fed on large Greenland halibut.

Seasonal differences in foraging

In the three communities, interviewees characterized ringed seals as feeding throughout the year, except when they were on the ice basking and moulting in late spring and early summer. As the ice disappeared ringed seals increased their foraging efforts and became the fattest by the end of summer or early fall.

Arctic Bay

There is variation between individual ringed seals concerning when their respective moulting periods start and end, and how long they last, but in Arctic Bay the moulting period begins around May or June and ends in August or September.

Three participants described ringed seals as feeding on *ugak* and *kinguk* throughout the year. Reports varied among participants as to whether ringed seals fed more often on *ugak* or *kinguk* during a certain season, but no identifiable trend emerged to indicate that ringed seals fed on one of these species over the other at any given time of the year. One participant remarked that in summer, the seals fed on a greater variety of prey, and another noted that ringed seals fed more in the fiords and inlets. One participant noted the presence of clams or shellfish in the stomachs of ringed seals during the winter.

Pond Inlet

Participants stated that during the moulting period the stomachs of ringed seals were not always empty, but rather that they had “*less content... because [ringed seals are] spending too much time on the ice, on top of the ice*” (Sheatie Tagak). Near Pond Inlet the moulting period typically starts around May and extends until July or August.

Four of the participants noted that ringed seals fed on both *ugak* and *kinguk* throughout the year. The only observation of a Greenland halibut being preyed upon by a ringed seal was in the spring. Prey that was observed specifically in the summer included: Arctic char (observed by two participants), the pink shrimp (observed by one participant), sculpins (observed by one participant), and small invertebrates called *iglunaaq* (observed by one participant), which was

also observed in the fall. The invertebrate, *tulluganak*, was observed by three people in the stomach contents of ringed seals during both the summer and fall, although one participant had observed this species was present year-round and in higher abundance during the fall. The shrimp, *kingukpak*, was observed by one interviewee in, September. Five of the participants described both *ugak* and *kinguk* as ringed seal prey in the winter, but two people specified that said that they had predominantly observed *kinguk* in the stomachs of ringed seals during this period.

Pangnirtung

Participants described ringed seals as feeding year-round and, as with the other two communities, the only time of year that they did not feed was during the period in which they basked and moulted, beginning in May and lasting until July or August. Once their new coats had grown in, the seals would start to feed again, and their stomachs would be full by September or October (observed by five participants). However, some participants described an earlier start to the moult and reported that it now sometimes lasts longer because of the ice melting earlier in the spring and the seals not having as much time on the ice to complete their moult, resulting in them staying in the water longer which in turn lengthens the period it takes for their new coat to grow.

Most interviewees observed *kinguk* in the stomachs of ringed seals throughout the year, while capelin, *ugak*, and *ijituk* were also observed year-round, but only by a few interviewees. Greenland halibut was observed by one participant year-round, but then three participants reported only observing this prey type in the winter months. One individual reported having not observed any seasonal changes in what ringed seals preyed upon.

Foraging differences by ringed seal age class

Some age-related differences in diet were observed by interviewees from the three communities. This mainly focused on the feeding patterns after young seals weaned from their mothers and how this differed from older seals.

Arctic Bay

Most participants noted a distinction in the prey consumed by juvenile and adult ringed seals. Four stated that juveniles were predominantly feeding on *kinguk*:

The bigger, the older [the ringed seals] are, it seems to be that they're feeding on cod more, and the younger ones, they are feeding more on [kinguk]. As soon as they leave their mother and they start on their own, [the] young, are after [kinguk] more, but when they grow older, as an adult, they are more into codfish (Koonoo Oyokuluk).

However, one participant characterized the taste of the meat of some pups as being more like *ugak* when they weaned from their mother's milk, reporting that during the "third month when they start feeding, the taste becomes more like cod fish" (Sakiasie Quanaq). One person stated that all ringed seals, regardless of age, would feed on both *kinguk* and *ugak*. Spatial separation associated with feeding between adult and juvenile ringed seals was discussed by Paul Ejangiaq, who said, "the young ones, juveniles are mostly seen around inlets or around the shore more, [in] summertime, although they mix with adults too sometimes", and that the separation continued into the fall.

Pond Inlet

One participant stated that once the seals weaned from their mother's milk they fed on the same food as adults, but three participants mentioned differences between juveniles and

adults, each with a different observation. One said that *nattivaq* (young of the year seals) fed on *tulluganak* and that “*when they have so much [of] those things, then they taste awful*” (Caleb Sangoya). Another observed that juveniles fed on *kinguk* once weaned, while the third simply said that during the period that seals are weaning and starting to feed independently, he would observe some *ugak* in the stomachs but not as much as what would be found in adults.

Pangnirtung

Three of the interview participants had observed differences between juveniles and adults. One person said that when juveniles first weaned from their mother, they would not have a lot of food in their stomachs because they would still be learning how to hunt for food, and that although the adults and juveniles fed on the same prey, they targeted *kinguk* when they first started feeding. The observation that juveniles fed on *kinguk* when first weaned was shared by another participant who stated that they were usually doing this in shallow areas and that young ringed seals also fed on capelin. A single interviewee observed juvenile ringed seals feeding on small fish with large eyes. One interviewee Greenland halibut was associated with older ringed seals.

Other observations associated with foraging

Some of the interviewees made observations that related to foraging which did not fit within the categories above. These related to interactions with other species, observations about prey species, or foraging behaviour.

Arctic Bay

Two of the participants had observed interactions between ringed seals and other species which related to feeding. One participant had noticed that when narwhal (*Monodon monoceros*) migrated into Admiralty Inlet, they drove the *ugak* towards shore and then ringed seals would feed on the *ugak* near shore. Another observed that in areas where ringed seals were feeding, seabirds would congregate.

Changes to the abundance of amphipods had been observed by a single participant. Specifically, he reported that there were fewer amphipods now compared to in the past and stated that while he still observed them in areas of current, he no longer saw them close to shore, which was a decrease that had occurred gradually over time.

Pond Inlet

One of the participants made two unique observations not mentioned by other participants. Namely, that in 2015 there were many dead Arctic cod on the ocean floor: “we saw many many many dead [Arctic cod] down on the bottom. I don't know why, maybe warmer waters cooked [them]? I don't know what happened. Seals, narwhals, that time of the year [were] really skinny” (Joshua Katsak). He had also observed that between 2009 and 2011 ringed seals were noticeably thinner, “maybe 20, 25 [% thinner] ... I think the food has changed from the current. I think [that is the] reason why seals were skinny in three years, 2009, 10, 11”.

Pangnirtung

A specific behaviour associated with feeding was described by three interview participants in Pangnirtung. This was called *angimitaqtu* and refers to when ringed seals are

observed bobbing up at the surface and then diving back down in the same area; “*hunters can tell when they're feeding [be]cause they're in the same spot diving down and coming up*” (Lasaloosee Ishulutaq).

Several participants observed connections between feeding ringed seals and other species. Three interview participants had observed gulls flying over, following, or feeding near ringed seals that were feeding. One participant observed ringed seals in areas known to have high concentrations of Arctic char and *kinguk*. Although he did not know if they were feeding on the Arctic char, he had noticed the seals near rivers that were known to carry many of the fish and noted that the number of *kinguk* was so high in these locations that they consumed the Arctic char that he would catch in his fishing nets.

2.5 Discussion

Inuit hunters have a detailed understanding of the regions within which they harvest and travel. The spatial extent of these areas is very large, and people’s knowledge of ringed seals extends throughout. The semi-structured interviews gave us the opportunity to explore the diverse and rich information shared with us by knowledge holders. Interview participants shared observations on the diversity of prey they found in ringed seal stomachs, how the flavour of ringed seal meat varied with geography and season, the differences observed in spatial and seasonal foraging, the differences, and similarities between the diets of adult and juvenile ringed seals, and other observations related to foraging.

Observations shared by hunters in all three communities identified *ugak* and *kinguk* as primary prey found in ringed seal stomachs. This is consistent with diet studies across the

circumpolar Arctic that identify Arctic cod and *Themisto sp.* as the most abundant or common prey in ringed seal stomach contents (Holst et al., 2001; Lowry et al., 1980; Matley et al., 2015; McLaren, 1958; Weslawski et al., 1994). In both Pagnirtung and Pond Inlet there was a greater diversity of prey than that observed by Arctic Bay hunters. I would expect that prey diversity would be highest in Pagnirtung, which is farther south and would experience poleward distributional shifts of marine species moving from subarctic and temperate waters as a result of warming waters sooner than higher latitudes (Greenan et al., 2018; Watt et al., 2016; Yurkowski et al., 2018). Interestingly, there is a large difference in the diversity of prey between Pond Inlet (n=10) and Arctic Bay (n=4), which are geographically near to one another and at similar latitudes. However, Pond Inlet is influenced by both the West Greenland Current and cold Arctic waters originating near Jones and Smith Sounds. These currents travel a distance of about 100 km westward into Lancaster Sound and then intrude southward into Eclipse Sound, bringing with them waters and biota originating in both the Arctic and western Greenland (Fissel et al., 1982; H. Melling, personal communication, June 15, 2021). On the other hand, central and western Lancaster Sound, as well as Admiralty Inlet and Arctic Bay, are influenced by a different current flowing from the west and originating from Arctic waters in the northern Canada Basin north west of Resolute Bay, Nunavut (Curry et al., 2014; Fissel et al., 1982; H. Melling, personal communication, June 15, 2021). Near southern Baffin Island, Cumberland Sound opens to southern Davis Strait and is subject to influences from both the southward flowing Baffin Island Current and the northward flowing West Greenland Current (Bedard et al., 2015; Curry et al., 2014). In this way, although Pond Inlet and Arctic Bay are geographically proximate, the

difference in the diversity of observed prey species may be a result of influences from the respective currents influencing each of these areas.

The taste of ringed seal meat was a characteristic that varied depending on the location, season, and diet of the harvested ringed seals. Furgal et al. (2002) found that hunters described some ringed seals as having a taste and smell similar to Arctic cod, and speculated that the taste of meat could be a reflection of local seal diets, or perhaps fine scale spatial differences among stocks. For prey to influence the taste of ringed seals in certain areas or seasons, seals would have to remain in the same areas or consistently select for preferred prey. Yurkowski et al. (2016) found that although ringed seals traveled across large distances and occupied a wide latitudinal range, both adults and subadults exhibited resident behaviour during the open water season, implying a focused approach to foraging. Although in northern latitudes ringed seals spent more time travelling, while in southern latitudes they exhibited more of the resident behaviour, this was likely related to the northern ringed seals needing to travel farther to find areas with adequate prey compared to seals tagged in southern areas (Yurkowski et al., 2016). Stable isotope and fatty acid analyses are used as proxies for animal diet and distribution (Budge et al., 2006; Iverson et al., 2004; Newsome et al., 2010), and could be used to investigate correlations between reported taste differences and inferred seal diet (e.g., trophic level, proportions of a given prey item) and distribution to assess the influences of these factors on the taste differences people have described.

Although some individuals identified certain areas where they had observed foraging behaviour, the overall results point to widespread feeding. This reflects the generalist feeding strategy often ascribed to ringed seals (e.g. Labansen et al., 2011; McLaren, 1958; Weslawski et

al., 1994), and also indicates that prey is available in many types of habitats (for example, at the floe edge, near shore, near river mouths, polynyas, etc.). Gryba et al. (2021) found that hunters had observed that ringed seals were found throughout the waters near Utqiagvik, Alaska, that they fed opportunistically, and that although people often observed the seals foraging near shore, that ring seals foraged more broadly as well. They also found that ringed seals had foraging hotspots (Gryba et al., 2021). This was captured by our study as well insofar as people described areas like the floe edge and polynyas as places where ringed seals foraged.

Studies across the Arctic have found that in some areas the primary prey of ringed seals varied seasonally. Lowry et al. (1980) put together the results of several studies (conducted between 1940-1978) outside of Alaska that described the seasonality of ringed seal prey. In the Sea of Okhotsk, Bathurst Inlet, and Kara Sea the primary prey in spring and summer were amphipods and mysids, in addition to euphausiids and shrimps in the Sea of Okhotsk specifically. In the Kara Sea and the Sea of Okhotsk during the fall and winter this shifted to fishes, specifically Arctic cod in the former and saffron cod (*Eleginus gracilis*), smelt, herring and other fishes in the latter. In other areas, southwest Baffin Island, northern Foxe Basin, Ungava Bay, and northern Labrador, ringed seals fed on amphipods, mysids, Arctic cod, and other invertebrates and fishes, but no seasonality was found. More recent studies (Chambellant et al., 2013; Quakenbush et al., 2011) have found seasonality in ringed seal prey. In Western Hudson Bay, seals harvested between 1991 and 2006 consumed sand lance (*Ammodytes sp.*) in the open water season, and greater numbers of Arctic cod, capelin and invertebrates when sea ice was present during spring (Chambellant et al., 2013). In Alaska, seals harvested between 1998 and 2009 consumed greater numbers of hyperiid amphipods in the fall and winter than in the spring and summer, but Arctic

cod presence did not change drastically between each season (Quakenbush et al., 2011). The lack of seasonal variation in the consumption of Arctic cod contrasts with what was observed in the same study, but between seasons, in an older data set: ringed seals harvested between 1961 and 1984 consumed greater numbers of Arctic cod in the fall and winter than in the spring and summer (Quakenbush et al., 2011). Although most studies show there to be seasonality in consumed prey, there is a high degree of variability between areas and types of prey. This is perhaps why the observations made by interview participants were not always consistent. However, *kinguk* and *ugak* were consumed year-round, with some participants observing specific prey types as being more dominant in certain seasons.

Most participants in our study observed that the moulting and basking period was the only time of year when ringed seals ate less, or not at all, resulting in them becoming the thinnest. This is consistent with the observation that ringed seals in Alaska are thinner in the summer and breeding season (Gryba et al., 2021). Young and Ferguson (2013) found that ringed seal body condition was poorest after the moulting period, in June and July, and would begin to improve in late summer until they reached their best body condition prior to freeze up.

Age related differences in diet were observed by some interviewees. The observation that juveniles had less prey in their stomachs than adults was made by one hunter in each of the communities. Juvenile ringed seals are often displaced from ideal habitat by adults (J. A. Crawford et al., 2012; McLaren, 1958), which may impact their ability to access food resources. Off the west coast of Spitsbergen, Norway, juvenile ringed seals consumed greater amounts of krill (*Thysanoessa sp.*) than adults, which may be a result of them spending more time in fiords as a result of competitive exclusion (Bengtsson et al., 2020). This behaviour was mirrored by the

observation of a hunter in Arctic Bay who had noticed young seals in the inlets and near shore in the summer and fall. Ringed seal diets have been shown to change with age in other areas, namely that the consumption of Arctic cod is positively correlated with age, and that invertebrate presence, particularly *Themisto libellula*, is greater in the diets of younger seals (Dehn et al., 2007; Holst et al., 2001; Lowry et al., 1980). This is consistent with the observation by some interviewees that after weaning, juveniles consumed more *kinguk* than other prey.

Interviewees described associations in foraging behaviours between ringed seals and other species in proximity to them, such as narwhals and seabirds. Both Arctic cod and pelagic crustaceans like *Themisto libellula* are important prey for many species in the Arctic marine food web (R. E. Crawford & Jorgenson, 1996; Dunbar, 1957; Havermans et al., 2019; Hop & Gjøsæter, 2013). Some seabirds that migrate to the Arctic during their breeding season, like black-legged kittiwakes and Northern fulmars (*Fulmarus glacialis*), are pelagic feeders who consume both of these prey items (Dahl et al., 2003; Mallory et al., 2010; Matley, Crawford, et al., 2012). Narwhals also prey on Arctic cod and amphipods like *Themisto libellula* (Matley et al., 2015). Seabirds are likely associating with ringed seals to increase their chances of finding prey or opportunistically stealing prey. This behaviour has been observed when glaucous gulls (*Larus hyperboreus*) sometimes fly in proximity to other seabirds in order to steal Arctic cod (Matley, Fisk, et al., 2012). In the example with narwhals, it seems to have been the opposite, that ringed seals were benefiting from prey herding behaviour of the narwhals in the area.

This study was limited by the inability to go back and complete an intersubjective review with interview participants before writing these results. This would have given the hunters an opportunity to verify the information was accurately captured during the interviews and to

ensure that I did not misinterpret or over interpret the results. An intersubjective review would have also provided participants with the opportunity to add information that may not have been captured during the interviews or remove information they did not believe should be shared or was incorrect. As a way of rectifying this gap in communication and community validation, I intend to provide a translated report of the results of this study to the GN for dissemination to the HTOs of each community and to the interview participants. If I can secure funding for travel and interpretation, I will also present these results to the HTOs in person and attempt to discuss with interviewees the results to ensure they have an opportunity to validate my interpretation of their knowledge. My study may have also been limited by only interviewing men. Harvesting is a practice that includes not only the capture and slaughter of an animal but a whole suite of activities that include men and women (Bodenhorn, 1990). Although men are typically considered hunters, women often accompany their male family members on hunts, sometimes hunting themselves, and often processing the catch, meaning they would have their own knowledge of plants, animals, and the environment (Dowsley et al., 2010).

Inuit Knowledge is utilized to understand species and ecosystems, and to subsequently feed into co-management decisions, policy development, and science (Houde, 2007; Usher, 2000; Wenzel, 2004). The lens through which IK is understood and summarized here is ecological. This is problematic in that the knowledge of value, that which is concerned with species and the environment, is selected, or filtered to fit within a western scientific point of view (Nadasdy, 1999). Indeed, I do not have the epistemological understanding to fully engage with Inuit Knowledge in the way an Inuk researcher might, and therefore, my natural science training and non-Indigenous background biases me in ways of which I am not fully aware. As a

colleague and friend in Nunavut pointed out to me, simply my presence as a researcher, government employee, and southerner creates a power dynamic between myself and the individual I would be interviewing that could influence the interview results, most especially because of the colonial history which Inuit have experienced. McGregor (2004) discusses how Indigenous peoples wish to have their knowledge acknowledged and included in decisions that affect their lives yet there exists a power imbalance wherein traditional ecological knowledge is utilized in a system that values western ways of thought and practice. Rectifying the power imbalance may require reframing how researchers, resource managers, and policy makers view and understand IK so that it is taken in full context to include spiritual, cultural, ecological and other aspects inherent to an Indigenous body of knowledge (Latulippe, 2015). Another mechanism should include shifting the seat of power from non-indigenous actors to Inuit which can be achieved by engaging Inuit in all stages of research, from conception to completion, and empowering Inuit with the autonomy of final decision-making power (Inuit Tapiriit Kanatami, 2018; Latulippe, 2015).

The information contained in this study contributes to our understanding of ringed seals and expands our knowledge of foraging ecology for this species in the areas around Arctic Bay, Pond Inlet, and Pangnirtung, Nunavut. Specifically contributing information on ringed seal prey types some of which were not identified in the stomach contents analysis that was conducted concurrently (Chapter 3) (e.g., Greenland halibut and Arctic char); knowledge on the flavour of ringed seal meat; spatial differences in foraging which are difficult to capture in traditional diet studies without having fine scale information on harvest location and associated features (e.g., polynyas, water depth); seasonal differences in foraging; foraging differences between age

classes; and other observations like behaviours associated with feeding and inter-species interactions. Most importantly, our study helps to address the gap of IK in the published literature and is a starting point for the larger body of information gathered during interviews for the Ringed Seal Inuit *Qaujimajatuqangit* project. Climate change continues to negatively impact sea ice habitats and change Arctic marine food webs (Fossheim et al., 2015a; Frainer et al., 2017; Hwang et al., 2020). By having access to diverse knowledge systems we can improve policy and provide wildlife managers with better decision making tools (Tengö et al., 2014) to address the potential adverse consequences that ringed seals, and the communities that rely on them, may face in the future.

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2.8 Supplementary Information

Research Ethics and Compliance with the University of Manitoba



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APPROVAL CERTIFICATE

April 27, 2015

TO: Maha Ghazal
Steve Ferguson
Principal Investigators

FROM: Susan Frohlick, Chair
Joint-Faculty Research Ethics Board (JFREB)

Re: Protocol #J2015:029
"Ringed Seal Inuit Qaujimagatuqangit Study"

Please be advised that your above-referenced protocol has received human ethics approval by the **Joint-Faculty Research Ethics Board**, which is organized and operates according to the Tri-Council Policy Statement (2). **This approval is valid for one year only.**

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please note:

- If you have funds pending human ethics approval, please mail/e-mail/fax (261-0325) a copy of this Approval (identifying the related UM Project Number) to the Research Grants Officer in ORS in order to initiate fund setup. (How to find your UM Project Number: <http://umanitoba.ca/research/ors/mrt-faq.html#pr0>)
- if you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.

The Research Quality Management Office may request to review research documentation from this project to demonstrate compliance with this approved protocol and the University of Manitoba *Ethics of Research Involving Humans*.

The Research Ethics Board requests a final report for your study (available at: http://umanitoba.ca/research/orec/ethics/human_ethics_REB_forms_guidelines.html) in order to be in compliance with Tri-Council Guidelines.

Ringed Seal Inuit Qaujimagatuqangit study consent form



UNIVERSITY
OF MANITOBA

RINGED SEAL INUIT QAUJIMAJATUQANGIT STUDY - CONSENT FORM

Thank you for agreeing to participate in our study. This project is an important opportunity for Inuit knowledge to be recognized and included in marine science, planning, and management.

Please take the time to read the form, if you have any questions or concerns please feel free to ask. If you are in agreement, please sign and date.

PROJECT DESCRIPTION

The Government of Nunavut (GN) Fisheries and Sealing Division is conducting an Inuit Qaujimagatuqangit study on ringed seal biology and habitat use. There have been concerns expressed by Inuit that not enough Inuit Qaujimagatuqangit is used in research. This study is meant to help address that concern.

The project relies on interviews conducted with hunters in Nunavut communities. We would like to gather local hunters' knowledge on ringed seal diet, behaviour when feeding, body condition, and health. This study will be completed in two years.

We have brought maps for participants to use if they wish. After something is drawn on the map we will discuss it and code it properly. We encourage you to discuss the species in as much detail as you can. We expect interviews to take approximately 2-4 hours.

Your participation is voluntary; however, an honorarium is offered, this will be based on GN rates of \$45/hour. This honorarium is fully funded by the Government of Nunavut's Department of Environment. The remainder of the project is being funded by a combination of funds from the Government of Nunavut's Department of Environment, the World Wildlife Fund, and the Federal Government through their Canadian Northern Economic Development Fund (CanNor).

CONFIDENTIALITY

The data collected in this study will be stored securely to ensure confidentiality. If you choose to remain anonymous, then all information regarding who you are will be removed from the knowledge collected.

The knowledge you share may be used in future projects within the Fisheries and Sealing Division, as well as by your community. If outside groups (e.g. private companies or non-Nunavut based researchers or organizations) wish to use this information they must make a request to request to the Fisheries and Sealing Division, who will evaluate if access will be granted. No charges will be levied for these materials when permission has been granted.

The results will be published in a public report which is shared with project partners, the interview participants, and the Iqaluit Public Library.

USE OF INFORMATION AND DISSEMINATION

At the end of the project, the results will be presented to the Regional Wildlife Organizations, a book will be published on ringed seal IQ in Nunavut, maps will be published containing the information drawn by participants, and a masters thesis with publications that are specific to ringed seal diet. The community, through the HTO and/or Hamlet, will receive copies of all publications as will all participants.

CONSENT

With your consent, the interview will be audio recorded. If you do not consent to being recorded, the interviewer will only take notes. During the interview you may ask us to turn off the voice recorders at any point in the interview if you feel uncomfortable, or if you feel it inappropriate to record any particular information.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate. In no way does this waive your legal rights nor release the researcher from her legal and professional responsibilities. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

If you have any questions regarding this research, please feel free to contact:

Maha Ghazal, Marine Mammal Advisor, Phone # 867.473.2669

Department of Environment, Fisheries and Sealing Division, PO Box 614, Pangnirtung, NU X0A 0R0

The ethics approval comes from the University of Manitoba's office of Research Ethics and Compliance. If you have questions regarding this process please feel free to contact the Human Ethics Coordinator: Margaret (Maggie) Bowman (P: 204-474-7122 or margaret.bowman@ad.umanitoba.ca).

A copy of this consent form has been given to you to keep for your records and reference.

If you agree to each of the following, please place a check mark next to each statement.

- I have read or had read to me the details of this consent form.
- My questions have been addressed.
- I agree to participate in this study.
- I agree to have the interview audio-recorded.
- I agree to have my name included with my quotes when published OR I would like to be anonymous
- I agree to have my name included in the acknowledgements of any report related to this project.
- I would like to receive updates and final results of the project.

Date: _____

Participant name (print): _____

Participant signature: _____

Witness name (print): _____

Witness signature: _____

To what address should we send you a copy of your interview?

PO Box _____ Community: _____ Postal Code: _____

Email: _____

Chapter 3: Ringed seal diet differs between north and south Baffin Island, Nunavut.

3.1 Abstract

Ringed seals (*Pusa hispida*) have a circumpolar Arctic distribution. As opportunistic predators they have a varied diet of fish and invertebrates, but primarily feed on Arctic cod (*Boreogadus saida*) and lipid-rich pelagic crustaceans. However, recent shifts in diet have been observed with a presumed link to climate change. In this study I evaluate the differences in the feeding ecology of ringed seals harvested from Admiralty Inlet, Cumberland Sound, and Eclipse Sound on Baffin Island, Nunavut using stomach contents analysis. Hunters provided 201 samples, of which 166 contained prey and were included in the analysis (Admiralty Inlet n= 47; Cumberland Sound n = 100; Pond Inlet, n = 19). Fish and invertebrates were found in most samples, frequency of occurrence = 87.3% and 83.7%, respectively. I identified 39 prey taxa, but many were present in low numbers or found in few samples. Arctic cod was the most abundant (mean percent abundance = $24.3 \pm 2.58\%$) fish species and most frequently found across all stomach samples (frequency of occurrence = 74.7%). Of invertebrates, Hyperiididae was the most abundant (mean percent abundance = $28.8 \pm 2.6\%$) and occurred most frequently in samples (frequency of occurrence = 67.5%). Multivariate tests found a significant difference in diets based on region ($p \leq 0.001$), year of harvest ($p \leq 0.001$), month of harvest ($p = 0.035$), age class ($p = 0.023$), and the interaction between age class and region ($p = 0.017$). Univariate tests indicated differences between regions in the prey counts of Arctic cod ($p = 0.04$) and Euphausiacea ($p = 0.018$). Arctic cod had higher abundance and biomass in both northern

regions than in Cumberland Sound, whereas Euphausiacea was not present in either of the northern regions. Temporal differences were driven by Euphausiacea among years ($p = 0.001$) and Amphipoda ($p = 0.035$) among months. Amphipoda differed significantly among age classes ($p = 0.042$) with young of the year consuming the highest abundance and biomass, followed by subadults, and then adults. Understanding the foraging ecology of ringed seals will help wildlife managers better understand the evolving dynamics of the Arctic food web and determine potential impacts on species at higher trophic levels.

3.2 Introduction

In the Arctic, the rate of temperature increase is double the global average and is predicted to continue climbing (IPCC, 2014; Overland et al., 2016). Changes to the marine Arctic as a result of warming temperatures have negatively impacted sea-ice distribution, reducing both coverage and thickness, and resulting in an increase in the duration of the open-water season (IPCC, 2014; Kwok, 2018; Lindsay & Schweiger, 2015; Stroeve et al., 2014). The indirect effects of increased ocean temperatures have contributed to changes in the distribution and abundance of marine species. The Arctic amphipod, *Themisto libellula*, has undergone range contractions (Havermans et al., 2019), while subarctic and temperate species like capelin (*Mallotus villosus*) have expanded their range (Havermans et al., 2019; Hop & Gjørseter, 2013; Kortsch et al., 2015; Møller & Nielsen, 2019). Shifts in the dominant prey species in an area can have impacts on the health of marine mammals, for instance because subarctic and temperate species (e.g., capelin or *Calanus finmarchicus*) may not be as lipid-rich as Arctic species, like Arctic cod (*Boreogadus saida*) (Frederiksen, 2017). Cascading effects on the Arctic marine food web have consequences for marine mammals, including behavioural changes (Hamilton et al., 2015) and negative impacts on body condition (Bogstad et al., 2015; Harwood et al., 2015).

Ringed seals are the most common ice-dependent marine mammal in the Arctic and subarctic regions and have been an essential harvest species in northern Canada for millennia (McLaren, 1958; Reeves, 1998). Ringed seals are generalists that feed on various prey ranging from fish to crustaceans and cephalopods. However, a few high-energy species make up the bulk of ringed seal diet (Barnhart et al., 2015; Kwok, 2018; Lindsay & Schweiger, 2015; Yurkowski et al., 2015), the most common being Arctic cod and lipid-rich pelagic crustaceans like *T. libellula*

(Chambellant et al., 2013; Crawford et al., 2015; Gjertz & Lydersen, 1986; Labansen et al., 2007; Matley et al., 2015; Siegstad et al., 1998; Weslawski et al., 1994). Arctic cod and *T. libellula* are both ice-associated species, distributed widely in the Arctic Ocean (David et al., 2016; Dunbar, 1946; Havermans et al., 2019). Although ringed seals are considered generalists, the strong reliance on ice-associated prey may predispose them to be vulnerable to changes in abundance and distribution of their prey, resulting in negative impacts to their diet and body condition (Kortsch et al., 2015; Kovacs & Lydersen, 2008; Labansen et al., 2007; Weslawski et al., 1994).

Arctic and subarctic regions such as Hudson Bay, the Beaufort Sea, and Svalbard have undergone changes in ringed seal diet due to warming temperatures and the altering composition of the Arctic food web (Chambellant et al., 2013; Crawford et al., 2015; Lowther et al., 2017; Young & Ferguson, 2014). In Hudson Bay, stomach contents of ringed seals harvested in 2000, and from 2003 to 2006, consisted mainly of sand lance (*Ammodytes sp.*) and capelin, species not significant in the diets of ringed seals harvested before 2000, whereas, the importance of Arctic cod in the diet was reduced compared to years before 2000 (Chambellant et al., 2013). The decreasing abundance of Arctic cod in the region, likely due to the extended open-water period, was hypothesized to be the reason for this dietary shift (Gaston et al., 2012; Young & Ferguson, 2014). Further, Yurkowski et al. (2016) inferred from stable isotope results that ringed seal diets in the Canadian Arctic became more diverse at southern latitudes, with increasing proportions of capelin and sand lance compared to diets more exclusively comprised of Arctic cod at northern latitudes. By way of analogy, ringed seal diets in west Spitsbergen, Norway, have also changed over the last 20 years as a consequence of food web modifications due to the recent influx of temperate and boreal fish species to the region (Lowther et al., 2017).

Diet studies of marine mammals inform our understanding of the ecological roles of species, including quantifying interactions with fish and other prey, assessing energy and biomass requirements, and describing responses to environmental changes (Hyslop, 1980; Pierce & Boyle, 1991). Stomach content analysis is a common method of investigating diet composition (Bowen & Iverson, 2012). The method involves the recovery and identification of undigested or partially digested prey parts, such as otoliths or squid beaks, which are then measured and used to extrapolate the size and biomass of prey taxa (Härkönen, 1986). Thus, this method provides high taxonomic resolution, prey size, and biomass information, allowing for assessment of prey importance (Hyslop, 1980; Matley et al., 2015) and shifts in key prey species over temporal or spatial scales. Some limitations of this method include: different digestion rates between soft and hard parts (leading to a bias towards hard parts) and the rapid digestion of prey reflecting feeding events shortly before sampling (Hyslop, 1980; Murie & Lavigne, 1986; Pierce & Boyle, 1991). Nonetheless, stomach content analysis remains a viable method in assessing prey availability and preference, and in turn might help predict how the focal species will respond to ecological and environmental variability (Bowen, 1997).

To improve our understanding of ringed seal foraging ecology in the eastern Canadian Arctic, I investigated the diet of harvested ringed seals from three regions: Admiralty Inlet, Cumberland Sound and Eclipse Sound, Nunavut (Figure 3.1). Specifically, I tested (1) regional diet differences, (2) temporal diet shifts between seasons and years, and (3) age or sex diet differences. Continued sea ice loss will result in changes to prey availability and ringed seal feeding habits, impacting their health, abundance, and distribution. Results from this study can inform long-term monitoring and conservation efforts for this species.

3.3 Methods

Stomach samples

I collected ringed seal stomachs ($n = 201$) from seals hunted by Inuit in Arctic Bay (1993, 1997), Pangnirtung (1996, 2008-2010, 2015-2016), and Pond Inlet (2015-2017) in a sample collection effort between the Hunters and Trappers Organization in each community and Fisheries and Oceans Canada. Whole stomachs were frozen at -20°C . Cementum growth-layer groups of canine teeth were counted to determine ringed seal age (Stewart et al., 1996). For most samples molecular sex was determined and only supplemented by harvester-identified sex when the former was not available. After thawing at room temperature, whole stomachs were weighed, cut open, and categorized as “empty” or “containing food.” When food remnants were present, I washed stomach contents and epithelium with water through a series of sieves of decreasing mesh size (4000, 2000, 500, 250, and $125\ \mu\text{m}$) to remove the hard parts. Hard parts included otoliths, fish bones, cephalopod beaks, and relatively large invertebrates. I identified stomach contents to the lowest taxonomic level possible, but because some invertebrate samples were identified only to family, I limited diet descriptions to species for fish and family for invertebrates. I refer to both levels of identification collectively as ‘prey taxa’ (Campana, 2004; Härkönen, 1986; Keast & Lawrence, 1990; Leung, 1972; McBride, 2010; Morrow, 1979; Svetcheva et al., 2007).

For most stomachs it was impractical to manually count the large number of invertebrate prey. Therefore, I suspended invertebrate prey in water and used a 500 ml Folsom plankton sample splitter to sequentially divide the sample in two until approximately 200 organisms were

present in a sub-sample. For the invertebrates in the sub-sample, I used tails for identification (Leung, 1972) and counts. To estimate total invertebrate prey count before splitting, I used the following equation: $N_{it} = N_{is} * 2m$, where N_{it} is the estimated total number of prey i , N_{is} is the number of prey i in the sub-sample, and m is the number of splits used to reach the sub-sample. I identified cephalopods by comparing beaks (also known as mandibles) with guides (Jereb et al., 2015; Wolff, 1984) and estimated counts by dividing the total number of mandibles by two.

Almost all invertebrates were digested to a certain degree. For this reason, I chose not to use weight measurements of whole individuals. Instead, I derived biomass estimates from values published in the literature (supplementary Table S3.3). When the lower mandible of cephalopods was present, I measured the lower rostral length (LRL) to calculate the length and weight using regressions (supplementary Table S3.3).

I identified fish species from recovered sagittal otoliths, using only otoliths with little to no degradation (surface structures were still visible). I measured length along the longest axis (parallel to the sulcus) using a Mitutoyo 505-646-50 calliper or an ocular micrometre. When a stomach contained over 25 otoliths of a given prey taxon, I randomly sub-sampled 25 for measurements. For unmeasured otoliths I estimated length by using the mean otolith length for each prey taxon.

To estimate the number of fish consumed I divided the total number of otoliths by two. Otolith lengths were then used for calculations in length and weight regressions (supplementary Table S3.3) to estimate the length and weight of the fish prior to consumption (Campana, 2004; Härkönen, 1986; McBride, 2010).

Data Organization

I grouped ringed seal samples into age class (adults [≥ 6 years based on age at sexual maturity], subadults [2-5 years], and young of the year [≤ 1 year, YOY] [Holst et al., 2001]); sex (female, male, and unknown); harvest year (1993, 1996, 1997, 2008-2010, 2015-2017); region (Admiralty Inlet, Cumberland Sound, and Eclipse Sound); and harvest month (January to December).

For analysis, I grouped prey into the following six categories: *Arctic cod*, other fishes, Amphipoda, Euphausiacea, Mysida, and other invertebrates. I used the following three indices, commonly used in stomach content studies, to characterize the diets: frequency of occurrence (FO%), abundance (A%), and biomass (B%) (Hyslop, 1980; Pierce & Boyle, 1991). I calculated frequency of occurrence thus: $FO_i\% = n_i/n * 100$, where FO_i was the frequency of occurrence of prey taxon i , n_i was the number of ringed seal samples with prey taxon i , and n was the total number of seals with prey in their stomachs. I calculated abundance as $A_i\% = A_{ij}/A_j * 100$, where A_i was the abundance of prey taxon i , A_{ij} was the abundance of prey taxon i in sample j , and A_j was the total abundance of all prey in sample j . I calculated biomass similarly, as $B_i\% = B_{ij}/B_j * 100$. I calculated the mean for abundance and biomass ($A_m\%$ and $B_m\% \pm se$).

In my analysis I excluded empty stomachs. Of 201 seals sampled, 31 stomachs were empty and four had only unidentifiable or non-prey contents (e.g., rocks), leaving 166 samples with prey contents for my analysis (Admiralty Inlet $n = 47$; Cumberland Sound $n = 100$; Eclipse Sound $n = 19$). Seal ages ranged from ≥ 1 to 38 years. Forty-seven seals were adults (≥ 6 years),

45 subadults (2-5 years), 69 young of the year (≤ 1 year), and 5 were of unknown age. The sex ratio was 94 males to 58 females, with 14 of unknown sex.

Statistical Analysis

I conducted all data management and analysis in R v.4.0.3 (R Core Team, 2020; Wickham et al., 2019). To visualize the spread of the prey abundance data and determine similarity among the communities, I used non-metric multidimensional scaling (NMDS) to create a distance matrix. Using the `metaMDS()` function in the 'Vegan' package (Oksanen et al., 2020), I applied an Anderson transformation on the count data. I ran the NMDS using the `decostand()` function, with three dimensions, 1000 iterations, and a Bray-Curtis ordination method.

From the `mvabund` package, I constructed a multivariate generalized linear model (mGLM) using the `manyglm()` function (Wang et al., 2012) to test for differences in prey composition between regions, month of harvest, year of harvest (1993, 1996, 1997, 2008-2010, 2015-2017), sex, and age class, as well as represent interactions between age class and region, and sex and region. I used the abundance of prey groups (*Arctic cod*, other fishes, Amphipoda, Euphausiacea, Mysida, and other invertebrates) as the response variables and fit a model using a negative binomial distribution to account for the large number of zeros (Warton, 2005). I checked the residuals plot to ensure random distribution and the model fit (Wang et al., 2012; Zuur et al., 2009). If differences were observed within the full model, then I ran an analysis of variance (ANOVA) with an adjusted p-value for multiple testing using a step-down resampling procedure (999 bootstrap iterations).

3.4 Results

Stomach samples

In most samples I found the presence of fish and invertebrates, FO = 87.3% and 83.7%, respectively. The abundance of invertebrates was higher ($A_m = 59.9 \pm 3.2\%$) than fish ($A_m = 40.1 \pm 3.2\%$), however, when comparing dry biomass fish ($B_m = 59.1 \pm 3.2\%$) were greater than invertebrates ($B_m = 39.1 \pm 3.2\%$) (Figure 3.2). In total I found 39 prey taxa, but many were present in low numbers or found in few samples. The highest number of distinct prey taxa found in an individual seal stomach was ten (Figure 3.3).

Of all fish taxa identified, Arctic cod was the most abundant ($A_m = 24.3 \pm 2.58\%$) and most frequently found across all stomach samples (FO = 74.7%). Other fish taxa were found in small quantities ($A_m \leq 6\%$), although Liparidae and Cottidae were both found in approximately one quarter of the samples (FO = 28.3% and 26.5%, respectively). Of invertebrates, Hyperiididae was the most abundant ($A_m = 28.8 \pm 2.6\%$) and occurred most frequently in samples (FO = 67.5%), followed by Mysidae ($A_m = 17 \pm 2.4\%$, FO = 49.4%), and Euphausiidae ($A_m = 6.6 \pm 1.4\%$, FO = 24.1%). Other invertebrate taxa were present in very small numbers ($A_m \leq 2\%$) (supplementary Table S3.2).

Non-metric Multidimensional Scaling (NMDS)

The representation of samples in the NMDS plot (Stress = 0.116) revealed overlap between the three regions, although ringed seals from both Admiralty Inlet and Eclipse Sound fed more on Arctic cod and other fishes, while ringed seals from Cumberland Sound tended to feed more on invertebrates and had a higher diversity of prey (Figure 3.4).

Effect of region, year, month, seal age, and sex

ANOVA revealed a significant effect with respect to region ($p \leq 0.001$), year of harvest ($p \leq 0.001$), month of harvest ($p = 0.035$), age class ($p = 0.023$), and the interaction between age class and region ($p = 0.017$). Sex was not found to be significant ($p = 0.061$), nor was the interaction between region and sex ($p = 0.569$) (Supplementary Table S3.1).

Univariate results indicate significant differences between regions in the prey counts of *Arctic cod* ($p = 0.04$). Abundance and biomass were higher in both northern regions (Admiralty Inlet: $A_m=43.4\pm6\%$, $B_m=59.5\pm6.1\%$; Eclipse Sound: $A_m=47.4\pm6.8\%$, $B_m=82.1\pm6.6\%$) compared to Cumberland Sound ($A_m=11.0\pm2.1\%$, $B_m=28.8\pm3.6\%$). Euphausiacea was also significant ($p = 0.018$) because it was not present in the diets of seals from Admiralty Inlet and Eclipse Sound, but was found in seals from Cumberland Sound ($A_m=10.9\pm2.3\%$, $B_m=3.3\pm0.9\%$), (Figure 3.5). The rest of the prey groups showed no trend and were not significantly different between regions ($p > 0.05$).

Euphausiacea abundance was significantly different among years ($p = 0.001$). In 2015 and 2016 mean abundance and mean biomass of Euphausiacea were greater than in each other year ($A_m=21.1\pm5.3\%$, $B_m=7.8\pm2.7\%$ and $A_m=13.2\pm4.7\%$, $B_m=2.6\pm1.0\%$, respectively). No other prey category showed significant variation over time ($p > 0.05$).

Diet differed by month, with variation driven largely by Amphipoda ($p = 0.035$). Consumption of Amphipoda was highest in January, and during the open-water period from June to October. Although there were no significant differences with respect to the other prey groups ($p > 0.05$), there did seem to be a general trend of lower *Arctic cod* consumption during the

open-water season (July to October) corresponding with a concomitant increase in *Mysida*, with the opposite pattern occurring during the ice-covered season. There was also lower *Arctic cod* consumption in March, which was accompanied by higher *Mysida* consumption during the same month (Figure 3.6).

Diet of Amphipoda differed significantly among ringed seal age classes ($p = 0.042$). Young of the year seals consumed the highest in abundance and biomass ($A_m=44.0\pm4.4\%$, $B_m=41.8\pm4.3\%$), followed by subadults ($A_m=30.7\pm5.0\%$, $B_m=16.9\pm4.4\%$) and then adult seals ($A_m=18.9\pm4.6\%$, $B_m=11.6\pm4.0\%$). The other prey types did not differ significantly with age class ($p > 0.05$). However, adults ($A_m=40.3\pm5.9\%$, $B_m=60.0\pm6.3\%$) and subadults ($A_m=28.6\pm4.6\%$, $B_m=52.8\pm6.0\%$) appeared to consume greater quantities of *Arctic cod* than YOY ($A_m=10.3\pm2.8\%$, $B_m=25.9\pm4.1\%$), and YOY consumed greater quantities of *Mysida* ($A_m=26.3\pm4.3\%$, $B_m=17.2\pm3.5\%$) than adults ($A_m=10.2\pm3.6\%$, $B_m=4.6\pm2.3\%$) and subadults ($A_m=9.6\pm3.2\%$, $B_m=3.5\pm2.3\%$) (Figure 3.7).

The significant interaction between region and age class was largely due to differences in consumption by seal age classes of Amphipoda ($p = 0.022$) and other fishes ($p = 0.022$). Adults and subadults consumed lower quantities of Amphipoda than YOY in both Admiralty Inlet (adults: $A_m=3.7\pm3.4\%$, $B_m=3.8\pm3.8\%$, subadults: $A_m=13.6\pm9.1\%$, $B_m=9.0\pm8.7\%$, and YOY: $A_m=28.4\pm8.6\%$, $B_m=30.0\pm9.2\%$) and Cumberland Sound (adults: $A_m=25.0\pm8.0\%$, $B_m=21.0\pm7.7\%$, subadults: $A_m=33.6\pm6.1\%$, $B_m=19.0\pm5.3\%$, and YOY: $A_m=48.7\pm5.4\%$, $B_m=48.5\pm5.0\%$). Other fishes were consumed in greater numbers across all age classes in Cumberland Sound (adults: $A_m=23.2\pm7.1\%$, $B_m=23.7\pm7.4\%$, subadults: $A_m=34.2\pm5.2\%$, $B_m=32.3\pm6.4\%$, and YOY: $A_m=2.6\pm1.1\%$, $B_m=15.1\pm4.1\%$), as compared to both northern regions, with the exception of adults in Admiralty

Inlet ($A_m=36.2\pm9.6\%$, $B_m=16.1\pm7.6\%$). The other prey categories were not found to be significant ($p > 0.05$) (supplementary Figure S3.1).

3.5 Discussion

The environmental changes resulting from warming temperatures are altering Arctic marine food webs (Fossheim et al., 2015; Kortsch et al., 2015; Møller & Nielsen, 2019). Ringed seal diets have been shown to vary spatially, temporally, and among age classes, suggesting flexibility in foraging (Holst et al., 2001; Labansen et al., 2007; McLaren, 1958; Wathne et al., 2000) and potential resilience in a changing Arctic. In this study, although I observed lower consumption of Arctic cod in Cumberland Sound than either of the northern Baffin Island regions, this species has not been replaced by subarctic and temperate forage fish as has been observed in other studies of the southern Canadian range for ringed seals (Chambellant, 2012; Chambellant et al., 2013; Yurkowski et al., 2016). Ringed seals focused consumption on Arctic cod, hyperiid amphipods, Mysidae, and Euphausiidae compared to other prey types, a finding consistent with many ringed seal prey studies (Crawford et al., 2015; Matley et al., 2015; Wathne et al., 2000). Siegstad et al. (1998) found Arctic and polar cod (*Arctogadus glacialis*) were the most dominant ringed seal prey in northwest Greenland. This was different from central west Greenland, where prey mainly consisted of amphipods, squid, capelin, and southwest Greenland where seals were feeding predominantly on capelin. Holst et al. (2001) found that in the high Arctic seals fed predominantly on fish, mainly Arctic and polar cod, and less so on invertebrates, which is consistent with our findings. Yurkowski et al. (2015) found a latitudinal difference in diet between ringed seal age classes (adults were ≥ 6 years and subadults 1-5 years) that was more

pronounced at higher latitudes, where adult consumption of forage fish was greater and consisted almost exclusively of Arctic cod. Meanwhile at mid- and low-Arctic latitudes the prey consumed was more varied, with greater overlap between adults and subadults (Yurkowski et al., 2015).

I found that diet was significantly different between years but did not observe a temporal trend. Other studies have found changes over time, but these results similarly did not always point in a clear direction. Crawford et al. (2015) found that in the Alaskan Bering and Chukchi Seas, the FO% of Arctic cod increased, and invertebrates declined over time, but this varied between study sites and age classes. In western Hudson Bay, Chambellant et al. (2013) described Arctic cod declining while capelin increased, and suggested that Arctic cod, an ice adapted species, was being replaced by subarctic species. Ferguson et al. (2020) found that year was an important factor on the body condition of ringed seals in southern Hudson Bay, which was not observed in the central Canadian Arctic.; there was a decline in ringed seal body fat between 2000 and 2016 that likely resulted from the region's environmental shift, which included changes in the availability of forage fish (Ferguson et al., 2020; Gaston et al., 2003).

Arctic cod consumption was lower the open-water months from June to October than in the ice-covered season from November to May. In contrast, Amphipoda consumption gradually increased during the open-water period and then declined during the ice-covered season. Chambellant et al. (2013) found that the diets of ringed seals differed between seasons in western Hudson Bay, specifically between fall and spring, with diets including a higher proportion of invertebrates, Arctic Cod and capelin in the spring as compared to the open-water period. On the other hand, in the open water season sand lance was the most important prey in

ringed seal diets (Chambellant et al., 2013). This is consistent with the findings of Young and Ferguson (2014), which described ringed seals as having different foraging patterns in the open water season, in which they fed pelagically, versus the ice-covered season in which the animals shifted towards benthic feeding. In northeast Greenland, the diets of ringed seals shifted from high quantities of *Themisto libellula* in the fall (September to October) to Arctic cod and very few invertebrates during spring (April to June) (Labansen et al., 2011). The diets of seals in west Greenland also showed seasonal differences, indicating opportunistic foraging on euphausiids that were more available in the spring and consumed in larger numbers than other prey (Siegstad et al., 1998).

Other studies in the Canadian Arctic have found no apparent diet differences between male and female ringed seals (Chambellant et al., 2013; Gjertz & Lydersen, 1986; Holst et al., 2001; Lowry et al., 1980; McLaren, 1958), which is in line with the results of my study. However, some research has found differences, for example Dehn et al. (2007) found that male stomachs were more likely to contain zooplankton and females more likely to contain fish. A different pattern was observed off the western coast of Svalbard whereby adult males were found to consume larger Arctic cod than females (Bengtsson et al., 2020).

I found a significant effect of age, even when examined between regions. Many other studies have found significant differences between age groups of seals (Bradstreet & Cross, 1982; Holst et al., 2001; Labansen et al., 2011; Lowry et al., 1980; Siegstad et al., 1998; Smith, 1987). Our findings that Arctic cod consumption increased with age, while the consumption of Amphipoda decreased with age, agrees with a study by Holst et al. (2001) which found that immature (<6) seals fed predominantly on pelagic crustaceans, mostly *T. libellula*, and adult seals

mainly ate fish, both Arctic and polar cod. Bradstreet and Cross (1982) noted that adult ringed seal diets were dominated by Arctic cod, whereas, amphipods specifically, *Themisto sp.*, were more important to the diets of immature seals. Dehn et al. (2007) found Arctic cod consumption was positively correlated with age, and observations by Lowry et al. (1980) described pups consuming fewer cod than adults. This pattern could be attributed to experience hunting, or potentially to adults excluding younger seals from optimal foraging areas (Dehn et al., 2007; McLaren, 1958; Stirling, 1977).

Certain limitations exist when describing diet based on stomach content analysis. Typically for pinnipeds, food items are present for a short window; in some studies, hard parts are still present and identifiable after six hours, but none after 18 hours (Murie & Lavigne, 1986; Pierce & Boyle, 1991). This is complicated further by variations in the clearance rate of various prey items. For example, cephalopod beaks can be found in the digestive system long after a feeding event (Pierce & Boyle, 1991) and may be over-represented in prey studies. In contrast, other prey, such as crustaceans, are digested more quickly and could be underrepresented (Lawson et al., 1995). Overall, digestive contents represent a short window of prey consumed near the location of harvest (Pierce & Boyle, 1991). One method of identifying species consumed that are beyond visual recognition is to use DNA barcoding. DNA barcoding has helped to resolve some of the issues with morphological identification of taxa, such as differentiating between species that are difficult to identify, or recognizing that morphologically unique life stages actually constitute a single species (Packer et al., 2009). In addition, DNA barcoding can help to identify a larger diversity of prey and species to a finer taxonomic level (e.g., Granquist et al., 2018; Jeanniard-du-Dot et al., 2017). Diet reflects both preference for and availability of prey.

Preference may obscure changes in prey availability if animals increase foraging effort to feed on their preferred prey. For example, Wathne et al. (2000) found that although Arctic cod made up only 1% of the available prey biomass along the Barents Sea ice edge, they were the most important prey item in ringed seal stomachs. There is no information on the abundance of prey species in the areas where ringed seals were harvested for this study, making it impossible to determine whether ringed seals were selective in their prey choice or simply preyed upon what was available.

As Arctic marine regions continue to warm, fish assemblages and the Arctic marine food web will change. Specifically, Arctic species may contract their ranges while subarctic and temperate species expand poleward. Arctic cod, an ice-associated species exclusively found in cold waters (David et al., 2016), may experience range contractions as temperatures increase due to global warming (Marsh & Mueter, 2020). For example, in Iceland and east Greenland, Arctic cod have undergone a distribution shift that may be related to temperature (Astthorsson, 2016). Astthorsson (2016) speculated that further warming will likely result in the disappearance of Arctic cod from Icelandic waters. Capelin, a species associated with subarctic and temperate waters (Hop & Gjørseter, 2013; Pedro et al., 2020), and considered quick responders to temperature change (Rose, 2005), have expanded their distribution northward in some areas, for example off the eastern coasts of Newfoundland and Labrador and in the Barents Sea (Carscadden et al., 2013; Ingvaldsen & Gjørseter, 2013). Although the distributional shifts observed in capelin stocks in the Northwest Atlantic cannot be directly linked to temperature increases, there is speculation that they are associated (Carscadden et al., 2013). Similarly, Ingvaldsen and Gjørseter (2013) found that the northward expansion of capelin is strongly

associated with temperature. Ringed seal consumption of Arctic cod was greater in both Admiralty Inlet and Eclipse Sound, as compared to Cumberland Sound, which may reflect shifting diets in southern regions. It is possible that with time the foraging ecology of high Arctic regions like Admiralty Inlet and Eclipse Sound may become more like Cumberland Sound.

The loss of sea ice may result in changes to the behaviour, health, population, and distribution of ringed seals. Hamilton et al. (2015) recorded several behavioural changes in ringed seals following a significant collapse of sea ice in the Svalbard region in 2006. The sea ice declines impacted both movement patterns and foraging behaviour, particularly of subadult ringed seals. In later years (2002-2003 vs. 2010-2012), time spent diving increased, as did the distances seals travelled, and ringed seals spent less time resting while moulting, all of which indicate increased foraging efforts and energetic costs (Hamilton et al., 2015). A more recent study in Svalbard found that despite dramatic changes to sea ice habitat over the last 30 years and a shift in fish and invertebrate communities to include more temperate species, ringed seal body growth rates and body condition remain largely unchanged (Andersen et al., 2020). The stability in demographic parameters may be a reflection of life-history plasticity and small-scale regional variations in conditions (Andersen et al., 2020). In the Amundsen Gulf, sampling from 1971–1978 and 1992–2019 revealed that ringed seal blubber thickness had declined over time (Harwood et al., 2020). The marked change in ringed seal body condition was not linked to any specific factor, but may be linked to factors such as prey availability and quality, changes to sea ice habitat, or shifts in weather that impact precipitation (Harwood et al., 2020). To fully understand the extent and impact of changing diets for ringed seals in the eastern Canadian Arctic we require data on fish and invertebrate availability, as well as studies examining the

health, body condition, and behaviour of ringed seals. These would be valuable data sets to complement diet analyses and expand our understanding of how environmental changes may impact ringed seals and the future of the greater Arctic food web.

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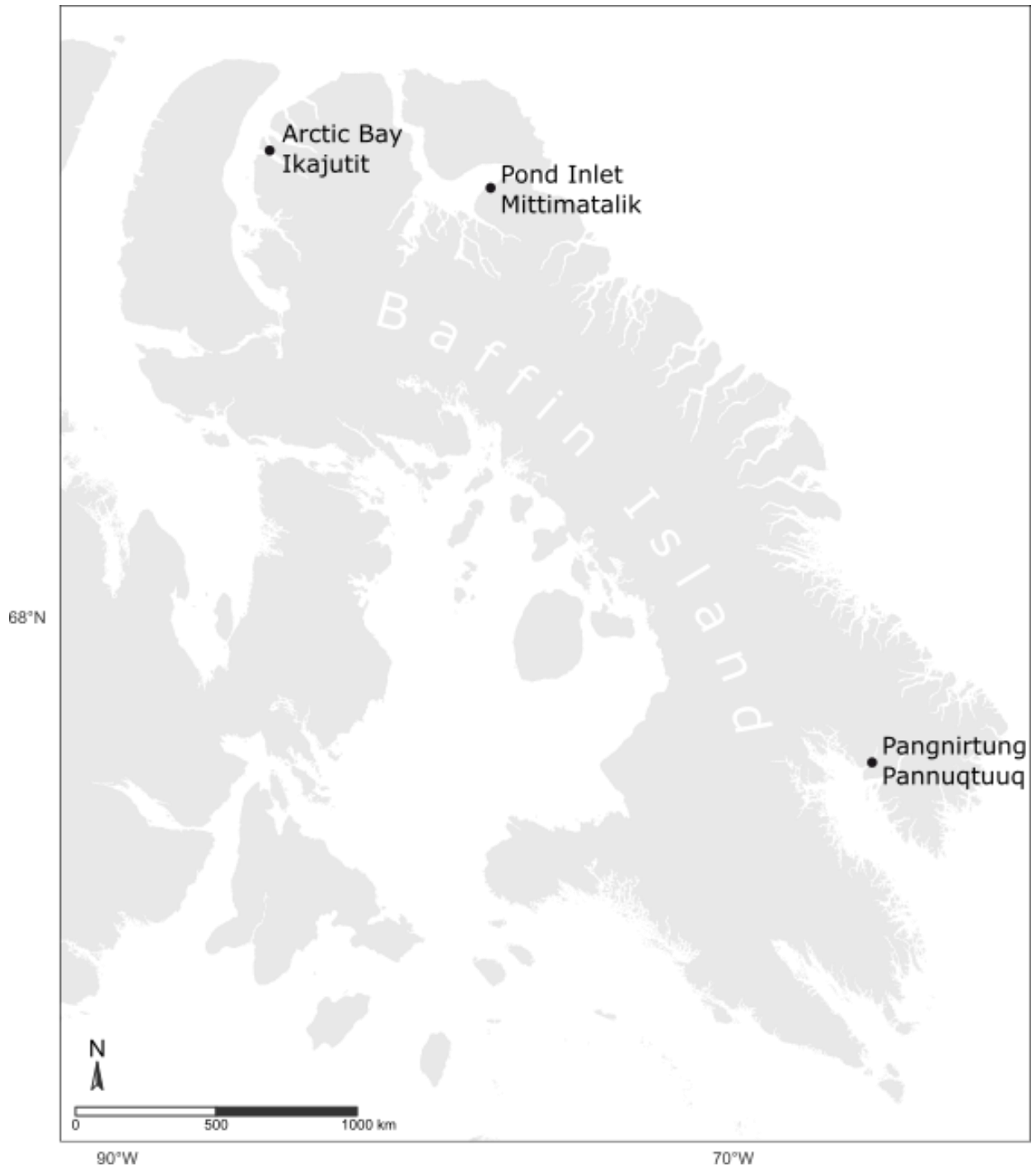


Figure 3.1: Map of Arctic Bay, Pond Inlet, and Pangnirtung, Nunavut

Diet indices (percent frequency of occurrence (FO%), mean percent abundance ($A_m\%$), and mean percent biomass ($B_m\%$)) showing consumed values of fish and invertebrates by ringed seals ($n = 166$) harvested in Admiralty Inlet, Eclipse Sound, and Cumberland Sound, collected over several years (1993, 1996, 1997, 2008-2010, 2015-2017).

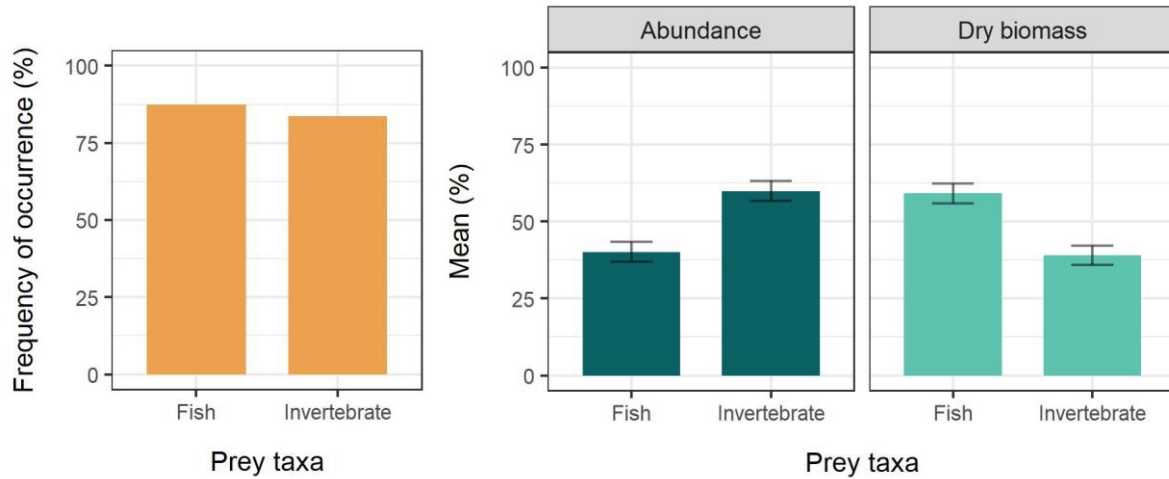


Figure 3.2: Diet indices (percent frequency of occurrence (FO%), mean percent abundance ($A_m\%$), and mean percent biomass ($B_m\%$)) showing consumed values of fish and invertebrates by ringed seals ($n = 166$) harvested in Admiralty Inlet, Eclipse Sound, and Cumberland Sound, collected over several years (1993, 1996, 1997, 2008-2010, 2015-2017).

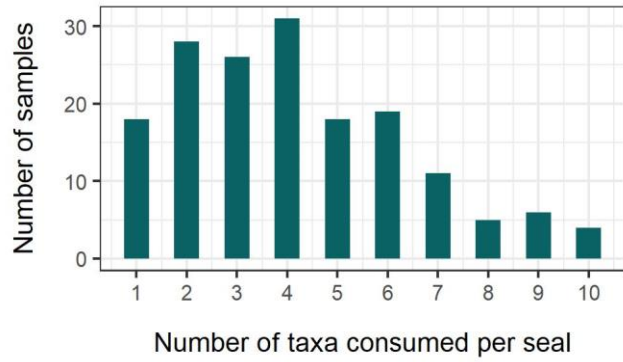


Figure 3.3: Distribution of the total number of prey taxa found in the stomachs of ringed seals ($n=166$), harvested from Admiralty Inlet, Eclipse Sound, and Cumberland Sound, and collected over several years (1993, 1996, 1997, 2008-2010, 2015-2017).

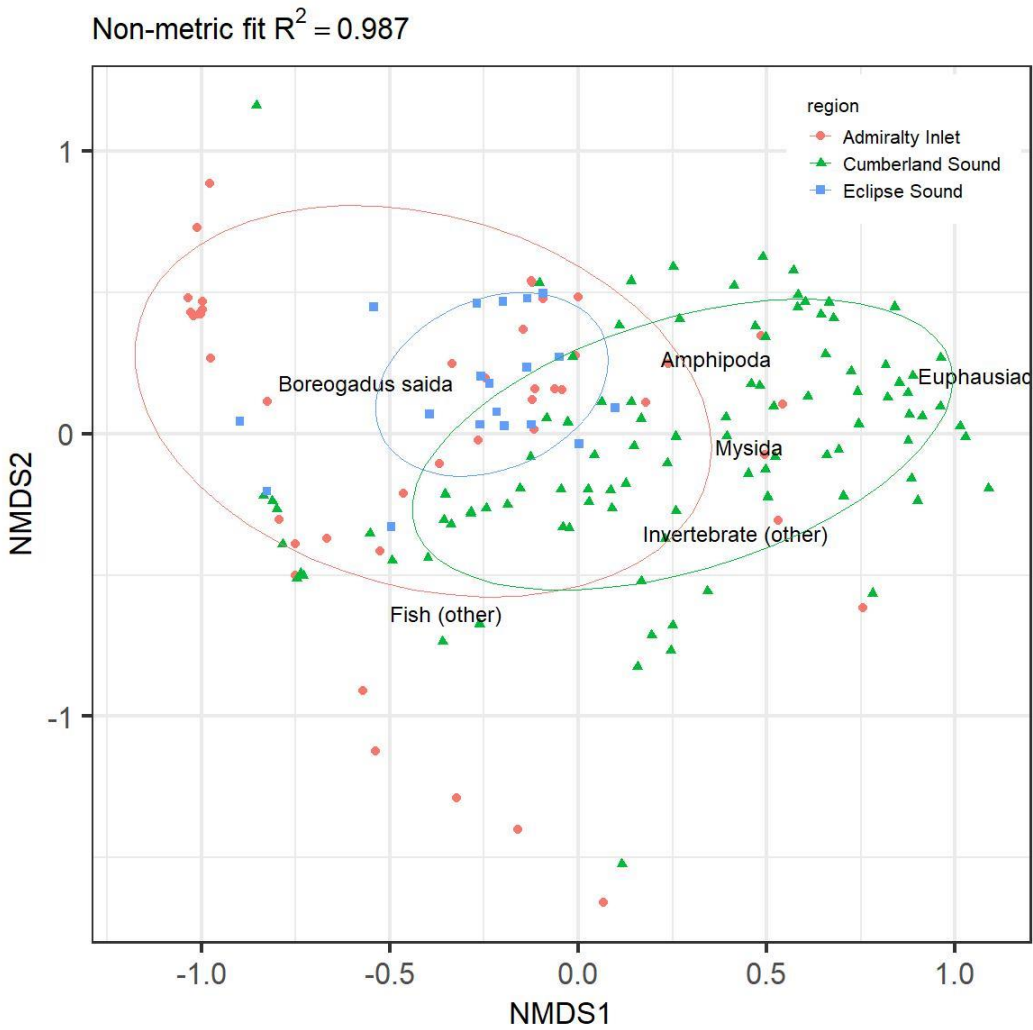


Figure 3.4: Non-metric dimensional scaling plot showing distribution of ringed seal samples ($n = 166$) in relation to prey taxa (*Boreogadus saida*, other fishes, Amphipoda, Euphausiacea, Mysida, and other invertebrates), harvested in Admiralty Inlet, Eclipse Sound, and Cumberland Sound, collected over several years (1993, 1996, 1997, 2008-2010, 2015-2017).

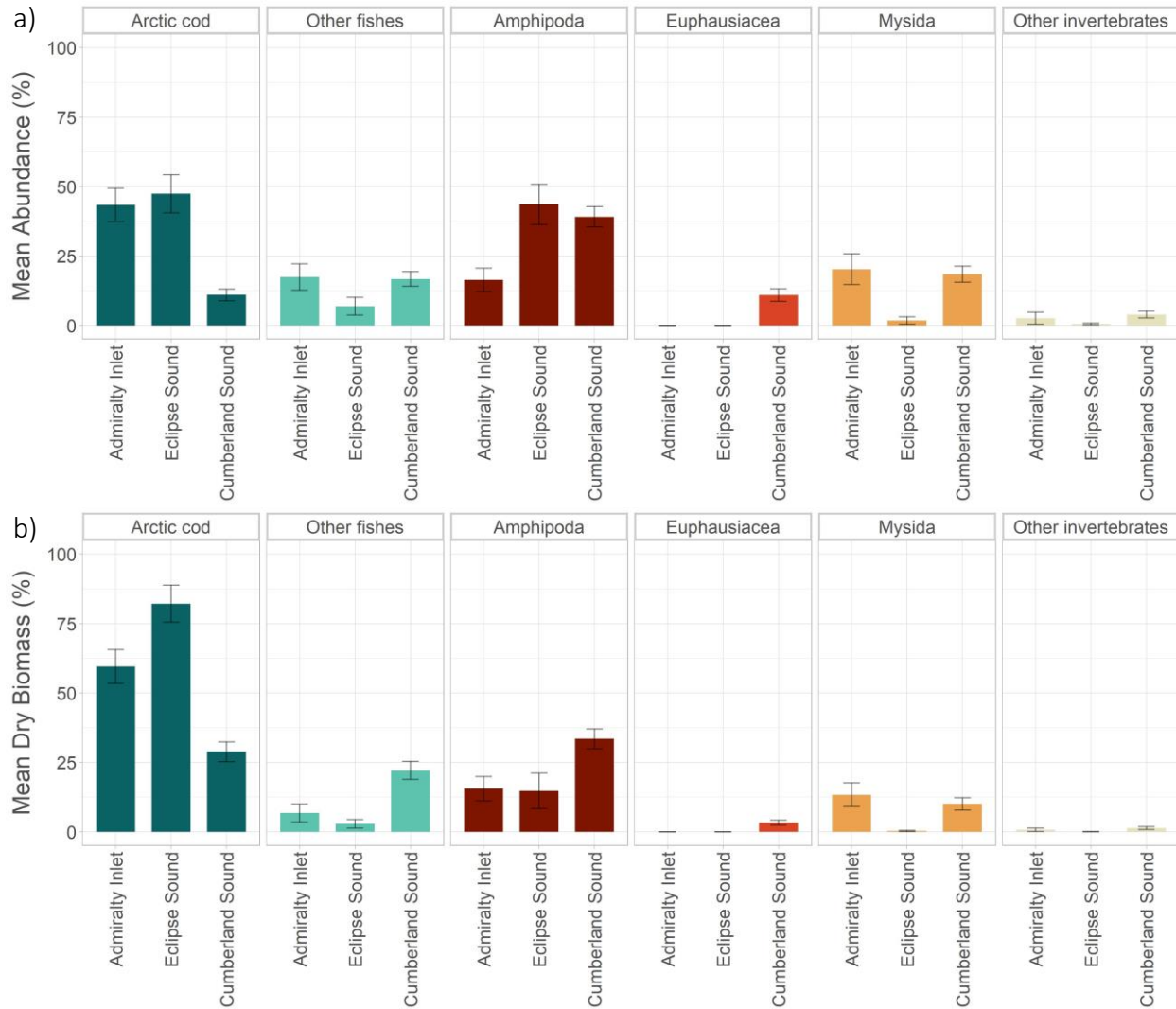


Figure 3.5: a) Mean percent abundance ($\pm se$) and b) mean percent biomass ($\pm se$) of ringed seal ($n=166$) stomach contents (Arctic cod, other fishes, Amphipoda, Euphausiacea, Mysida, and other invertebrates), harvested (Admiralty Inlet, Eclipse Sound, and Cumberland Sound). Samples collected over several years (1993, 1996, 1997, 2008-2010, 2015-2017).

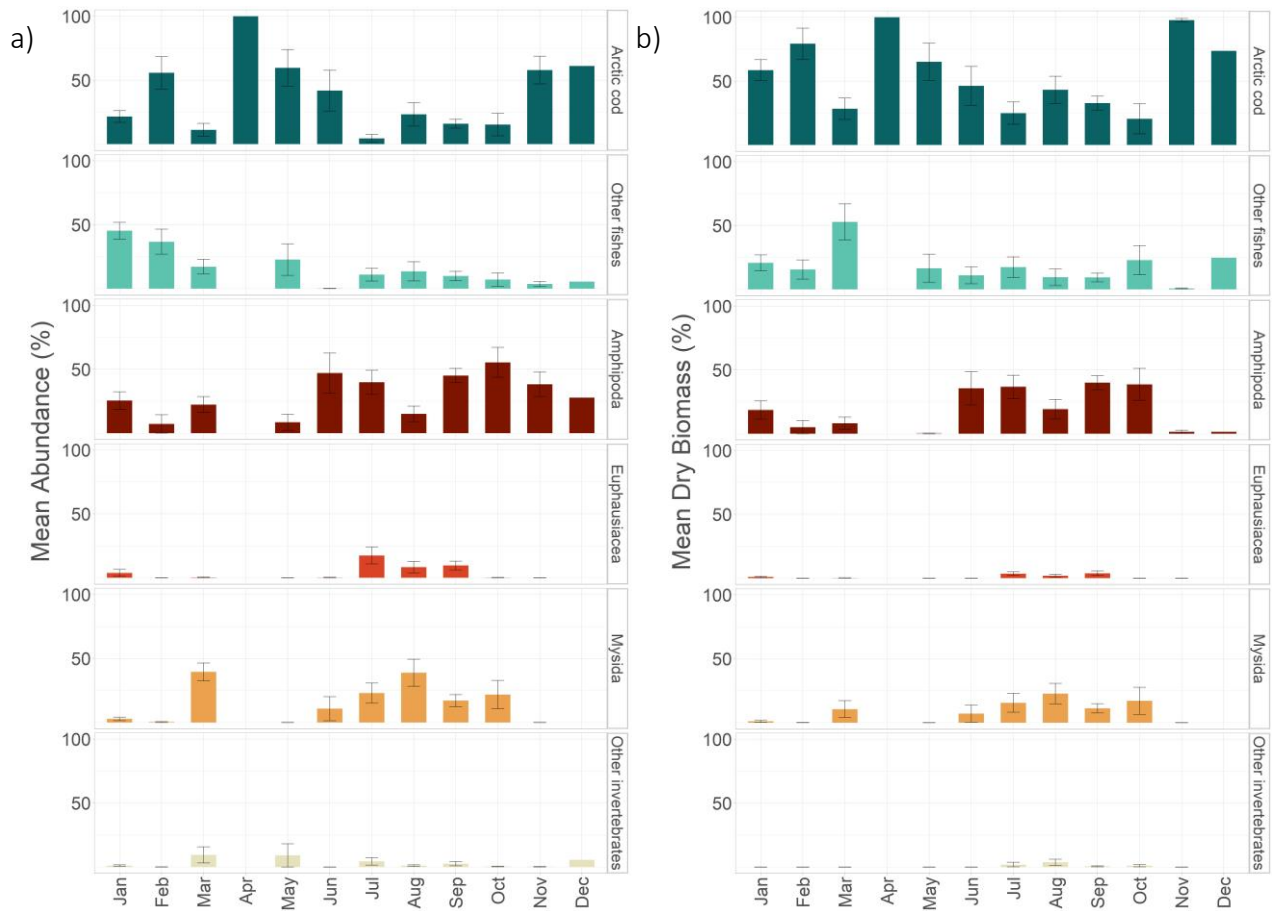


Figure 3.6: a) Mean percent abundance ($\pm se$) and b) mean percent biomass ($\pm se$) of ringed seal ($n=166$) stomach contents (Arctic cod, other fishes, Amphipoda, Euphausiacea, Mysida, and other invertebrates) by harvest month, harvested in Admiralty Inlet, Eclipse Sound, and Cumberland Sound and collected over several years (1993, 1996, 1997, 2008-2010, 2015-2017).

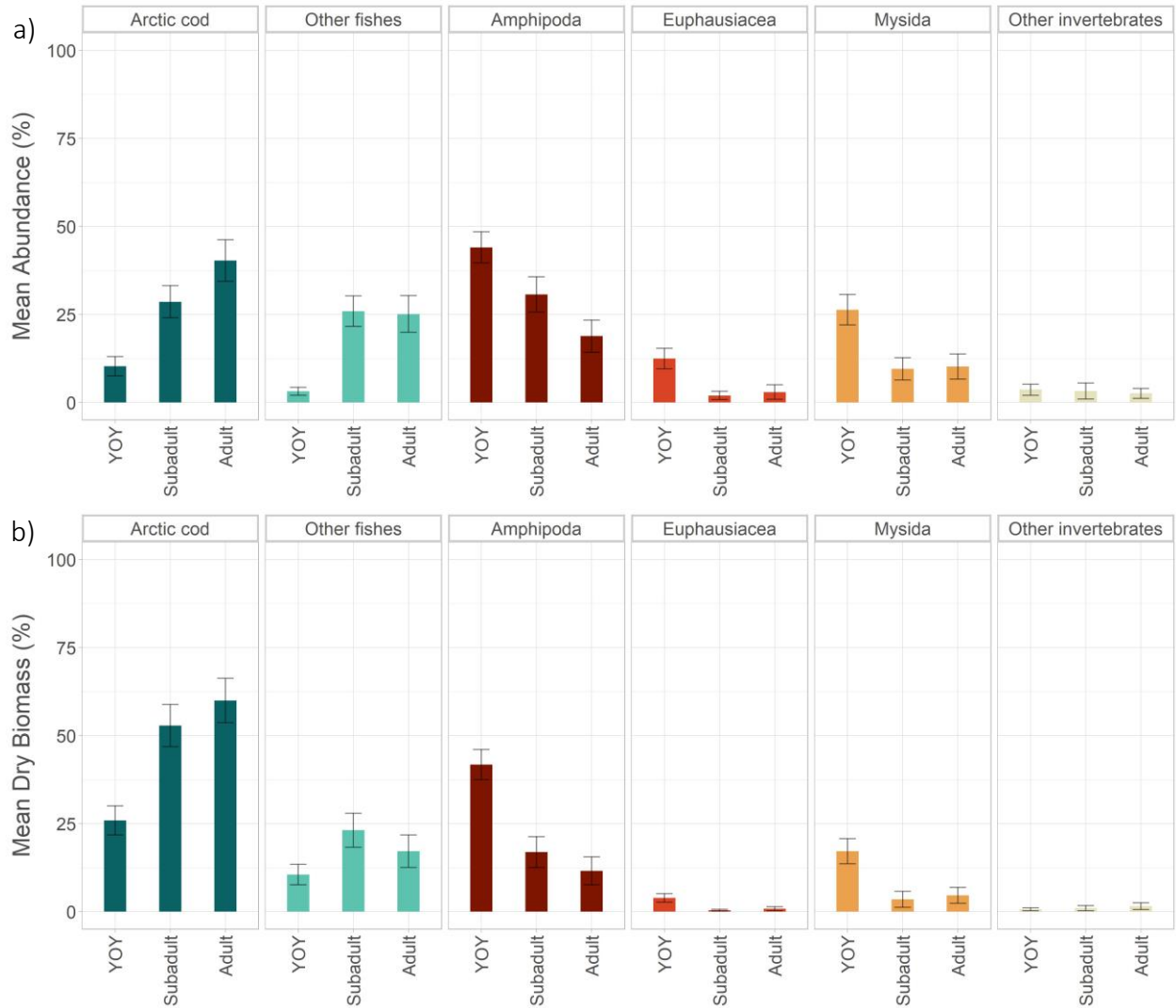


Figure 3.7: a) Mean percent abundance ($\pm se$) and b) mean percent biomass ($\pm se$) of ringed seal ($n=166$) stomach contents (Arctic cod, other fishes, Amphipoda, Euphausiacea, Mysida, and other invertebrates) by age class (young of the year (YOY), subadult, and adult), harvested in Admiralty Inlet, Eclipse Sound, and Cumberland Sound and collected over several years (1993, 1996, 1997, 2008-2010, 2015-2017).

3.8 Supplementary Information.

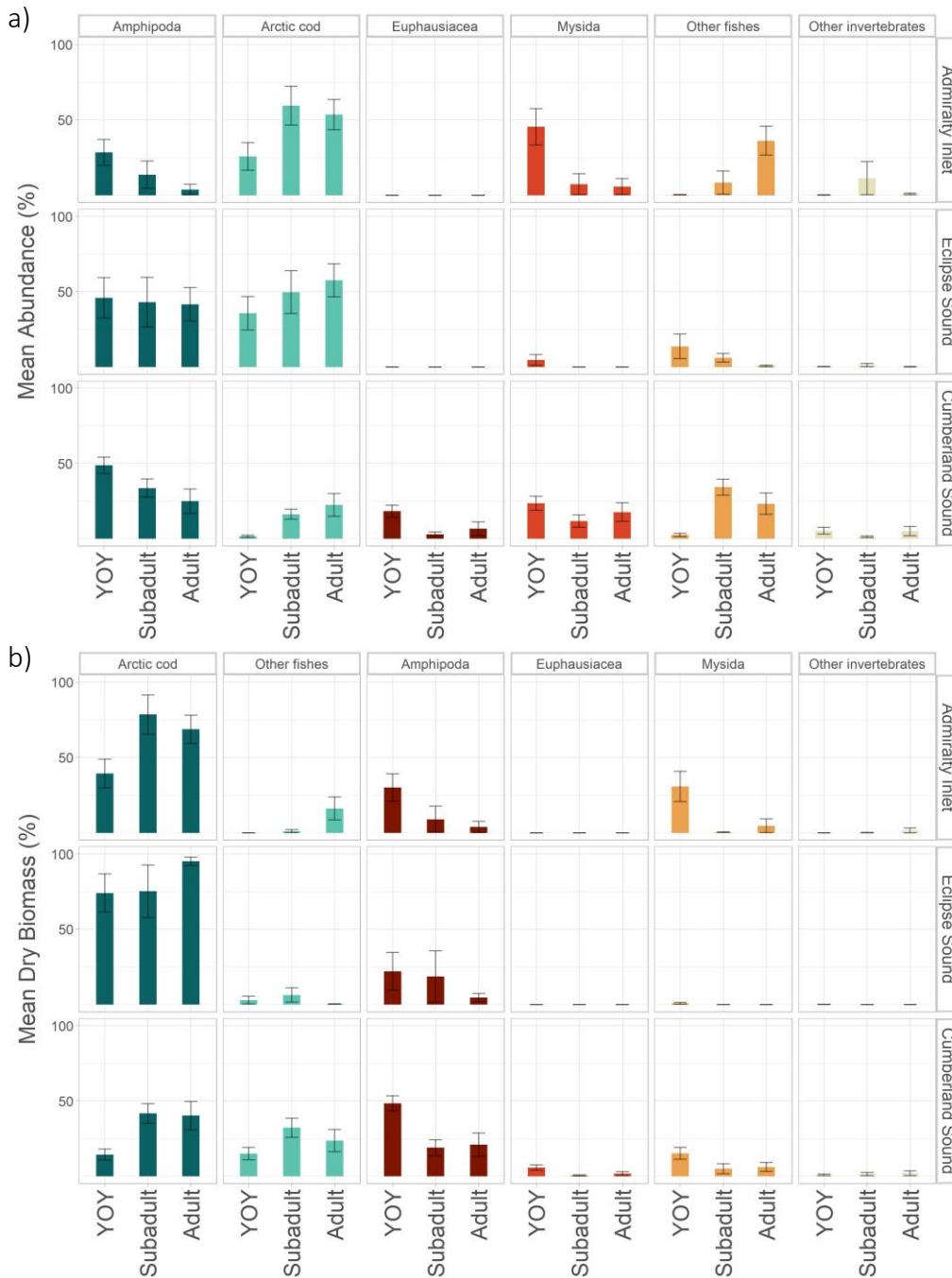


Figure S3.1: a) Mean percent abundance ($\pm se$) and b) mean percent biomass ($\pm se$) of ringed seal ($n=166$) prey taxa (Arctic cod, fish (other), amphipoda, euphausiacea, mysida, and invertebrates (other)), by region (Admiralty Inlet, Eclipse Sound, and Cumberland Sound) and age class (adult, subadult, and young of the year (YOY)), which were collected over several years (1993, 1996, 1997, 2008-2010, 2015-2017).

Table S3.1: ANOVA results of a multivariate generalized linear model (GLM) using percent biomass of ringed seal ($n=166$) prey taxa (*Boreogadus saida*, fish (other), amphipoda, euphausiacea, mysida, and invertebrates (other)). Fixed factors included are: region (Admiralty Inlet, Eclipse Sound, and Cumberland Sound), year of harvest (1993, 1996, 1997, 2008-2010, 2015-2017), month of harvest, age class (adult, subadult, and young of the year), sex, and interaction terms between region and age class, and region and sex. Note: bold text highlights significant variables.

Intercept	Multivariate test		Univariate tests											
	Dev	<i>P</i>	Amphipoda		Euphausiacea		Mysida		Invertebrate (other)		<i>Boreogadus saida</i>		Fish (other)	
			Dev	<i>P</i> _{adj}	Dev	<i>P</i> _{adj}	Dev	<i>P</i> _{adj}	Dev	<i>P</i> _{adj}	Dev	<i>P</i> _{adj}	Dev	<i>P</i> _{adj}
Region	102.16	≤ 0.001	13.69	0.054	31.962	0.018	3.675	0.114	21.511	0.054	24.005	0.040	7.312	0.109
Year of harvest	45.13	≤ 0.001	2.463	0.269	26.18	0.001	6.474	0.119	4.477	0.189	0.022	0.961	5.512	0.154
Month of harvest	46.79	0.035	38.612	0.035	1.842	0.627	2.816	0.575	0.256	0.735	0.729	0.735	2.537	0.588
Age class	43.68	0.023	16.42	0.042	10.56	0.125	3.586	0.545	3.052	0.565	0.487	0.856	9.575	0.125
Sex	19.45	0.061	1.142	0.561	3.309	0.441	3.538	0.429	8.002	0.111	2.161	0.515	1.302	0.561
Region*Age class	63.51	0.017	23.661	0.022	0	0.818	10.212	0.254	1.486	0.818	5.203	0.654	22.944	0.022
Region*Sex	10.17	0.569	0.897	0.967	0	0.970	0	0.996	5.873	0.354	0.39	0.970	3.015	0.760

Table S3.2: Taxonomic groupings of ringed seal (n=166) prey. Ringed seals were harvested in Admiralty Inlet, Eclipse Sound, and Cumberland Sound and collected over several years (1993, 1996, 1997, 2008-2010, 2015-2017).

Prey Item			Prey Count	FO%	A _m %	se	B _m %	se		
Fish	Ammodytidae	<i>Ammodytes sp.</i>	1	0.602	0.001	± 0.001				
		Cottidae								
			<i>Arteidiellus atlanticus</i>	3	0.602	0.055	± 0.055	0.043	± 0.04	
			<i>Arteidiellus sp.</i>	5	1.807	0.012	± 0.008	0.028	± 0.02	
			<i>Gymnocanthus tricuspis</i>	2	1.205	0.033	± 0.028	0.246	± 0.18	
			<i>Myoxocephalus scorpius</i>	4	2.410	0.195	± 0.153	1.062	± 0.72	
			<i>Myoxocephalus sp.</i>	1	0.602	0.001	± 0.001	0.088	± 0.09	
			<i>Triglops sp.</i>	1	0.602	0.018	± 0.018	0.103	± 0.10	
			Cottidae (not det.)	293	26.506	1.296	± 0.324	5.939	± 1.26	
		Cyclopteridae	Cyclopteridae (not det.)	16	3.012	0.049	± 0.033	2.338	± 1.04	
		Gadidae	<i>Arctogadus glacialis</i>	194	9.639	2.928	± 0.902			
			<i>Boreogadus saida</i>	4852	74.699	24.315	± 2.580	43.608	± 3.21	
			Gadidae (not det.)	76	6.024	0.833	± 0.374			
		Liparidae	<i>Liparis sp.</i>	145	6.627	0.632	± 0.340	0.741	± 0.61	
				Liparidae (not det.)	848	28.313	6.043	± 1.288	1.742	± 0.64
		Osmeridae	<i>Mallotus villosus</i>	42	5.422	0.424	± 0.320	3.196	± 1.22	
		Stichaeidae	<i>Eumesogrammus praecisus</i>	1	0.602	0.029	± 0.029			
			<i>Leptoclinus maculatus</i>	7	3.012	0.035	± 0.020			
	Zoarcidae	<i>Lycodes sp.</i>	4	1.205	0.045	± 0.033				
		Fish (not det.)	915	35.542	3.150	± 0.812				
Crustacea	Amphipoda	Calliopiidae	181	0.602	0.371	± 0.371	0.164	± 0.16		
		Eusiridae	2	0.602	0.002	± 0.002	0.005	± 0.00		
		Gammaracanthidae	4	1.807	0.019	± 0.015	0.016	± 0.01		
		Gammaridae	421	12.048	1.452	± 0.748	1.833	± 0.76		
		Hyperiididae	23075	67.470	28.784	± 2.565	20.544	± 2.35		
		Lysianassidae	1	0.602	0.002	± 0.002	0.005	± 0.00		
		Uristidae	1159	2.410	0.556	± 0.520	0.098	± 0.10		
			Amphipoda (other)	1022	15.663	2.006	± 0.798	3.579	± 1.14	
			Decapoda	Crangonidae	7	1.807	0.009	± 0.006	0.010	± 0.01
				Hippolytidae	12	1.807	0.014	± 0.011	0.025	± 0.02
		Pandalidae		1	0.602	0.002	± 0.002	0.011	± 0.01	
			Decapoda (other)	16	4.217	0.105	± 0.070	0.663	± 0.30	
		Euphausiacea	Euphausiidae	7694	24.096	6.556	± 1.425	1.972	± 0.56	
		Isopoda	Isopoda	16	0.602	0.003	± 0.003	0.003	± 0.00	
		Mysida	Mysidae	18561	49.398	17.026	± 2.368	9.854	± 1.83	

Prey Item	Prey Count	FO%	A _m %	se	B _m %	se
Copepoda	51	6.024	0.066	± 0.038	0.001	± 0.00
Crustacea (other)	5937	7.831	2.085	± 0.761	0.278	± 0.21
Echinodermat a	5	0.602	0.008	± 0.008		
Cephalopoda	43	9.639	0.839	± 0.609		
Total	65618					

Table S3.3: Regression equations used to estimate body length (BL, cm) from otolith length (OL, mm) of fish and values for estimating body length of invertebrates, prey recovered from ringed seal stomachs.

Prey Item	Body length: Regression or value		Note	Reference	
Fish	Ammodytidae	<i>Ammodytes sp.</i>	$(18.76 + (45.75 * OL)) / 10$	From <i>Ammodytes tobianus</i>	(Härkönen, 1986)
		<i>Ammodytidae</i>	$(18.76 + (45.75 * OL)) / 10$	From <i>Ammodytes tobianus</i>	(Härkönen, 1986)
	Clupeidae	<i>Clupea harengus</i>	$(15.627 + (57.860 * OL)) / 10$		(Lidster et al., 1994)
	Cottidae	<i>Arteidiellus atlanticus</i>	$(-0.1261) * OL^2 + 2.9693 * OL$	From <i>Arteidiellus sp.</i>	(Chambellant, 2012)
		<i>Arteidiellus sp.</i>	$(-0.1261) * OL^2 + 2.9693 * OL$		(Chambellant, 2012)
	Cottidae		$(0.5445 * OL^2) + (1.1569 * OL) + 2.9606$	From <i>Triglops murrayi</i>	(Chambellant, 2012)
		<i>Gymnocanthus tricuspis</i>	$(0.5445 * OL^2) + (1.1569 * OL) + 2.9606$	From <i>Triglops murrayi</i>	(Chambellant, 2012)
		<i>Icelus sp.</i>	$(0.2956 * OL^2) + (1.7028 * OL)$	From <i>Icelus spatula</i>	(Chambellant, 2012)
		<i>Icelus spatula</i>	$(0.2956 * OL^2) + (1.7028 * OL)$	From <i>Icelus spatula</i>	(Chambellant, 2012)
		<i>Myoxocephalus quadricornis</i>	$((-9.95) + (34.84 * OL)) / 10$	From <i>Myoxocephalus scorpius</i>	(Härkönen, 1986)
		<i>Myoxocephalus scorpioides</i>	$((-9.95) + (34.84 * OL)) / 10$	From <i>Myoxocephalus scorpius</i>	(Härkönen, 1986)
		<i>Myoxocephalus scorpius</i>	$((-9.95) + (34.84 * OL)) / 10$		(Härkönen, 1986)
		<i>Myoxocephalus sp.</i>	$((-9.95) + (34.84 * OL)) / 10$	From <i>Myoxocephalus scorpius</i>	(Härkönen, 1986)
		<i>Triglops sp.</i>	$(0.5445 * OL^2) + (1.1569 * OL) + 2.9606$	From <i>Triglops murrayi</i>	(Chambellant, 2012)
	Gadidae	<i>Arctogadus glacialis</i>	$(35.17 + (23.13 * OL)) / 10$		(Härkönen, 1986)
		<i>Boreogadus saida</i>	$(6.088 + (24.711 * OL)) / 10$		(Lidster et al., 1994)
		Gadidae	$(0.1001 * OL^2) + (0.9985 * OL) + 2.6473$	From <i>Gadus ogac</i>	(Chambellant, 2012)
		Gadiformes	$(0.1001 * OL^2) + (0.9985 * OL) + 2.6473$	From <i>Gadus ogac</i>	(Chambellant, 2012)
		<i>Gadus morhua</i>	$(25.751 + (10.109 * OL) + (0.165 * (OL^2))) / 10$		(Lidster et al., 1994)
		<i>Gadus ogac</i>	$(0.1001 * OL^2) + (0.9985 * OL) + 2.6473$	From <i>Gadus ogac</i>	(Chambellant, 2012)
		<i>Gadus sp.</i>	$(0.1001 * OL^2) + (0.9985 * OL) + 2.6473$	From <i>Gadus ogac</i>	(Chambellant, 2012)
	Gasterosteidae	Gasterosteidae	$7.21 * OL$	CD not available (Leopold et al., 1991)	(Leopold et al., 1991 as cited in Chambellant, 2012)
		<i>Pungitius pungitius</i>	$7.21 * OL$	CD not available (Leopold et al., 1991)	(Leopold et al., 1991 as cited in Chambellant, 2012)
	Liparidae	Liparidae	$5.7414 * OL^{1.3634}$	From <i>Liparis sp.</i>	(Chambellant, 2012)
		<i>Liparis sp.</i>	$5.7414 * OL^{1.3634}$		(Chambellant, 2012)
		<i>Paraliparis bathybius</i>	$5.7414 * OL^{1.3634}$	From <i>Liparis sp.</i>	(Chambellant, 2012)
	Myctophidae	Myctophidae	$((0.3437 * OL^{0.6088}) * OL) + 3.6332$		(Chambellant, 2012)
	Osmeridae	<i>Mallotus villosus</i>	$(11.726 + (56.221 * OL)) / 10$		(Lidster et al., 1994)
		<i>Osmerus mordax</i>	$(11.726 + (56.221 * OL)) / 10$	From <i>Mallotus villosus</i>	(Lidster et al., 1994)
	Psychrolutidae	<i>Cottunculus microps</i>	$(0.5445 * OL^2) + (1.1569 * OL) + 2.9606$	From <i>Triglops murrayi</i>	(Chambellant, 2012)

Prey Item		Body length: Regression or value		Note	Reference
	Stichaeidae	<i>Eumesogrammus praecisus</i>	$3.4394 * OL^{0.982}$		(Chambellant, 2012)
	Stichaeidae	<i>Leptoclinus maculatus</i>	$9.2666 * OL^{0.6212}$		(Chambellant, 2012)
	Stichaeidae	<i>Lumpenus lampretaeformis</i>	$9.2666 * OL^{0.6212}$	From <i>Leptoclinus maculatus</i>	(Chambellant, 2012)
	Zoarcidae	<i>Lycodes reticulatus</i>	$(21.19 + (37.74 * OL)) / 10$	From <i>Lycodes vahli</i>	(Härkönen, 1986)
		<i>Lycodes sp.</i>	$2.6478 * OL^{1.5958}$		(Chambellant, 2012)
Invertebrate	Amphipoda	Amphipoda	3.91	Means	(Elliot & Gaston, 2008)
		<i>Apherusa glacialis</i>	1.2	Used max length of age 1 individuals; https://doi.pangaea.de/10.1594/PANGAEA.811353?format=html#download	(Hop et al., 2011)
		<i>Gammaracanthus loricatus</i>	3.36	Used mean length of <i>Gammarus wilkitzkii</i>	(Poltermann, 2000)
		Gammaridae	3.36	Used mean length of <i>Gammarus wilkitzkii</i>	(Poltermann, 2000)
		<i>Gammarus wilkitzkii</i>	3.36	Used mean length of <i>Gammarus wilkitzkii</i>	(Poltermann, 2000)
		<i>Onisimus edwardsii</i>	2		(Weslawski et al., 1994)
		<i>Onisimus litoralis</i>	2	From <i>Onisimus edwardsii</i>	(Weslawski et al., 1994)
	Cephalopoda	Cephalopoda	8.5	From <i>Gonatus fabricii</i>	(Lawson et al., 1998)
		<i>Gonatus fabricii</i>	8.5		(Lawson et al., 1998)
	Crustacea	Eumalacostraca	1.6	Used max length 16mm	(Mumm, 1991)
	Decapoda	<i>Argis dentata</i>	5.2	From <i>Sclerocrangon ferox</i>	(Weslawski et al., 1994)
		Crangonidae	5.2	From <i>Sclerocrangon ferox</i>	(Weslawski et al., 1994)
		<i>Sclerocrangon boreas</i>	5.2	From <i>Sclerocrangon ferox</i>	(Weslawski et al., 1994)
		Brachyura	7.6	From Decapoda	(Elliot & Gaston, 2008)
		Decapoda	7.6		(Elliot & Gaston, 2008)
		Dendrobranchiata	7.6	From Decapoda	(Elliot & Gaston, 2008)
		<i>Eualus fabricii</i>	4.5	From <i>Eualus gaimardii</i>	(Weslawski et al., 1994)
		<i>Eualus gaimardii</i>	4.5		(Weslawski et al., 1994)
		<i>Eualus macilentus</i>	4.5	From <i>Eualus gaimardii</i>	(Weslawski et al., 1994)
		<i>Eualus sp.</i>	4.5	From <i>Eualus gaimardii</i>	(Weslawski et al., 1994)
		Hippolytidae	4.5	From <i>Eualus gaimardii</i>	(Weslawski et al., 1994)
		<i>Lebbeus groenlandicus</i>	4.5	From <i>Lebbeus polaris</i>	(Weslawski et al., 1994)
		<i>Lebbeus polaris</i>	4.5		(Weslawski et al., 1994)
		<i>Spirontocaris lilljeborgii</i>	4	From <i>Spirontocaris turgida</i>	(Weslawski et al., 1994)
	Euphausiacea	Euphausiacea	1.6	Used max length 16mm	(Mumm, 1991)
		Euphausiidae	1.6	Used max length 16mm	(Mumm, 1991)

Prey Item		Body length: Regression or value		Note	Reference
	Hyperiidæ	<i>Hyperia galba</i>	2.3	From <i>Themisto libellula</i>	(Weslawski et al., 1994)
		Hyperiidæ	2.3	From <i>Themisto libellula</i>	(Weslawski et al., 1994)
		<i>Themisto libellula</i>	2.3		(Weslawski et al., 1994)
		<i>Themisto sp.</i>	2.3	From <i>Themisto libellula</i>	(Weslawski et al., 1994)
	Mysida	<i>Boreomysis arctica</i>	1.5	From <i>Mysis oculata</i>	(Weslawski et al., 1994)
		Mysidæ	1.5	From <i>Mysis oculata</i>	(Weslawski et al., 1994)
		<i>Mysis oculata</i>	1.5		(Weslawski et al., 1994)

Table S3.4: Regression equations and values used to estimate wet mass (g), in some cases using body length (BL, cm or dm) or otolith length (OL, mm), for fish and invertebrates, prey recovered from ringed seal stomachs.

Prey Item			Wet mass: Regression or value	Note	Reference
Fish	Ammodytidae	<i>Ammodytes sp.</i>	$0.6041*(OL^{2.763})$	From <i>Ammodytes tobianus</i>	(Härkönen, 1986)
		Ammodytidae	$0.6041*(OL^{2.763})$	From <i>Ammodytes tobianus</i>	(Härkönen, 1986)
	Cottidae	<i>Arteidiellus atlanticus</i>	$7.37*(BL_{dm}^{2.57})$	From Cottidae	(Elliot & Gaston, 2008)
		<i>Arteidiellus sp.</i>	$7.37*(BL_{dm}^{2.57})$	From Cottidae	(Elliot & Gaston, 2008)
		Cottidae	$7.37*(BL_{dm}^{2.57})$		(Elliot & Gaston, 2008)
		<i>Gymnocanthus tricuspis</i>	$11.11*(BL_{dm}^{4.03})$		(Elliot & Gaston, 2008)
		<i>Icelus sp.</i>	$0.0059*(BL_{cm}^{3.2476})$	From <i>Icelus spatula</i>	(Chambellant, 2012)
		<i>Icelus spatula</i>	$0.0059*BL_{cm}^{3.2476}$		(Chambellant, 2012)
		<i>Myoxocephalus quadricornis</i>	$0.2261*(OL^{3.496})$	From <i>Myoxocephalus scorpius</i>	(Härkönen, 1986)
		<i>Myoxocephalus scorpioides</i>	$0.2261*(OL^{3.496})$	From <i>Myoxocephalus scorpius</i>	(Härkönen, 1986)
		<i>Myoxocephalus scorpius</i>	$0.2261*(OL^{3.496})$	From <i>Myoxocephalus scorpius</i>	(Härkönen, 1986)
		<i>Myoxocephalus sp.</i>	$0.2261*(OL^{3.496})$	From <i>Myoxocephalus scorpius</i>	(Härkönen, 1986)
		<i>Triglops sp.</i>	$6.48*(BL_{dm}^{2.96})$		(Elliot & Gaston, 2008)
	Cyclopteridae	Cyclopteridae	$6.7*(BL_{dm}^{3.29})$	From <i>Eumesogrammus praecisus</i>	(Elliot & Gaston, 2008)
	Gadidae	<i>Arctogadus glacialis</i>	$0.0038*(BL_{cm}^{3.1754})$		(Aschan et al., 2009)
		<i>Boreogadus saida</i>	$6.24*(BL_{dm}^{2.98})$		(Elliot & Gaston, 2008)
		Gadidae	$0.0101*OL^{4.0995}$	From <i>Gadus ogac</i>	(Chambellant, 2012)
		Gadiformes	$0.0101*OL^{4.0995}$	From <i>Gadus ogac</i>	(Chambellant, 2012)
		<i>Gadus ogac</i>	$0.0101*OL^{4.0995}$		(Chambellant, 2012)
		<i>Gadus sp.</i>	$0.0101*OL^{4.0995}$	From <i>Gadus ogac</i>	(Chambellant, 2012)
Gasterosteidae	<i>Pungitius pungitius</i>	$1.54*OL^{2.62}$		(Chambellant, 2012)	
Liparidae	Liparidae	$0.5*(BL_{dm}^{3.73})$	From <i>Liparis sp.</i>	(Elliot & Gaston, 2008)	
	<i>Liparis sp.</i>	$0.5*(BL_{dm}^{3.73})$		(Elliot & Gaston, 2008)	
	<i>Paraliparis bathybius</i>	$0.5*(BL_{dm}^{3.73})$	From <i>Liparis sp.</i>	(Elliot & Gaston, 2008)	
	Myctophidae	$(0.1538*BL_{cm}^{2}) - (1.1205*BL_{cm}) + 3.3602$		(Chambellant, 2012)	
Osmeridae	<i>Mallotus villosus</i>	$4.18*(BL_{dm}^{3.77})$		(Elliot & Gaston, 2008)	
Psychrolutidae	<i>Cottunculus microps</i>	$7.37*(BL_{dm}^{2.57})$	From Cottidae	(Elliot & Gaston, 2008)	
Stichaeidae	<i>Eumesogrammus praecisus</i>	$6.7*(BL_{dm}^{3.29})$		(Elliot & Gaston, 2008)	
	<i>Leptoclinus maculatus</i>	20		(Weslawski et al., 1994)	
	<i>Lumpenus lampretaeformis</i>	$3.04*(BL_{dm}^{2.16})$	From <i>Leptoclinus maculatus</i>	(Elliot & Gaston, 2008)	
	Zoarcidae	<i>Lycodes reticulatus</i>	10	From <i>Lycodes Sp.</i>	(Weslawski et al., 1994)
	<i>Lycodes sp.</i>	10		(Weslawski et al., 1994)	
Invertebrate	Amphipoda	Amphipoda	0.3		(Elliot & Gaston, 2008)
		<i>Gammaracanthus loricatus</i>	0.5	From <i>Gammarus setosus</i>	(Weslawski et al., 1994)

Prey Item		Wet mass: Regression or value	Note	Reference
	Gammaridae	0.5	From <i>Gammarus setosus</i>	(Weslawski et al., 1994)
	<i>Gammarus wilkitzkii</i>	0.5	From <i>Gammarus setosus</i>	(Weslawski et al., 1994)
	<i>Onisimus edwardsii</i>	0.25		(Weslawski et al., 1994)
Cephalopoda	Cephalopoda	22	From <i>Gonatus fabricii</i>	(Lawson et al., 1998)
	<i>Gonatus fabricii</i>	22		(Lawson et al., 1998)
Copepoda	Copepoda	1	Originally from Omori 1969	(Weslawski et al., 1994)
Decapoda	<i>Argis dentata</i>	0.7	From <i>Sclerocrangon ferox</i>	(Weslawski et al., 1994)
	Crangonidae	0.7	From <i>Sclerocrangon ferox</i>	(Weslawski et al., 1994)
	<i>Sclerocrangon boreas</i>	0.7	From <i>Sclerocrangon ferox</i>	(Weslawski et al., 1994)
	Brachyura	4.38	From Decapoda	(Elliot & Gaston, 2008)
	Decapoda	4.38	From Decapoda	(Elliot & Gaston, 2008)
	Dendrobranchiata	4.38	From Decapoda	(Elliot & Gaston, 2008)
	<i>Eualus fabricii</i>	1	From <i>Eualus gaimardii</i>	(Weslawski et al., 1994)
	<i>Eualus gaimardii</i>	1		(Weslawski et al., 1994)
	<i>Eualus macilentus</i>	1	From <i>Eualus gaimardii</i>	(Weslawski et al., 1994)
	<i>Eualus sp.</i>	1	From <i>Eualus gaimardii</i>	(Weslawski et al., 1994)
	Hippolytidae	1	From <i>Eualus gaimardii</i>	(Weslawski et al., 1994)
	<i>Lebbeus groenlandicus</i>	1	From <i>Eualus gaimardii</i>	(Weslawski et al., 1994)
	<i>Lebbeus polaris</i>	1		(Weslawski et al., 1994)
	<i>Spirontocaris lilljeborgii</i>	0.7	From <i>Spirontocaris turgida</i>	(Weslawski et al., 1994)
	<i>Hyas sp.</i>	4.38	From Decapoda	(Elliot & Gaston, 2008)
	Paguridae	4.38	From Decapoda	(Elliot & Gaston, 2008)
	<i>Pandalus borealis</i>	4.38	From Decapoda	(Elliot & Gaston, 2008)
	<i>Pandalus montagui</i>	4.38	From Decapoda	(Elliot & Gaston, 2008)
	<i>Pandalus sp.</i>	4.38	From Decapoda	(Elliot & Gaston, 2008)
Hyperiididae	<i>Hyperia galba</i>	0.45	From <i>Themisto libellula</i>	(Weslawski et al., 1994)
	Hyperiididae	0.45	From <i>Themisto libellula</i>	(Weslawski et al., 1994)
	<i>Themisto libellula</i>	0.45		(Weslawski et al., 1994)
	<i>Themisto sp.</i>	0.45	From <i>Themisto libellula</i>	(Weslawski et al., 1994)
Isopoda	Isopoda	0.026		(Weslawski et al., 1994)
Mysida	<i>Boreomysis arctica</i>	0.12	From <i>Mysis oculata</i>	(Weslawski et al., 1994)
	Mysidae	0.12	From <i>Mysis oculata</i>	(Weslawski et al., 1994)
	<i>Mysis oculata</i>	0.12		(Weslawski et al., 1994)

Table S3.5: Regression equations and values used to estimate dry mass (g), in some cases using wet mass (WM, g), for fish and invertebrates, prey recovered from ringed seal stomachs.

Prey Item		Dry mass: Regression or value	Note	Reference			
Fish	Cottidae	<i>Arctiellus atlanticus</i>	$1000*0.237*WM_g$	From <i>Myoxocephalus Scorpius</i>	(Mace & Davis, 1972)		
		<i>Arctiellus sp.</i>	$1000*0.237*WM_g$	From <i>Myoxocephalus Scorpius</i>	(Mace & Davis, 1972)		
		Cottidae	$1000*0.237*WM_g$	From <i>Myoxocephalus Scorpius</i>	(Mace & Davis, 1972)		
		<i>Gymnocanthus tricuspis</i>	$1000*0.237*WM_g$	From <i>Myoxocephalus Scorpius</i>	(Mace & Davis, 1972)		
		<i>Icelus sp.</i>	$1000*0.237*WM_g$	From <i>Myoxocephalus Scorpius</i>	(Mace & Davis, 1972)		
		<i>Icelus spatula</i>	$1000*0.237*WM_g$	From <i>Myoxocephalus Scorpius</i>	(Mace & Davis, 1972)		
		<i>Myoxocephalus quadricornis</i>	$1000*0.237*WM_g$	From <i>Myoxocephalus Scorpius</i>	(Mace & Davis, 1972)		
		<i>Myoxocephalus scorpioides</i>	$1000*0.237*WM_g$	From <i>Myoxocephalus Scorpius</i>	(Mace & Davis, 1972)		
		<i>Myoxocephalus scorpius</i>	$1000*0.237*WM_g$		(Mace & Davis, 1972)		
		<i>Myoxocephalus sp.</i>	$1000*0.237*WM_g$	From <i>Myoxocephalus Scorpius</i>	(Mace & Davis, 1972)		
		<i>Triglops sp.</i>	$1000*0.237*WM_g$	From <i>Myoxocephalus Scorpius</i>	(Mace & Davis, 1972)		
			Cyclopteridae	Cyclopteridae	$1000*0.2193*WM_g$		(Davenport & Kjørsvik, 1986)
			Boreogadus saida	<i>Boreogadus saida</i>	$1000*0.165*WM_g$		(Walkusz et al., 2012)
			Liparidae	Liparidae	$1000*0.14*WM_g$		(Walkusz et al., 2012)
	<i>Liparis sp.</i>	$1000*0.14*WM_g$			(Walkusz et al., 2012)		
	<i>Paraliparis bathybius</i>	$1000*0.14*WM_g$			(Walkusz et al., 2012)		
	Osmeridae	<i>Mallotus villosus</i>	$1000*0.318*WM_g$		(Lawson et al., 1998)		
Invertebrate	Amphipoda	Amphipoda	$1000*0.207*WM_g$		(Ricciardi & Bourget, 1998)		
		Caprellidea	$1000*0.207*WM_g$	From Amphipoda	(Ricciardi & Bourget, 1998)		
		<i>Apherusa glacialis</i>	4.2		(Kohlbach et al., 2016)		
		<i>Eusirus holmi</i>	86.3		(Kohlbach et al., 2016)		
		<i>Gammaracanthus loricatus</i>	51.53867915	<i>Gammarus wilkitzkii</i>	(Poltermann, 1997)		
		Gammaridae	51.53867915	<i>Gammarus wilkitzkii</i>	(Poltermann, 1997)		
		<i>Gammarus wilkitzkii</i>	51.53867915		(Poltermann, 1997)		
						(Berestovskii et al., 1989, as cited in Karnovsky et al., 2003)	
			Lysianassidae	19.99423537	From <i>Apherusa glacialis</i>	(Weslawski et al., 1999)	
			<i>Onisimus edwardsii</i>	1.938		(Weslawski et al., 1999)	
			<i>Onisimus litoralis</i>	1.938	From <i>Onisimus edwardsii</i>	(Weslawski et al., 1999)	
	Copepoda	Copepoda	1.5		(Weslawski et al., 1999)		
	Crustacea	Eumalacostraca	2.92758582	From <i>Thyssanoesa longicaudata</i>	(Mumm, 1991)		
	Decapoda	<i>Argis dentata</i>	$1000*0.262*WM_g$	From Decapoda	(Ricciardi & Bourget, 1998)		

Prey Item		Dry mass: Regression or value	Note	Reference	
	Crangonidae	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Sclerocrangon boreas</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	Brachyura	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	Decapoda	1000*0.262*WM_g		(Ricciardi & Bourget, 1998)	
	Dendrobranchiata	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Eualus fabricii</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Eualus gaimardii</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Eualus macilentus</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Eualus sp.</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	Hippolytidae	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Lebbeus groenlandicus</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Lebbeus polaris</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Spirontocaris lilljeborgii</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Hyas sp.</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	Paguridae	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Pandalus borealis</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Pandalus montagui</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	<i>Pandalus sp.</i>	1000*0.262*WM_g	From Decapoda	(Ricciardi & Bourget, 1998)	
	Euphausiacea	Euphausiacea	2.92758582	From <i>Thyssanoesa longicaudata</i>	(Mumm, 1991)
		Euphausiidae	2.92758582	From <i>Thyssanoesa longicaudata</i>	(Mumm, 1991)
	Hyperiidae	<i>Hyperia galba</i>	0.008124		(Berestovskii et al., 1989, as cited in Karnovsky et al., 2003)
		Hyperiidae	0.008124	From <i>Hyperia galba</i>	(Berestovskii et al., 1989, as cited in Karnovsky et al., 2003)
		<i>Themisto libellula</i>	0.006		(Weslawski et al., 1991)
		<i>Themisto sp.</i>	0.006	From <i>Themisto libellula</i>	(Weslawski et al., 1991)
	Isopoda	Isopoda	1000*0.203*WM_g		(Ricciardi & Bourget, 1998)
	Mysida	<i>Boreomysis arctica</i>	17.111	Average of values	(Norrbín & Båmstedt, 1984)
		Mysidae	0.008	<i>Mysis oculata</i>	(Weslawski et al., 1991)
		<i>Mysis oculata</i>	0.008		(Weslawski et al., 1991)

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Chapter 4: Conclusion

4.1 Summary and Conclusions

This study used two approaches to describe ringed seal diet and improve our understanding of ringed seal foraging ecology in the eastern Canadian Arctic. The aim of Chapter 2 was to collect and document information on ringed seal diet and foraging ecology from Inuit hunters and knowledge holders from Arctic Bay, Pangnirtung, and Pond Inlet, Nunavut using semi-structured interviews. Inuit knowledge studies of foraging ecology for this species are rare and this study will increase the representation of Inuit Knowledge in the literature. Chapter 3 aimed to investigate and compare the diet of ringed seals harvested from the marine areas of Admiralty Inlet, Cumberland Sound, and Eclipse Sound using stomach contents analysis. Specifically, I investigated regional diet differences, temporal diet shifts between seasons and years, and age or sex diet differences. The results of each chapter are brought together below in a final side-by-side comparison to examine how the findings concur or contradict one another (Creswell, 2014).

During the semi-structured interviews hunters from both Pond Inlet and Pangnirtung identified a high number of prey ($n=10-15$). From the stomach contents analysis, we found the highest number of prey taxa consumed by a single seal was ten, and 39 prey taxa overall.

Most interview participants observed both *kinguk* and *ugak* in the stomachs of seals year-round, across spatial scales, and within all age classes. *Kinguk* are amphipods, and the term commonly refers to the carnivorous *Themisto sp.*, whereas *ugak* are cod, usually Arctic cod (*Boreogadus saida*). These observations concur with the results of the stomach contents analysis, in which we found that Arctic cod was the most abundant ($A_m = 24.3 \pm 2.58\%$) fish species and most frequently found across all stomach samples (FO = 74.7%). Of the invertebrates, Hyperiididae was the most abundant ($A_m = 28.8 \pm 2.6\%$) and occurred most frequently in samples (FO = 67.5%). In turn, the Hyperiididae taxa group was predominantly made up of *Themisto libellula*. This leads me to believe that either these two species are present in numbers large enough that ringed seal diet is largely unaffected, or that ringed seals are preferentially selecting these species if there does happen to be a shift in fish and invertebrate communities in the marine areas near Arctic Bay, Pangnirtung, and Pond Inlet.

The flavour of ringed seal meat was a factor unique to the semi-structured interviews. Participants identified this variable as being associated with geographic locations, types of prey, and seasons. Some participants also described preferences for flavours of seal. The flavour profile of the ringed seal meat was difficult to articulate, words like “pure” and “heavy” were used in association with individual seals that had been feeding on certain types of prey or in different areas.

Interview participants stated that ringed seals foraged in widespread areas, but interviewees did identify some hotspots, such as the floe edge, polynyas, and areas of current. Some participants noted differences in what ringed seals fed on in some of these

hotspots and in other locations. Unfortunately, these observations could not be compared to the stomach content analysis because we did not have specific information on the exact location from which ringed seals were harvested, only that they had been taken from Admiralty Inlet, Cumberland Sound, and Eclipse Sound. This could mean that differences in prey distribution and abundance exist at small spatial scales which may be lost in the stomach contents analysis.

Throughout the year interview participants had observed ringed seals feeding and this was interrupted only during the late spring and summer when the seals would bask on the ice and moult, during which time hunters observed little to no prey in the stomachs of the ringed seals they harvested. In the stomach contents analysis, however, we found that ringed seals fed throughout the year but that there were shifts in the dominance of fish and invertebrates. We excluded empty stomachs from analysis and are not able to state if these seals were harvested during the moulting period or other times of the year. Also, we did not examine the data to determine if the total biomass or abundance of all prey differed throughout the year.

Although we included questions on changes over time in our interview guide, most participants did not observe changes related to diet and foraging, except for capelin (*Mallotus villosus*) being observed as a newer species in the stomachs of ringed seals harvested in Cumberland Sound. Our stomach contents analysis did not include prey taxa at a species level, although by examining the raw data (note that we did not include information at this scale in the results of chapter 3), capelin was present in stomachs

harvested by hunters in Pangnirtung, and only present in seals harvested after the year 2000.

Age related differences in both studies were similar. Interview participants observed that juvenile ringed seals fed more on *kinguk* when they were first weaned than on other prey types. Similarly, in the stomach contents analysis we found that young of the year seals consumed more invertebrates than fish as compared to adults and subadults. Specifically, Amphipoda differed significantly ($p = 0.042$), with young of the year consuming the highest abundance and biomass, followed by subadults, and then adults.

Further work needs to be done to examine areas where these two studies seem in agreement and disagreement. Certain limitations exist in comparing the two studies including in temporal and spatial scales, for example, to make the two studies more compatible temporally interview questions could have been framed to have participants discuss foraging in the three decades that the ringed seal stomach samples were harvested. This limits my ability to make definitive conclusions of concordance between results.

Interview participants made observations that are outside of what was possible to capture in a stomach contents analysis. These include: the flavour of ringed seal meat, observations relating to foraging behaviours between ringed seals and other species in proximity to them, as well a specific behaviour associated with feeding observed by hunters from Pangnirtung such as *angimitaqtu*, which refers to when ringed seals bob up at the surface and then dive back down in the same area.

We used both qualitative and quantitative methods to describe ringed seal diet and foraging in the eastern Canadian Arctic. There are many aspects of using semi-structured interviews and stomach contents analysis that are complementary, for example describing foraging differences between age classes, and others that are unique, for example species level identification of prey using otoliths in the stomach content analysis versus behavioural observations of ringed seals shared during the interviews.

Next steps in the IK work will include communicating results to the Hunters and Trappers Organizations in Arctic Bay, Pond Inlet, and Pangnirtung as well as all the interview participants. Results should also be discussed more fully with participants so that they have an opportunity to add, modify or remove information and ensure my interpretation of their interview responses was accurate.

To improve and build up on the IK study future could also include a community-based monitoring program. Community members could develop questions based on their priorities, and with the support of researchers, academics, and government officials to build capacity in the communities, Inuit can be engaged in areas of data collection and analysis. In this way there is a greater possibility of inclusive use of IK in research because knowledge is appropriately applied by knowledge holders and users.

Future work is needed to understand ringed seal foraging ecology more fully in northern and southern Baffin Island. There is a gap in the literature of prey availability in the Eastern Canadian Arctic. Sampling these areas regularly to develop a long-term data set of the fish and invertebrate communities would be helpful in determining if these assemblages are changing over time (e.g., Møller & Nielsen, 2019), if they have cycles of

abundance associated with factors such as the North Atlantic Oscillation (e.g., Stige et al., 2006), and to determine how the fish and invertebrate communities in each of the marine areas near Arctic Bay, Pond Inlet, and Pangnirtung compared to one another. Understanding local variability in ringed seal prey availability and distribution would help in understanding ringed seal prey preference (e.g., Wathne et al., 2000), how diet and foraging are affected temporally and spatially, as well as examining foraging effort.

Stomach contents analysis was limited by the identification of ringed seal prey morphologically. A study employing DNA barcoding could be a next step in diet analysis to identify species to a finer taxonomic level, increase the diversity of species identifiable, and identify species digested beyond what can be visually recognized (Packer et al., 2009).

Combining foraging studies with body condition would be beneficial in determining how changes in diet and foraging effort may impact ringed seal health. Results from Amundsen Gulf (Harwood et al., 2020) and western Svalbard (Andersen et al., 2021) describing contrasting differences in ringed seal body condition over time, specifically declines in the Amundsen Gulf and stability in western Svalbard seals, show how important it is to understand local differences because ringed seals from different areas are not equally affected by changing environments.

All approaches to understanding diet and foraging have limits associated with their assumptions and methodology (Bowen & Iverson, 2012). Therefore, there is value in bringing together multiple and complementary techniques to study diet and foraging of Arctic marine mammals (Kimmerer, 2002) and this fusion has been utilized in recent

studies (eg. Breton-Honeyman et al., 2016; Matley et al., 2015; Ogloff et al., 2019; Watt & Ferguson, 2015). The summary and description of IK is limited to the aspects of this knowledge which are associated with the environment. In this context, understanding of IK is colonial in nature and used within a western scientific paradigm (Latulippe, 2015; McGregor, 2004; Nadasdy, 1999). Nonetheless, in Nunavut, use of IK is mandated by the Nunavut Agreement and the Fisheries Act (*Fisheries Act, RSC 1985. c. F-14*, 2019; Tunngavik Federation of Nunavut & Indian Affairs and Northern Development, 1993). The National Inuit Strategy on Research (Inuit Tapiriit Kanatami, 2018) outlines the importance of why shifting research from being done to Inuit to research being done by and for Inuit is important for self-determination. By having IK considered and represented in policy and alongside science Inuit can become actors in the decision-making process that affects their lives.

The observations shared by harvesters contributes considerable knowledge to ringed seal ecology literature, specifically on ringed seal prey, spatial and temporal diet differences, diet differences among age classes, and ringed seal foraging behaviour. The results of both studies can be incorporated into management decisions and used for assessment and monitoring, for example within the COSEWIC species assessment process (COSEWIC, 2019).

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