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"It's Not that Simple": A Collaborative Comparison of Sea Ice Environments, Their Uses, Observed Changes, and Adaptations in Barrow, Alaska, USA, and Clyde River, Nunavut, Canada

The Arctic environment, including sea ice, is changing. The impacts of these changes to Inuit and Iñupiat ways of life vary from place to place, yet there are common themes as well. The study reported here involved an exchange of hunters, Elders, and others from Barrow, Alaska, USA, and Clyde River, Nunavut, Canada, as members of a larger research team that also included visiting scientists. Although the physical environments of Barrow and Clyde River are strikingly different, the uses of the marine environment by residents, including sea ice, had many common elements. In both locations, too, extensive changes have been observed in recent years, forcing local residents to respond in a variety of ways. Although generally in agreement or complementary to one another, scientific and indigenous knowledge of sea ice often reflect different perspectives and emphases. Making generalizations about impacts and responses is challenging and should therefore be approached with caution. Technology provides some potential assistance in adapting to changing sea ice, but by itself, it is insufficient and can sometimes have undesirable consequences. Reliable knowledge that can be applied under changing conditions is essential. Collaborative research and firsthand experience are critical to generating such new knowledge.

INTRODUCTION

Considerable attention has been given in recent years to environmental change in the Arctic (1), including indigenous observations (2–4) and implications and impacts (5). Changes to sea ice, a key feature of the Arctic marine environment, have similarly garnered a great deal of study and analysis from both scientific (6–9) and indigenous perspectives (10–12). Across much of the Arctic, sea ice is receding, thinning, or both. This reduction poses a significant challenge for indigenous peoples who use sea ice for hunting and travel or for communities whose sea ice acts as a barrier against wave-driven erosion (13). In light of these changes, an important question has arisen: which variables of change, impacts, and experiences cut across communities and regions, and which are constrained to one community or to a limited region?

To begin to address this question, our study made a comparison of sea ice environments and uses thereof between Barrow, Alaska, USA, and Clyde River, Nunavut, Canada. Our project had four objectives: *i)* to compare sea ice environments in the two locales in terms of physical characteristics, human uses, observed changes, and adaptations to any changes; *ii)* to compare and combine scientific and indigenous/local knowledge with regard to *(i)*; *iii)* to evaluate similarities and differences in responses to sea ice changes in order to assess prospects for and challenges in making generalizations within and between communities about impacts from climate and environmental change; and *iv)* to assess the effectiveness of our collaborative team approach to sea ice research.

To make sure that local and scientific perspectives were both fully represented in the project, the research team included scientists representing different disciplines and local residents from both communities. Our paper begins with an introductory description of the study communities and a description of our methods. The Results section presents our findings with regard to our first objective. The Discussion addresses the second, third, and fourth objectives.

STUDY COMMUNITIES AND METHODS

Barrow, Alaska, is located on a relatively smooth coastline in the generally flat and low-lying terrain north of the Brooks Range, about 20 km southwest of the convergence of the Beaufort and Chukchi Seas near Point Barrow (Fig. 1). Located entirely within a few kilometers of the Chukchi Sea coast and with no inlets or bays, Barrow is exposed to the actions of drifting pack ice as well as shore-fast ice, and is subject to potentially severe flooding and shoreline erosion associated with severe storms (13). The indigenous population is Iñupiat Eskimo, comprising some 60% of Barrow's 4600 people (14). Traditional subsistence hunting is an important activity and source of food, with bowhead whales, caribou, seals, walrus, fish, and birds making up the majority of the annual harvest of well over 100 kg per capita (15). Sea ice is generally present from November through July. Some seal hunting takes place on the ice in winter, and bowhead whaling is conducted from the edge of the shore-fast ice from mid-April through early June, with an additional open-water hunt in fall.

In contrast to the low-lying terrain and exposed location of Barrow, Clyde River is situated in the midst of dramatic, rugged terrain at the head of Patricia Bay, near the mouth of Clyde Inlet, a 100-km-long fjord on the northeastern coast of Baffin Island in Nunavut, Canada. Unlike Barrow, the community is protected from most wave and other marine action. The population of 785 is 96% Inuit (16). Traditional hunting is a major activity, perhaps even more so than in Barrow, providing a substantial portion of the diet and a source of income for seal hunters and guides on polar bear hunts. Ringed seals are the primary food species, with Arctic char, polar bear, narwhal, and caribou making up the major sources of country food (*niqituinnak*), with some small amounts of bearded seal, Arctic hare, and migratory waterfowl and their eggs rounding out a yearly diet (17). The sea ice near Clyde River consists of broad expanses of smooth shore-fast ice (*tuvaq* in Inuktitut).

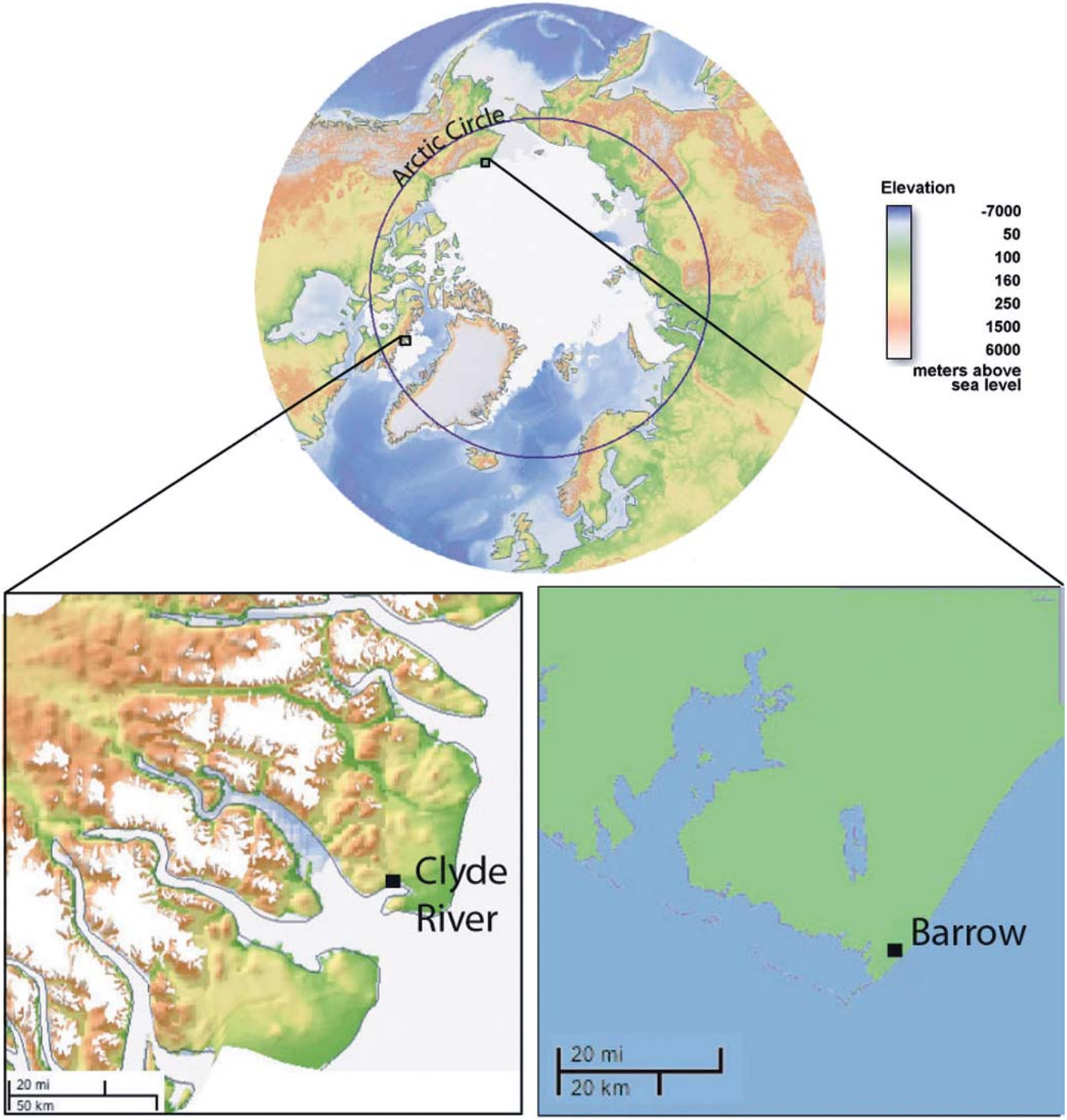

Figure 1. Map of study communities, Barrow, Alaska, USA, and Clyde River, Nunavut, Canada.

This ice covers the fjords and inlets of the region, and at the coast of Baffin Bay, extends to the interface with open water or pack ice (termed the "floe edge" by Clyde River residents), the location of which varies from about 20–50 km from Clyde River. Grounded icebergs are common within the shore-fast ice zone, and these help to stabilize the sea ice. Ice begins to form in November, though in recent years locals report freeze-up has not occurred until later in December (18, 19). The usual spring breakup occurs in July, though breakup timing has also changed and today sea ice begins to deteriorate in June in some areas (19).

Our project worked closely with members from each of the two communities. The research team comprised an experienced Inuit hunter/Elder from Clyde River, Ilkoo Angutikjuaq (I.A.), with Geela Tigullaraq (G.T.) as interpreter, Iñupiat counterparts from the community of Barrow, hunter/Elder Warren Matumeak (W.M.), hunter Darlene Matumeak Kagak (D.M.K.), and hunter Joe Leavitt (J.L.), climatologist Roger Barry (R.B), sea ice physicist Jim Maslanik (J.M.), and two researchers with experience documenting traditional knowledge in the respective communities, Shari Gearheard (S.G.) and Henry Huntington (H.H.). We drew on local knowledge of the research team, previous collaborations with local residents including scientists, and existing studies (10–12, 17, 19–24) to identify basic parameters of sea ice and sea ice use, and to characterize the two environments in preparation for the actual comparison.

The comparison itself was conducted as an exchange of Inuit and Iñupiat, accompanied by the academic scientists. The local residents were researchers as well as informants, studying the ice

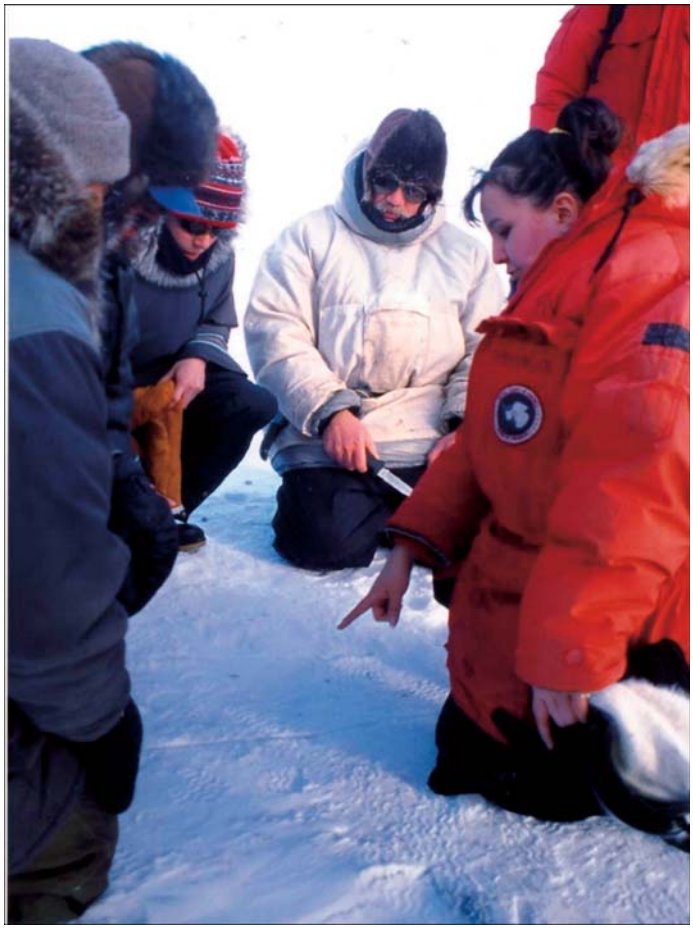

Figure 2. Research team studying the sea ice together off Barrow, Alaska, USA. From left: Ilkoo Angutikjuaq, Joe Leavitt, Shari Gearheard, Craig George (Barrow scientist visiting with the team), and Geela Tigullaraq. Photo: H. Huntington.

in each location and providing insights into what was similar and what was distinctive, based on their own perspectives as to the types of ice conditions that are most significant for their activities. The scientists added their perspectives on sea ice characteristics, weather, and climate as well, so that discussions during the exchanges were between Inuit and Iñupiat as well as between indigenous residents, local researchers, and the visiting scientists.

In April 2004, I.A. and G.T. traveled to Barrow accompanied by S.G., meeting the rest of the team there (except for R.B., who did not take part in the fieldwork). J.M. and H.H. had visited Barrow the previous January to identify participants, to determine what field opportunities existed, and to make other logistical arrangements. Before leaving for Barrow, S.G., I.A., and G.T. met in Clyde for a week to go over basic Barrow history, geography, and sea ice information provided by H.H. During this time, other Clyde River sea ice experts were consulted so that the Clyde team went prepared with an informed understanding of current sea ice conditions and concerns to share in Barrow. The Barrow end of the exchange included two trips by snow machine onto the sea ice, guided by J.L. assisted by North Slope Borough scientist Craig George, and involved a series of semistructured conservations involving most of the research team as well as other local residents and researchers. We visited a range of shore-fast ice conditions, illustrating the various processes that affect nearshore ice near Barrow (Fig. 2).

In June 2004, the research team went to Clyde River, meeting I.A. and G.T. there. S.G. had arrived ahead of the rest of the visitors to help prepare for the visit. During our stay, we made three trips out onto the ice as a group, including an overnight stay at one of I.A.'s camps. Clyde River Elders Peter and Raygeelee Paneak joined us for one of the trips and invited us for a visit to their cabin. We were joined by Rebecca Ootoovak (an experienced hunter) and her family on another trip. On the sea ice, we traveled across smooth ice in the fjord, tidal cracks in the otherwise uniform nearshore ice, and through small pressure ridges and other relatively rough ice near the mouth of the fjord.

We also visited icebergs within the fjord and outside its mouth, which was of great interest to the Iñupiat partners who had not seen icebergs before. We attempted to visit the floe edge during the on-ice trips at Clyde, but after getting within a few kilometers, both Peter Paneak and I.A. deemed the conditions too dangerous to continue because of refrozen leads that we would have to cross, and the relatively long distance back to Clyde. Because the whole research team had at this point seen both locations, Barrow and Clyde River, the conversations in Clyde River (both on the ice and during meetings back in the community) were able to cover more ground and discuss in greater detail the features we saw and our interpretations of them from our various perspectives.

It is relevant to note that although our exchange trips were focused on being on the sea ice and talking about sea ice, opportunities for cultural exchange were an important aspect of the project that helped create trust and comfort in the research team (Fig. 3). For example, in Barrow, we all participated in an Elder/youth conference that was going on in the community. I.A. was invited to demonstrate Baffin Inuit seal skinning and butchering techniques to compare with Iñupiat techniques during an instructional seal-skinning event for youth. In addition, the Clyde team met with local leaders in Barrow, participated in a call-in radio show about their visit, and learned about local bowhead whaling techniques. In Clyde, I.A., S.G., and G.T. helped organize a community feast, and the local square dance group provided entertainment. W.M. and D.M.K. performed traditional Iñupiat dancing, singing, and drumming and taught local Inuit in return. In both communities, we were all invited to visit the homes and families of our local hosts and all of the travel, whether by air or snow machine, provided important time for us to get to know each other, and as a result, strong, lasting friendships were made in the research process.

It is worth noting that this research did not take place *de novo*, but with an extensive history of research and contact between many members of the research team. H.H. has over 15 years' experience working in Barrow and J.M. over 10 years' experience. Both have worked with W.M. on previous research, and H.H. used to be a resident of Barrow. S.G. has worked with Inuit in Nunavut since 1995 worked with Clyde River since 2000, and has been a resident there since 2004. Through this longtime experience and relationships with communities, S.G., J.M., and H.H. have carried out much of the necessary preparatory work for a project such as this. Making contacts, gaining local trust, learning about the local environment, conducting interviews, and so on have taken place over the course of several years. A project starting from scratch, without the benefit of this background as well as support from experienced local groups such as the Barrow Arctic Science Consortium (BASC), would have required a more formal structure for the preparatory work, and would most likely have required considerably more time and effort to prepare for the exchange. The point of this explanation is simply to make explicit the advantages with which we started, so that others who may take a similar approach will be better able to evaluate the level of effort that their work is likely to entail.

Figure 3. The research team shares a seal together during an on-ice trip near Clyde River. From left: Peter Paneak, Shari Gearheard, and Geela Tigullaraq. Photo: H. Huntington.

RESULTS OF COMPARISON OF SEA ICE ENVIRONMENTS

Physical Environment

The east coast of Baffin Island is characterized by many fjords, some of which have 1000+ m vertical cliffs that are among the most dramatic in the world. Inuit travel, camp, and hunt in these fjords and fish in the rivers that run into the fjords from inland lakes and glaciers. The sea ice is an important platform not only for Inuit hunting and traveling, but also for visitors attracted to climbing, sport hunting, skiing, and sightseeing. Sea ice tends to break up in the fjords first. Since the late 1990s, Clyde Inuit have observed that the heads of fjords like Sam Ford Fjord and Clyde Inlet have been open several weeks before what is usually expected (19). Also, during breakup, the ice is now tending to break up all at once, as opposed to the usual pattern of fjords first, and early breakup has ended the spring hunting season earlier than usual in some places (18, 19). Thinner sea ice conditions and changing wind patterns also contribute to the early and relatively rapid breakups of recent years. Overall, as we also note later for Barrow, these changes have led to less predictable and thus more dangerous sea ice conditions.

Baffin Bay is dominated by first-year ice (with some multiyear ice persisting as shore-fast ice in protected inlets) with a strong seasonal cycle, with ice extent covering approximately 1.4×106 km^2 during its maximum in February or March but decreasing to near zero during August and September (25). Scientific studies have found sea ice is generally thin between 0.5 and 1.5 m (26), and Inuit note that the thickness varies in different locales with different physical features and local weather conditions. In the north Baffin region, sea ice begins to form in autumn, *Ukiaqsaak* (October–November), and is frozen over by early winter, *Ukiaq* (November–December). The month of November is called *Tusartuut*, which translates to "when one is able to hear from other camps" or "news time" (27) (J. Sanguya pers. comm., 2004). Like the names of the other months in Inuktitut (the Inuit language), the name indicates the expected environmental conditions for the period—in this case, that the ice is frozen over and people can begin to travel to other camps to visit. The ice remains frozen over through winter, *Ukiuq* (December–early March), until leads begin to form approximately in April in early spring, *Upingaksaaq* (late March–May). In the month of July, *Upingaaq* (May–July), ice will begin to break up.

As introduced earlier, the Barrow area presents a striking geographical contrast to Clyde River. Whereas the fjord and bay environment at Clyde produces a dramatic mix of high cliffs, long, deeply incised bays, and deep water, the Barrow coastline is exposed directly to the Chukchi Sea, with no inlets or bays to provide areas of calm water and shelter for boats. Further to the north and east, the spit extending to Point Barrow and the barrier islands to the east of Point Barrow provide relatively sheltered, though shallow (a few meters deep), waters in Elson Lagoon. Variations in bathymetry are important, with shallow waters to the north of Barrow serving as locations where shore-fast ice can become grounded to the seabed. The location of the most stable and persistent ice corresponds to the relatively shallow water. At the edge of the shallow water, the shore-fast ice is typically ridged and rubbled due to interaction with drifting pack ice.

Typically, the force of the pack ice generates large ridges (the "stamukhi zone"), the keels of which act to anchor the shore-fast ice to the seabed along the westward edge of the fast ice. Once these ridges form, ice that freezes seaward of the ridges forms a floating pan of ice that, although technically considered to be shore-fast ice, is actually only weakly attached to the more stable ice where it connects to the ridges. This ice is thus much more susceptible to breaking off under the influences of currents, winds, or interaction with pack ice. Whaling operations typically take place on this weakly anchored ice. In some years, the force of pack-ice floes impacting the Chukchi Sea shore-fast ice drives ice up onto land, sometimes for distances of tens of meters. These "ice push," or *ivu,* events, one of which occurred in January 2006, occur quickly and are capable of damaging structures and roads near shore.

Another factor affecting stability of the shore-fast ice is the presence of thick, old-ice floes that become grounded within the nearshore zone. Such floes were typically relatively common in previous years, but more recently have become rare as a result of the record northward retreat of the ice-pack edge in late summer (28).

Along the Beaufort Sea coast, to the east of Point Barrow, barrier islands along with a shallow coastal plain provide a more benign environment for fast ice formation. The location around Point Barrow itself is typically a region of very rugged ice conditions, associated with piling up of pack ice floes as they drift from deeper water into shallower conditions near the Point. Within Elson Lagoon, the smooth ice conditions are more typical of those near Clyde River, although even in this area the currents associated with gaps between barrier islands can affect the ice. In particular, W.M. noted that the gap between Plover Point and the adjacent island to the east is an

area where ice conditions can differ considerably from ice elsewhere in Elson Lagoon and present some added risk late in the ice season. In recent years, ice in the Barrow area has typically formed in November, although October has the Iñupiat name of *Sikkuvik*, or "freeze-up time." Ice breakup begins in May (*Suvlugvik*—"ice breakup time") or June.

Because of the embayments and fjords, which yield a relatively quiescent environment during freeze-up, Clyde River sea ice is very smooth, allowing snow machines and dog teams to enjoy flat (*maniraq*) traveling for great distances, although ice roughness (*maniilaq*) increases as one nears the interface between the drifting pack ice and the shore-fast ice and around points of land or icebergs. Drift of the pack ice is dominated by the southward drift of the ocean current and a north wind. This drift is persistent and reliable, according to the Inuit, with few situations where the pack ice drifts directly shoreward, against the shore-fast ice. Some south winds are cause for concern as they can change shore-fast ice conditions, creating more cracks and potential for large pieces to break off (Qillaq and Angutikjuaq pers. comm., 2006). I.A. explained that he could tell that there were forces pushing perpendicular to the fast ice at Barrow. He said that he could tell that was how the pressure ridges were being created, and he was interested to see where local Iñupiat had blazed trails over fast ice and ridges. After the experience, he felt lucky about the smooth ice conditions in Clyde River.

This contrast between the relatively smooth, benign nature of shore-fast ice near Clyde versus the variable and dynamic ice near Barrow was one of the main differences noted by the Iñupiat and Inuit participants. Team members from Barrow (W.M., D.M.K., and J.L.) remarked on the extreme flatness of the ice in Clyde Inlet, particularly the lack of any sign of contact or deformation at the tidal cracks. Icebergs, presence of a floe edge, and the great depth of the water were also of great interest, being very different than Barrow. The lack of any water along the shoreline, the integrity of the ice in mid-June, and the lack of ponded water formed from melting snow on ice at that time in the season (they do form later in July) were also in contrast to conditions in Barrow. Before the trip, W.M. had expressed some surprise and even uneasiness that we would be traveling on the ice in Clyde River that late in the year. When the Barrow team arrived, however, the ice appeared stable and solid, with plenty of snow machine and dogsled activity, and no further reservations were expressed. People typically travel on the ice into July at Clyde. I.A. and G.T. were impressed with the extent of ridging and other deformation offshore from Barrow, although by Barrow standards, the pressure ridges in April 2004 were relatively low.

During both halves of the exchange, the visitors appeared comfortable traveling on the ice and identifying significant features such as cracks that indicated weakness or potential danger. At the same time, the visitors in both cases preferred traveling with experienced local residents. From this experience, and the many terms for ice features that are identical in Iñupiaq and Inuktitut, we infer that the basic features of sea ice for hunters are consistent and recognizable in very different environments, but that specific conditions and patterns indicating danger are locally distinct, related to local conditions such as bathymetry and currents, and cannot be readily transferred from one place to another.

Human Uses

In Barrow, the traditional seasonal round of hunting makes extensive use of sea ice and its various features. In fall, shortly after freeze-up, people fish through the ice, particularly on the protected, relatively smooth ice of Elson Lagoon. Later in winter, when the ice is thick enough for travel, hunters pursue ringed seals at breathing holes and in their dens. In early spring, preparations for bowhead whaling include selecting sites for whaling camps and making trails to the ice edge. Spring whaling occurs on the Chukchi Sea side of Point Barrow where, as described above, the shore-fast ice typically has extensive pressure ridging and where shore-fast ice may break off during the whaling season. Whaling crews comprise between 10 and 20 persons, and there are over 40 whaling crews in Barrow. Thus, a considerable portion of the community is engaged in whaling during spring, though not all whalers are on the ice at all times.

Many factors influence the selection of sites for whaling camps at the ice edge and fallback sites for use when conditions are dangerous at the ice edge. Among these factors are location of grounded pressure ridges, which are more stable than ungrounded ice; indentations in the edge of the shore-fast ice, in which whales are more likely to appear; the presence of old ice, offering additional stability as well as a source of drinking water; and patterns of cracks indicating the history of ice formation that winter and thus likely weak points where the ice may fracture and break off. With these considerations in mind, the whalers are also likely to move camp many times during the course of the whaling season, both back and forth from the edge to the fallback sites, and to new sites altogether as ice conditions change (10).

Although the proportions harvested in spring and fall vary from year to year, whaling typically produces a quarter to a third of Barrow's annual subsistence harvest (15), and thus a successful harvest is of considerable importance to the community. Depending on the patterns of the ice and the whales' migration in a given year, and the overall success or lack thereof of the hunt, the specific patterns of use of sea ice may vary. If the hunt has not been successful, or if a whale is being chased or has been caught, whalers may travel farther and onto more dangerous ice than they otherwise would, a practice that may be exacerbated by the knowledge of the presence of search-and-rescue capability including helicopters for reaching stranded crews (10). If the season has been successful, whaling may be curtailed early as hunters head inland after geese, which arrive at this time of year. Lack of whaling success in spring may be compensated by increased harvest during autumn whaling, but with the potential for increased exposure to a different set of hazards associated with use of small boats on the open ocean.

At Clyde River, ringed seals are abundant in all seasons and are by far the most important subsistence food resource for the community. As soon as new ice is safe for travel in fall, seals are hunted through *agluit* (seal breathing holes). Through the winter months seal hunting continues, and I.A. notes that hunters look for refrozen cracks in the ice as these are likely spots for *agluit*. Hunters locate the active breathing holes and wait by the hole, usually shooting the seal when it comes up for a breath and then hooking it with a *niksik*. The seal is hauled onto the sea ice, where it is sometimes skinned and butchered at that time to bring home. In spring months, as the sea ice begins to break up, seals are hunted on the ice where they haul out of the water through cracks, *alguit* (the holes become larger in warmer temperatures), or at the edge of landfast ice (floe edge).

Also in spring, seal pups are born in dens that the mothers make under the snow and ice. The pups are a highly prized food for both Inuit and polar bears. In the open water season of summer, seals are hunted from boats and shore and seal nets are utilized year round. The open water is a difficult time for seal hunting because they must be hunted from boats and the seals have only a thin layer of blubber and do not float well (24). During summer, most hunters invest their time and equipment into narwhal hunting and traveling to caribou hunting grounds (24). Narwhal are hunted in open-water areas at the seaward

edge of the shore-fast ice in July when conditions permit. This type of hunting presents some similar concerns regarding ice safety and the interactions of pack ice with shore-fast ice as exist at Barrow. Narwhal hunting remains an important activity into the fall season and the skin with blubber attached (*muktaaq*) is a highly desired food. As well, the tusks can be sold for around US$100 per foot or more as a trophy piece or for carving material.

Inuit in Clyde rarely travel onto moving ice and people are very careful about traveling to the floe edge in spring—increasingly so in recent years because of changing sea ice conditions. There is a search-and-rescue group in Clyde River, but it consists only of local residents with snow machines; helicopters, or other support would have to be called in from hours away. However, local search and rescue has been, and does get, used frequently, and they respond to satellite or radio calls or reports of stranded hunters.

Another important wildlife resource for Clyde River, and one closely connected to the rhythms of sea ice (and ringed seals), is polar bears. Although polar bears contribute only in a minor way in terms of food, the income gained through the selling of skins and bear-centered tourism (sightseeing and sport hunting) is significant. A polar bear hunting trip sold to a sport hunter may bring in as much as US$15000 per bear to a community (29, p. 674). The sea ice has a very significant influence on the timing and distribution of bears, as well as their health. The open water season is a time of hunger for polar bears, and later freeze-up is contributing to thinner, less healthy bears. Later freeze-up also means more bears coming close to the community in fall months in search of food and more bear visits later into the year.

Comparing locations, the team members commented upon the effects of ice roughness on ease of travel via snow machine and dog teams. Snow machines are the typical means of transport in both communities, but at Clyde River, there has been a strong resurgence of interest in dog sledding, and there are currently at least 13 active dog teams in Clyde River that are used for regular travel and hunting. Being safe in the sea ice environment is one reason for this revival, because dogs can detect thin ice and open leads, alert and protect hunters from bears, and get hunters home in bad weather. No dog teams are used for hunting in Barrow at present.

Observed Changes

In the Barrow region, the pack-ice edge has been unusually far off shore in recent years, with a decrease in the presence of thick ice floes that have survived one or more years of melt (i.e., old or multiyear ice) (28, 30). Interestingly, as remarked upon earlier, when speaking English, Barrow-area residents refer to this type of ice as "glacier ice" (*piqaluyak* in Iñupiaq) perhaps in the context that these ice floes are typically made up of ice that has lost its brine content and is drinkable as freshwater.

In recent summers, the retreat of the pack ice hundreds of kilometers from the northern coast of Alaska has reduced seasonal hunting opportunities, particularly for species such as walrus that inhabit the ice edge. According to the Iñupiat, of equal importance is the frequency with which the pack ice edge moves near shore during summer and autumn. Movement of the edge to near shore, within reach of hunters, was common before the late 1990s but has been rare in recent years as a result of extreme retreat of the pack. The summer retreat of sea ice and delayed formation of shore-fast ice in fall also leave the coastline more vulnerable to erosion from wave action during storms (13).

Since the late 1990s, the ice pack has also appeared to be more diffuse in midsummer, i.e., the distance between individual ice floes is greater and the floes may be smaller. With southerly winds, these floes drift northward, rapidly increasing the distance between shore and the relatively compact ice edge. A situation like this in autumn of 2001 resulted in the apparent stranding of numerous polar bears on shore in the Barrow area. In this case, a narrow strip of ice was maintained by winds along shore near Barrow, which gave the impression that the main body of the ice pack was near shore, when in fact the main ice edge was hundreds of kilometers to the north. A change in wind direction rapidly removed this nearshore ice.

In recent years, hunters have also noted some changes in shore-fast ice characteristics, including absence or rarity of old ice, thinner ice that has at times impeded the ability of whalers to haul large whales onto the ice for butchering, extensive breakoffs of shore-fast ice during winter, changing the patterns of pressure ridge formation and the stability of shore-fast ice during the whaling season. The general impression of the Barrow team members was that the shore-fast ice in the Barrow area has been rougher in recent years. This is consistent with the observed thinning of the shore-fast ice and the decrease in anchoring features such as large ridges and old ice floes.

In the Barrow area, air temperatures have generally been increasing for an extended period with the most pronounced changes in winter and spring, although perhaps a tendency toward no increase or cooling in winter since the early 1990s. Other factors, such as changes in Arctic Ocean water temperatures and changes in large-scale ocean advection (31), have the potential to contribute to major changes in the annual ice regime. Of particular interest here are thinner ice and occasional open water in winter and spring, observed locally and over at least a portion of the Arctic and possibly the Arctic as a whole (7, 8), the extensive retreat of ice in late summer (6, 9, 28), the lack of old floes consistent with an overall reduction in old ice in the Arctic Basin (32, 33), and delayed formation of stable shore-fast ice in autumn. For example, a significant cover of shore-fast ice did not form along the Chukchi coast until early January 2005 (C. George pers. comm., 2004).

At Clyde River, air temperatures trended downwards over the station record from 1947 to 2000, but have shown signs of increasing in recent years, particularly in winter where the average temperature has warmed by approximately 4°C (E. Weatherhead pers. comm., 2005). Scientific assessments of the local and regional sea ice have been few compared to the Barrow region. In Baffin Bay, sea ice increased through the 1970s and 1980s (34) but more recent analyses show that sea ice has been decreasing 6% per decade with extremely low extent in the years 2002–2005 compared to the record since 1979 (25). The downward trend in sea ice extent is found in all months, with the largest trends in summer (June, July) and during the beginning of freeze-up (October, November) (25). Although the rate of breakup in the melt season has remained the same (though melt onset is earlier), the rate of freeze-up is much slower than usual and October extents are much lower in recent years (25). This change in the seasonal cycle is the primary cause for the anomalously low sea ice extents in Baffin Bay in recent years.

Local hunters and Elders have observed some of these conditions at Clyde River. Freeze-up is several weeks later than normal (December instead of October/November) and temperature conditions have been *ijaituq* in recent years—the weather is expected to be cold, but it turns out to be not as cold as expected (P. Paneak pers. comm., 2004). Sea ice has been thinner since the mid- to late 1990s and breaks up earlier (also by about two or three weeks). The earlier breakup and later freeze-up results in a net loss of about one month from the period in which sea ice is present (19, J. Sanguya pers. comm., 2004). Earlier breakup has an impact on the quality of seal skins

as seals need an ice platform to rub against when they molt, helping to reveal new fur that is desirable for seal skins to be sewn or sold (P. Paniloo pers. comm., 2004). A shorter ice cover season in spring also means that seals might spend more time swimming, resulting in weight loss and fat reduction and forcing baby seals to move from their birthing platforms to the water sooner. Thinner sea ice in particular has caused travel concerns for Inuit as some usual travel routes have become dangerous and hunters have had to stop spring hunting earlier than usual in some areas south of Clyde River near Home Bay (19). Thinner sea ice interacts with other recent environmental changes such as increased weather variability, changing wind patterns, seasonal timing of breakup and freeze-up, and snow conditions, to create new hazards for those using the sea ice. For example changes in winds can result in snow blown onto the ice, hiding cracks or weak areas, or changing the structure of ice as it freezes up. Unexpected and unpredictable storms can force Inuit to stay out longer on the land where emergency igloos are more difficult to build in some areas because snow is packed too hard from changing wind conditions (19).

As with all patterns and processes in the environment, Clyde Inuit are very aware that there is variability in sea ice conditions year to year. Some recent observations, however, fall outside that expected variability. For example, usual spring cracks are not appearing in some areas and unexpected cracks are appearing in other areas. Thinner than expected ice is observed by assessing thickness at cracks and seal holes and thinner ice is occurring over areas that would usually be thicker. A change in sea ice texture has been an important topic of concern for Clyde Inuit as they have noticed rougher sea ice, softer sea ice (assessed by the way the ice responds to being struck with a harpoon or *tuuq*—a kind of icepick). Inuit suggest that changes in sea ice texture are caused by stronger ocean currents and more snow deposited on ice due to changing wind patterns. Sea ice is also observed as melting more from the bottom, which has a dramatic effect on spring conditions because ice melts more quickly and is more dangerous.

Adaptations

For this paper, we use the term *adaptation* to refer to changes in behavior or decisions that are made in response to observed or anticipated changes in environmental and other external conditions. We note that adaptation is in many respects the normal response of Inuit and Iñupiat to the great variability in the Arctic. As stated in a report from Nunavut, "Adapting is not necessarily a conscious effort to respond to conditions brought upon because of climate change; it is just something that you do" (35). Nonetheless, the extent of recent changes may push beyond previous variability and thus challenge the adaptive capacity of Inuit and Iñupiat. It is thus worth describing some adaptive measures that have been made by residents of Barrow and Clyde River, which may offset (at least in part) the severity of the impacts from changes in sea ice.

For people in Barrow, changes in seasonal patterns have affected the seasonal round of hunting activities, including spring and fall whaling. As noted earlier, a successful spring whaling season in Barrow may induce whalers to stop early to engage in goose hunting. An unsuccessful season may cause some whalers to stay on the ice. Earlier snowmelt has changed this equation, and thinner ice that breaks up earlier may increase the importance of early success. In fall, late freeze-up may create opportunities for whaling season to continue later, when days are shorter, or alter the seasonal harvest patterns for caribou, fish, whales, and other species. Already, as J.L. notes, later freeze-up of lake ice has reduced opportunities for catching whitefish prior to spawning, causing some people to abandon fall fishing through the ice. Because spring whaling holds more significance in terms of local traditions, celebrations, and history, a decrease in the significance of spring whaling due to changing ice conditions presumably would affect these important aspects of Barrow's culture. Fall whaling, through the use of larger boats, radios, GPS units, and the availability of search-and-rescue capabilities, also involves a greater reliance on technology than is the case for spring whaling.

Changes in shore-fast ice have reduced the applicability of traditional understanding of sea ice dynamics, thus increasing uncertainty and attendant risk (10, 36) (A. Brower Sr. pers. comm., 2004). Decrease in predictability is particularly important in the sense that the ability of Elders, especially whaling captains, to reliably predict ice conditions is an important aspect of social standing. The more attention and energy devoted to coping with ice conditions (for example, by needing to repeatedly pull crews away from the ice edge or dig new roads through the rough and ridged ice), the less that is available for whaling itself.

The summer and fall retreat of ice poses other problems. Coastal erosion along the Barrow-area Chukchi Sea coast yields a mean rate of shoreline retreat of about 1 m y^{-1}, but is closely associated with infrequent but severe storms (37). This erosion may require extensive and costly adaptations and mitigative measures, including beach nourishment, barriers, and the relocation of some buildings and other infrastructure, the extent and cost of which reduce the ability of the community to relocate as needed (13). Access to marine mammals on the more distant pack ice or in the more extensive open water may be made safer with larger, faster boats, which are already becoming more common in Barrow. These boats, however, consume more fuel than the smaller boats presently used in late summer and autumn and the bearded-seal skin boats currently used for spring hunting, which may be exacerbated by recent increases in fuel costs, especially when combined with the need to travel farther, and they require larger boat-launch facilities or the construction of a sheltered harbor. This leads to a greater dependence on costly sources for fuel, boats, infrastructure, and so on.

For Clyde Inuit, recent sea ice and other environmental changes have "not really been scary, yet" (38). Local responses and coping strategies have managed so far to handle any environmental change impacts. Where thin sea ice has cut the spring hunting season short, hunters have moved to a new area. Hunters also pack extra supplies with the expectation of being delayed out on the land by unpredictable weather and ice conditions. Hunters without boats can become frustrated by the early breakup and late freeze-up, but new cracks in the spring sea ice make for more locations for seal hunting. Like the Elders in Barrow, however, Elders in Clyde River are disappointed and even saddened at the loss of their ability to predict weather using traditional skills and the loss of confidence in knowing the ice conditions. Many Elders no longer feel comfortable advising hunters about when and where to go out (38). This has had an emotional impact on Elders, who before the recent changes held an important advisory position in the community on these matters (39).

For the Baffin region, future scenarios of change include warming and reduction of sea ice thickness and extent. Because Clyde Inuit depend on traveling long distances on the ice, any decrease in stability and safety of the ice could have increasingly negative consequences, from loss of food resources as ice-dependent animals like seals and polar bears disappear, to more accidents and loss of access to important hunting grounds and travel routes to camps and other communities. These effects are exacerbated by the lack of search and rescue capability such as the North Slope's helicopters and planes.

Along with environmental and climate changes, the Inuit culture at Clyde River, as at Barrow, is increasingly changing as well. Many younger Inuit are not learning the on-the-land knowledge and skills of their parents and grandparents which might help them deal with a more unpredictable environment. As such, the increasingly unpredictable weather and ice conditions are even more dangerous for young hunters and "weekend hunters" who are already not as experienced as their Elders in "normal" conditions, and face even more challenges in quickly changing environmental conditions. Under future scenarios, loss of sea ice and thinning may be beneficial at first. For example, there may be opportunities for commercial fisheries, and seals may haul out more easily, and seal hunting might be easier, but in the long term it could mean fewer seals. This would mean fewer polar bears, which are an important source of income, as we noted above.

DISCUSSION

Similarities, Differences, and Generalizations

Our examination and comparison of sea ice and its uses at Barrow and Clyde River illuminate two main points with regard to the making of generalizations between communities. First, sea ice has common features regardless of location, many of which are captured in the terminology that has remained similar or identical in Iñupiaq and Inuktitut despite centuries of physical separation of the two groups. The dynamics of sea ice movements and deformation were recognizable and familiar to the visitors in both locations. At the same time, the ice environments are complex and many features were not readily comprehensible to the visitors. The lack of deformation at the tide cracks in Clyde River is but one example. The Barrow team members speculated about this feature, but were unable to account for it to their satisfaction even when taking into account the much less dynamic nature of the Clyde River ice. Although it appears that a hunter who moved from one place to the other would be able to apply a great deal of his or her knowledge in the new location, he or she would also be likely to exercise great caution at first and to travel when possible with a local resident while learning. This observation may be analogous in some ways to what can be expected under scenarios of change, with the exception that there will be no reliable local guides.

Our second point follows from the first. Generalizations about sea ice environments and uses should only be made with great caution, recognizing the degree of local variation. Our two sites are over 3000 km apart, but variation exists over much smaller spatial scales as well. Thus, we do not claim that our descriptions or findings are representative of northern Alaska and Baffin Bay, but only of Barrow and Clyde River. To be precise, they are only indicative of conditions in spring 2004, with additional time depth provided by the hosts in each location and the previous experience of the nonindigenous visitors. The comparison of vulnerability and potential adaptations underscores this point. Local patterns of use and the availability of additional options and resources are of crucial significance in determining how hunters might adapt. Indeed, the habits of different individuals are likely to cause differences in their ability to respond effectively to environmental change.

Furthermore, while extreme changes such as the disappearance of sea ice may have obvious impacts, the results of smaller changes are harder to predict or anticipate. Inuit and Iñupiat teach us to pay attention to the interaction of various impacts, for example that risks from sea ice changes are compounded by social changes that mean young people do not spend enough time on the ice to understand ice conditions even without the complications of environmental change. The title for this paper comes from a comment by Joelie Sanguya from Clyde River during a discussion about changes and their implications. Joelie reminded the scientists in particular that the temptation to draw neat conclusions should be resisted because "it's not that simple"; the system is too complex to allow such reductionist thinking. Instead, he urged us to recognize that changes were not simply good or bad, but must be understood in the broader context both of other changes to environment and society and of the potential responses that Inuit could make.

With Joelie's advice in mind, we recognize a need for more research that focuses on regional and local conditions such as shore-fast ice processes and changes in ocean temperatures and currents, as well as research that connects larger-scale climate observations and predictions to the local scale. More extensive local collaborative work, as well as more comparative studies, are required if we are to understand better the implications of environmental change for northern communities. Local involvement in research is particularly needed to move beyond individual experiments and case studies toward programs that provide detailed monitoring over seasons and years. Such observations are particularly important for the topics discussed here because Barrow and Clyde River residents assimilate numerous observations (winds, ice breakouts, presence of cracks, etc.) over entire seasons in order to judge the safety and utility of the sea ice for hunting and transport.

The Collaborative Approach to Research

Finally, a few words about the collaborative approach used in this project. Few of our insights would have been possible without the diverse research team involved in this project. The costs and logistical complexity of setting up the exchange were high (even discounting the hidden costs noted earlier with regard to the previous experiences on which this project was based). In the end, however, a great deal of information was gained that would likely have been missed had we not been able to share firsthand experiences. Discussions indoors were helpful, but time on the ice was essential to our learning about sea ice and how people in both communities understand and use the ice. Time on the ice also established a common denominator for our diverse team. Our confidence in our results, from both local and scientific perspectives, was correspondingly increased by the ability to discuss what we were seeing and ground-truth our ideas on the spot. We were also able to uncover many subtleties about sea ice and its uses that would have been hard to convey in the abstract, away from the ice. In many cases, it would have proven impossible to formulate specific "Western science"–type questions that could have elicited the information learned during these excursions. For example, simple observations such as watching the snow machine routes chosen by the Iñupiat and Inuit, provided insight into the significance of different ice conditions. We hope that our experience will contribute both to an improved understanding of the implications of environmental change and to increased use of the collaborative approach in studies of this kind (40).

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