ARCTIC
VOL. 62, NO. 4 (DECEMBER 2009) P. 429–442

Advancing Landscape Change Research through the Incorporation of Iñupiaq Knowledge

WENDY R. EISNER,[1] CHRIS J. CUOMO,[2] KENNETH M. HINKEL,[3] BENJAMIN M. JONES[4] and RONALD H. BROWER, Sr.[5]

(*Received 18 August 2008; accepted in revised form 12 March 2009*)

ABSTRACT. Indigenous knowledge is a valuable but under-used source of information relevant to landscape change research. We interviewed Iñupiat elders, hunters, and other knowledge-holders in the villages of Barrow and Atqasuk on the western Arctic Coastal Plain of northern Alaska to gain further insight into the processes governing the ubiquitous lakes and the dynamics of landscape change in this region of continuous permafrost. The interviews provided a suite of information related to lakes and associated drained lake basins, as well as knowledge on landforms, environmental change, human events, and other phenomena. We were able to corroborate many observations independently and verify the timing of several large and significant lake drainage events using either aerial photography or remotely sensed time series. Data collected have been incorporated into a geodatabase to develop a multi-layer Geographic Information System that will be useful for local and scientific communities. This research demonstrates that indigenous knowledge can reveal a new understanding of landscape changes on the Arctic Coastal Plain in general and on lake processes in particular. We advocate ongoing, community-oriented research throughout the Arctic as a means of assessing and responding to the consequences of rapid environmental change.

Key words: Alaska, Arctic coast, database management, environmental change, Geographic Information Systems, Iñupiat, indigenous knowledge, landscape processes

RÉSUMÉ. Les connaissances indigènes représentent une source d'information à la fois précieuse et sous-utilisée en matière de recherche sur les changements caractérisant le paysage. Nous avons interviewé des aînés de la nation Iñupiat, de même que des chasseurs et des personnes qui possèdent des connaissances dans les villages de Barrow et d'Atqasuk sur la plaine côtière occidentale de l'Arctique du nord de l'Alaska afin de mieux comprendre les processus qui gouvernent les lacs ubiquistes et la dynamique du changement de paysage dans cette région au pergélisol permanent. Les entrevues nous ont permis de recueillir une série de renseignements se rapportant aux lacs et aux bassins lacustres asséchés connexes de même que des connaissances sur les reliefs, le changement environnemental, les événements humains et d'autres phénomènes. Nous avons réussi à corroborer de nombreuses observations de manière indépendante et à vérifier le moment auquel plusieurs grands et importants événements d'assèchement lacustre se sont produits et ce, à l'aide de photographies aériennes ou de séries chronologiques télédétectées. Les données ainsi recueillies ont été intégrées à une banque de données cartographiques afin de permettre l'élaboration d'un système d'information géographique multicouche qui sera utile aux communautés locales et scientifiques. Cette recherche démontre que les connaissances indigènes peuvent aider à mieux comprendre les changements de paysage sur la plaine côtière de l'Arctique en général, et les processus lacustres en particulier. Nous favorisons donc la réalisation de recherches permanentes et axées sur la communauté dans l'Arctique pour évaluer les conséquences du changement environnemental rapide et les façons d'y réagir.

Mots clés : Alaska, côte de l'Arctique, gestion de banque de données, changement environnemental, système d'information géographique, Iñupiat, connaissances indigènes, processus caractérisant les paysages

Traduit pour la revue *Arctic* par Nicole Giguère.

[1] Department of Geography and Environmental Studies Program, University of Cincinnati, Cincinnati, Ohio 45221-0131, USA; wendy.eisner@uc.edu
[2] Department of Philosophy and Institute for Women's and Gender Studies, University of Georgia, Athens, Georgia 30602-1627, USA
[3] Department of Geography, University of Cincinnati, Cincinnati, Ohio 45221-0131, USA
[4] Alaska Science Center, U.S. Geological Survey, Anchorage, Alaska 99508-4664, USA
[5] Alaska Native Language Center, University of Alaska Fairbanks, Fairbanks, Alaska 99775, USA

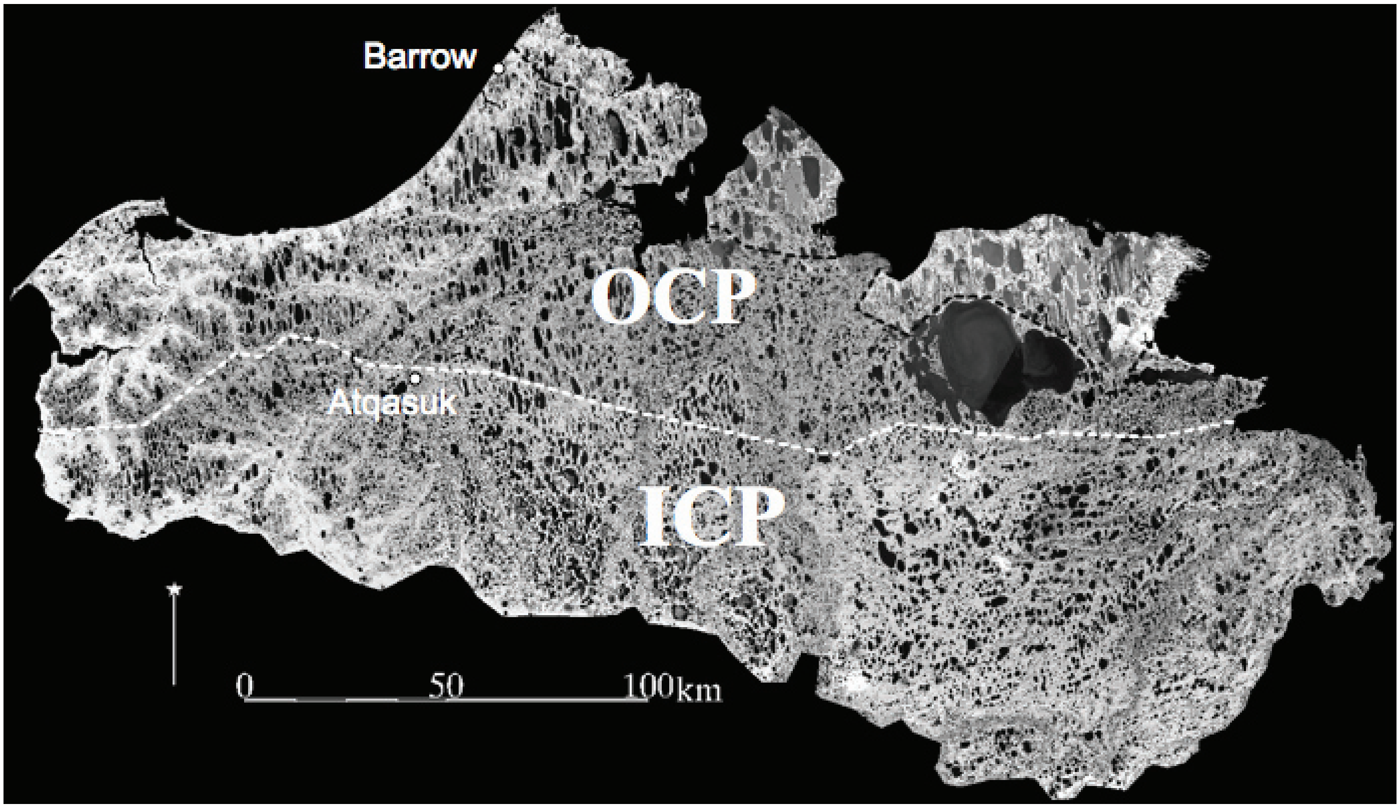


FIG. 1. Satellite mosaic (Landsat ETM+) of western Arctic Coastal Plain showing younger outer coastal plain (OCP) and older inner coastal plain (ICP).

INTRODUCTION

For the past decade, our research team of geomorphologists, ecologists, soil scientists, and climatologists has focused on extant lakes and the associated drained lake basins (DLBs) that developed atop continuous permafrost on the western Arctic Coastal Plain (WACP) of northern Alaska. Analysis of a Landsat-7 ETM+ mosaic of the area (152 – 162˚ W longitude) indicates that more than 7400 contemporary lakes, each exceeding 10 ha in area, cover about 20% of the total area (Fig. 1). An additional 26% of the landscape is scarred by DLBs of various ages that remain after lake drainage. Lakes fulfill a crucial role in the traditional subsistence economy of the Iñupiat people as a source of fresh water, fish, and waterfowl (Schroeder et al., 1987).

During our field studies, we became interested in the potential for Iñupiaq knowledge to help us acquire better scientific understanding of regional geomorphic processes. Local elders and hunters have access to highly relevant knowledge about landscape elements and processes. These environmental observations may be contemporary or they may overlap and predate the aerial photographs and satellite images that became available after 1955. We also sought to integrate principles of environmental ethics into our scientific work and to foster positive and cooperative connections with local communities. We initiated the collaborative effort with the community by presenting public lectures on our work in the North Slope villages of Barrow and Atqasuk, which sparked lively discussions on lake processes and environmental changes. Conversations with Iñupiat residents made it clear that they had first- and second-hand knowledge of landscape changes and recognized many of the causative processes involved in landscape evolution. Furthermore, residents were eager to engage in discussions on landscape changes, to retrieve memories of stories told by their elders, and to learn more about the scientific work being done on their traditional lands.

Our overarching objective has been to investigate, document, verify, and archive local observations about geomorphological processes, landscape changes, and local resource use. We hypothesized that Iñupiaq knowledge could help us refine our understanding of the spatial and temporal components of lake processes.

In weaving our commitment to "environmental ethics" into this research project, we have three additional goals. One is to generate scientific knowledge that will improve our understanding of important geomorphic processes acting on the landscape. Such knowledge is necessary to address the impact of climate and other changes occurring at both local and regional scales. Second, we anticipate that the accumulating body of data generated from this study will help strengthen ties between local and scientific communities in northern Alaska by providing an online, easily accessible resource (a web-based Geographic Information System) that various parties can use. Third, we hope these efforts will direct scientific attention to issues of vital importance to northern communities during a time of rapid and significant environmental change (Cuomo, 2008).

Indigenous knowledge often includes moral and ethical layers that do not recognize the stark ontological division between nature and culture that is often assumed in Western scientific approaches (Berkes, 1999). We do not view this disparity as a hindrance to our research, although such research comes with its own challenges. Carmack and MacDonald (2008), in their study that used indigenous knowledge to provide direction to their assessment of Arctic coastal processes, recognized that part of the challenge of working with indigenous people is treating their observations and beliefs as inherently valid, although the development of that knowledge may be based on different assumptions. We agree with this perspective, and we look upon the implied or actual differences between Iñupiaq knowledge and Western science as an opportunity for growth and enrichment for ourselves, our disciplines, and local communities.

Here we discuss the methods used to collect and verify our data, describe the transfer of the data into a Geographic Information System (GIS) database for use by researchers and the community, provide an overview and examples of our preliminary findings, and discuss the significance of this type of integrative research.

BACKGROUND

The lakes and DLBs of the WACP of Alaska are not uniformly distributed across the tundra landscape. The Outer Coastal Plain, defined as 0–23 m asl, is a younger surface that emerged following marine regression some 58–79 thousand years ago (Brigham-Grette and Hopkins, 1995; Brigham-Grette, 2001). It covers about one-third of the WACP (Fig. 1). The surface geology is characterized by ice-rich marine silts and sands, extremely low relief, and high lake density. Thaw lakes tend to be quite large, shallow, and elliptical, with the major axis oriented NNW and perpendicular to the prevailing ENE wind direction. By contrast, the older Inner Coastal Plain (23–120 m asl) is characterized by aeolian sands, rolling topography, higher relief, smaller lakes, and lower lake density (Hinkel et al., 2007). These older lakes appear to occupy deep depressions.

The classic "thaw-lake cycle" hypothesis was developed to explain the formation, enlargement, and eventual drainage of thaw lakes and is specific to the flat, ice-rich fine grained sediments of the Outer Coastal Plain. In this model, thermokarst ponds expand over time and eventually coalesce with adjacent ponds to form a small lake. These lakes grow wider and deeper by thermomechanical processes, but eventually they drain to form a DLB, which is subsequently re-vegetated. In deeper lakes (> 2 m), a thaw bulb may develop in the underlying permafrost, but upon drainage, permafrost aggrades into the sediments, and the ice-wedge network is reestablished.

Of major interest to us has been identifying and understanding the processes that cause lake drainage, identifying spatial patterns of lake drainage, and determining the direct and indirect impact of human activity on drainage events. By comparing satellite mosaics collected in the mid-1970s with those from the early 2000s, we determined that only 50 of the ~7400 extant lakes on the WACP drained over the ~25-year period; this result suggests landscape stability (Hinkel et al., 2007). Further, most cases of catastrophic drainage—defined here as loss by lakes of at least 20% of their surface area over the duration—occurred as a result of breaching by stream meandering, headward erosion of streams, or lake coalescence. Often, however, it was difficult to infer the operative drainage process using satellite images or aerial photographs owing to their inadequate spatial and temporal resolution.

Another significant challenge in our research to date has been scaling between processes that operate across a range of time intervals, from decadal to multi-millennial. Until recently, our research on the lake processes of the WACP has relied on remote sensing technology, GIS analysis, extensive field sampling programs, and radiocarbon dating of organic sediments in DLBs (Hinkel et al., 2003, 2005, 2007; Bockheim et al., 2004; Eisner et al., 2005, 2008; Frohn et al., 2005). To some extent, our work has been restricted to the short term owing to the general lack of paleoecological tools with the precision necessary for scalability. Aerial photography going back to 1955 exists for much of the proposed area of interest, and these photographs, in combination with modern high-spatial resolution satellite imagery, can be analyzed to identify land cover changes at the half-century timescale.

Interviews with Iñupiat elders on drainage processes have proven to be a useful way of overcoming several of the temporal limitations of satellite images and photographs because often our informants witnessed an event or its immediate aftermath. Further, local people with first-hand experience of drainage events and other phenomena are able to bracket drainage dates more closely. In some cases, Iñupiat collaborators offered explanations concerning the causes of lake drainage that we had not previously considered, but which appeared to be scientifically viable.

THE STUDY AREAS: BARROW AND ATQASUK

The Arctic Coastal Plain of Alaska, where we have been studying lake and landscape processes, has traditionally been populated by Iñupiat Eskimos. These resilient people have maintained deep connections to their environment through cultural traditions and subsistence practices. However, they are worried that some of these ties to the natural environment may be weakening. For example, many of the elders we interviewed cited the loss of traditional lifestyle and the use of motorized vehicles as responsible for their recent geographic limitations in navigating the tundra and recognizing changes to the landscape (Eisner et al., 2008). The land and the people have experienced considerable external pressures and disruptions, and these forces have operated at different frequencies and levels of intensity. A series of events that began around the mid-1800s had a huge impact on the social and cultural disconnect of the Iñupiat on the North Slope. The unpredictability of the caribou, apparently caused by herd migration and population fluctuations, caused much of the interior area to be abandoned by the Iñupiat. In addition, the introduction of diseases like measles and influenza by outsiders wiped out many settlements along river systems (Brower, 1942; Spencer, 1976; Blackman, 1989). The traditional system was further disrupted by the commercial whaling era, during which significant numbers of Iñupiaq and others were encouraged to migrate to the coast (Brower, 1942; Spencer, 1976; Blackman, 1989; Chance, 1990).

Another dominant influence is the business of petroleum exploration, extraction, and transportation. Oil exploration has heavily impacted the landscape and communities since the late 1940s (e.g., Brower, 1942; Blackman, 1989). The effects of global climate change, amplified in the Arctic, include warming, permafrost degradation, soil and coastal erosion, and sea ice thinning. These changes have been observed to be increasing in intensity for the past decades, and their effects on North Slope communities are profound (Serreze et al., 2000; Huntington and Fox, 2005).

Our study area, which includes both the Inner and Outer Coastal Plain, encompasses two distinct subsistence activities. Barrow (Utqiagvik) is a coastal village. It is the largest Iñupiaq community in Alaska, with a population of about 4580 residents of which 57% are Iñupiat. The cultural focus is on whaling, although subsistence hunting and fishing are also important. Atqasuk, located inland about 100 km south of Barrow, has a population of approximately 230 people, of which 94% are Iñupiat (U.S. Census Bureau, 2000). It is situated between the banks of the Meade River (Kuulugruaq) and the shore of Imakruak Lake, which serves as the town's freshwater source. Atqasuk's subsistence economy relies on inland resources such as caribou, fish, and waterfowl.

Atqasuk was established as a community in 1972, although the numerous traditional sod huts along the banks of the Meade River are evidence that the inland Iñupiat have lived in the region for centuries (Spencer, 1976). We identified Atqasuk as a community where people would likely be well versed in inland sites, and particularly in lake dynamics. However, many Barrow residents are also active caribou and waterfowl hunters and engage in subsistence activities at inland sites as well. We were interested to see if there was an appreciable difference between the geographic knowledge demonstrated by Barrow residents and that of Atqasuk residents.

This study focuses on interviews with North Slope Iñupiat elders because of their great experience with subsistence practices and traditional knowledge and because the archiving of their knowledge is a matter of urgency. The most recent mortality statistics indicate that Alaska Native elders are dying at a faster rate than the U.S. average; their life expectancy of 69.4 years is about five years less than that of the average Alaskan. This rate is reflected in the population age pyramid: while 12.4% of the U.S. population is older than 65 years, this age group is only 5.3% of the Alaska Native population (Alaska Native Tribal Health Consortium, 2001). The situation is especially acute among the Iñupiat, whose native language has only taken written form in the last few decades. A number of elders in Atqasuk and Barrow expressed a sense of obligation to preserve their cultural and ecological knowledge. Because of this, we found members of both the Barrow and Atqasuk communities extremely supportive of our research and willing to contribute time and effort to ensure the survival of this information.

Another distinct aspect of the North Slope that contributed to our research is the existence of the Barrow Arctic Science Consortium (BASC), a community-owned non-profit organization dedicated to the facilitation of research and educational activities pertaining to Alaska's North Slope and adjacent portions of the Arctic Ocean. Since 1995, the BASC has served as liaison between scientists and local communities, and provides local logistical support (Kelley and Brower, 2001). Many of the elders of Barrow and Atqasuk are familiar with the BASC and made significant contributions to scientific research through the Naval Arctic Research Laboratory, which operated in Barrow from 1947 until its incorporation into the Ukpeagvik Iñupiat Corporation in 1989 (Brewster, 1997; Albert, 2001). Thus, the community generally considers scientific work potentially helpful and interesting rather than exploitative or inherently suspicious, and this trust has provided an invaluable foundation for our collaboration.

METHODS

Conducting Collaborative Interviews

Over the past four years, we conducted extensive interviews with Iñupiat elders and younger community members who are actively accessing inland subsistence resources. A primary objective of these interviews was to obtain first- and second-hand accounts of lake drainage events and locate these lakes within our GIS. We were particularly interested not only in establishing the date of lake drainage, but in identifying the processes leading to lake drainage. We also inquired about other lake processes such as lake coalescence, development of lake orientation over time, and the impact of heavy seasonal snow or strong winds on lake flooding and breaching. Additional questions concerned anthropogenic changes to the lakes and landscape and general inquiries about recent environmental changes, such as thermokarst, shoreline or stream erosion, and changes in animal population or behavior.

Between 2003 and 2006, a total of 27 interviews (38 hours) were conducted and videotaped. Interviews began with an explanation of our scientific project concerning lakes and included the signing of the Institutional Review Board-approved consent forms. Interviewees were then asked to identify lakes that had drained or filled in, or to identify any changes in the lake hydrology that they had

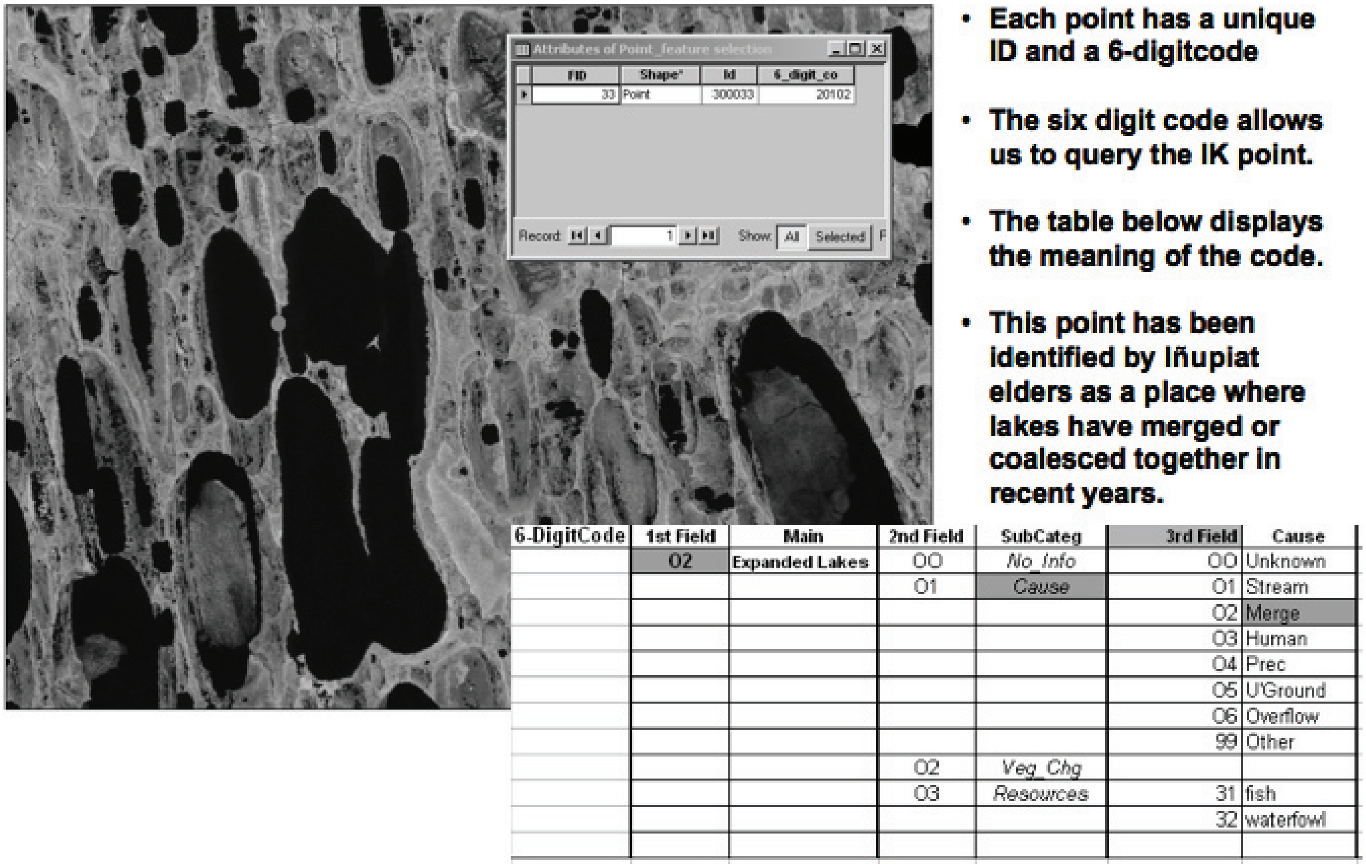


FIG. 2. Iñupiaq Knowledge GIS database point and example of 6-digit coding (020102).

noticed or heard of. U.S. Geological Survey topographic maps, the North Slope Borough "Camps and Cabins" maps, or satellite images were available for the interviewee to identify the site location. An interpreter, often a close friend or relative of the interviewee, was almost always present.

We used unstructured talks and semi-directive interviewing methods (Huntington, 2000; Bernard, 2002; Fox, 2002). Questions were embedded within the context of the semi-directive interviews, during which we invited people to share information on specific events or locations. Although the focus of conversations was on lakes and associated processes, interviews allowed local elders and experts to share any information about changes and particularities in the local environment, as well as stories, anecdotes, and oral histories. Elders appreciated the opportunity to share their stories and to archive their knowledge for younger generations. A number of insights from the elders made it clear that the range and depth of their knowledge could not always be anticipated by an interviewer, and at times, the most fruitful practice was to provide free rein to share the knowledge they identified as most useful (Cruikshank, 1990).

Development of the Iñupiaq Knowledge GIS

After the interview, information from the entire videotaped session was logged. This entailed identifying each geographic feature, site, or event with a six-digit descriptive, hierarchical code (Fig. 2). The first two digits identify the general category of the feature; the next two, the type of information being recorded; and the third two-digit field incorporates more specific aspects of the feature. All information that was identified as specific to a site (point), linear feature, or area was assigned geographic coordinates (geocoded) and given the six-digit descriptive code in the GIS attribute table. The attribute table also contains information on the interviewee and the date of the interview and is linked to a digital video clip of the interview.

Some observations had no geographic specificity; i.e., they were not specific to a site or region. Examples include information about meteorological events (unusual occurrences such as storms, blizzards, lightning, droughts, strong winds), methods of navigation (e.g., on snow or during blizzard conditions), or traditional or current use of resources (fish, waterfowl, fresh water springs, coal). Although such information cannot be mapped in the GIS, it is archived through links to original interviews that are accessible through the GIS.

Following the geocoding process, we carried out two modes of verification: examination of aerial photography or satellite imagery, and direct field observation. We also conducted follow-up interviews when clarification was needed. As discussed below, a significant objective of the verification process was achieved when we transported some of our collaborators to sites they had identified and discussed during the interviews.

Ultimately, the entire data suite (GIS layers, videotaped interviews, and related archived data) will be part of a web-based GIS and a contributor to the ELOKA (Exchange for Local Observations and Knowledge of the Arctic) network. ELOKA has been designated by the National Science Foundation to provide data management that "keeps control of data in the hands of community data providers, while still allowing for broad searches and sharing of information" (http://eloka-arctic.org/about/index.html). The GIS will also be linked to the web-based Barrow Area Information Database – Internet Map Server (BAID-IMS) at http://www.baidims.org/.

RESULTS AND DISCUSSION

The general classification of the 260 records from the Iñupiaq Knowledge GIS is shown as a frequency diagram in Figure 3. The categories, which are derived from the most general division of the coding protocol (field one), are discussed below. The first three categories address lakes. Since lakes were the focus of the study, it is not surprising that these three categories encompass about 30% of the responses. *Lakes that drained* were identified 36 times (14%); of these lakes, about two-thirds drained completely while the remainder experienced partial drainage. Many interviewees identified the same lake or drainage process, and several common drainage processes were identified. Only three respondents discussed *lakes that expanded*. *Lake characteristics* were discussed 34 times, primarily as they related to fish resources. Other characteristics observed included water depth, bottom conditions, gas efflux sites, and ice strength and safety. Only a few people appeared to be interested or familiar with *drained lake basins*. Discussions suggest that people avoid these areas because they are too difficult to traverse and generally lacking in resources of interest.

Nine observations addressed freshwater *springs* and focused on those that emerged in lakes or on the tundra. A few springs were identified as "underground." *Streams* generated considerable response (n = 21, 8%), with most observations related to bank erosion, channel bed sedimentation and shallowing, and pool deepening. *Thermokarst* was identified at six sites and typically associated with human use of heavy tracked vehicles.

The *landforms* category elicited the largest number of responses (n = 39, 15%). Coastal changes, including beach erosion and near-shore sedimentation, were of primary interest. Ridges as travel routes were also noted, as well as the location of large rocks and boulders. A few respondents identified pingos as important landscape elements. The *resources* category (n = 20 or 8%) focused on animals (especially caribou) and animal movement routes. Places where geese nested were also identified, as were berry-picking and driftwood collection sites.

Historical and cultural features were clearly of interest to people (n = 33, 13%). The focus was on old cabins and campsites for hunting or fishing, but a few observations identified the location of sod huts and cultural artifacts. *Other changes* (n = 12) included shifts in vegetation type or height, or the impact of ice roads and gravel landing strips. Issues related to *technology* (n = 16) largely dealt with identifying overland travel routes and route changes over time. *Observations and stories* (n = 9) related unusual events that involved animal behavior, getting lost, or shaman influences.

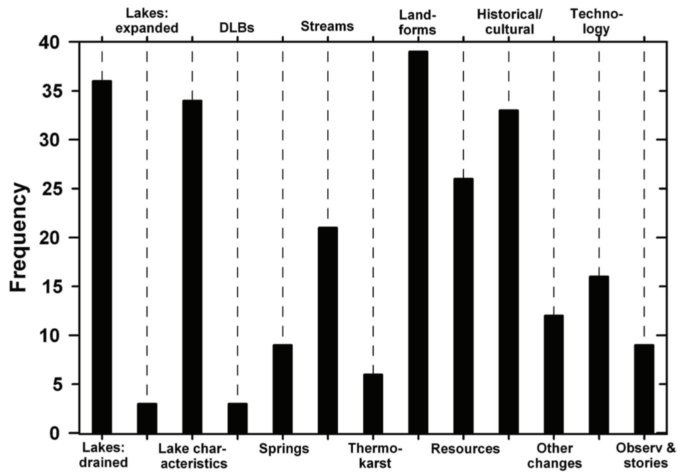


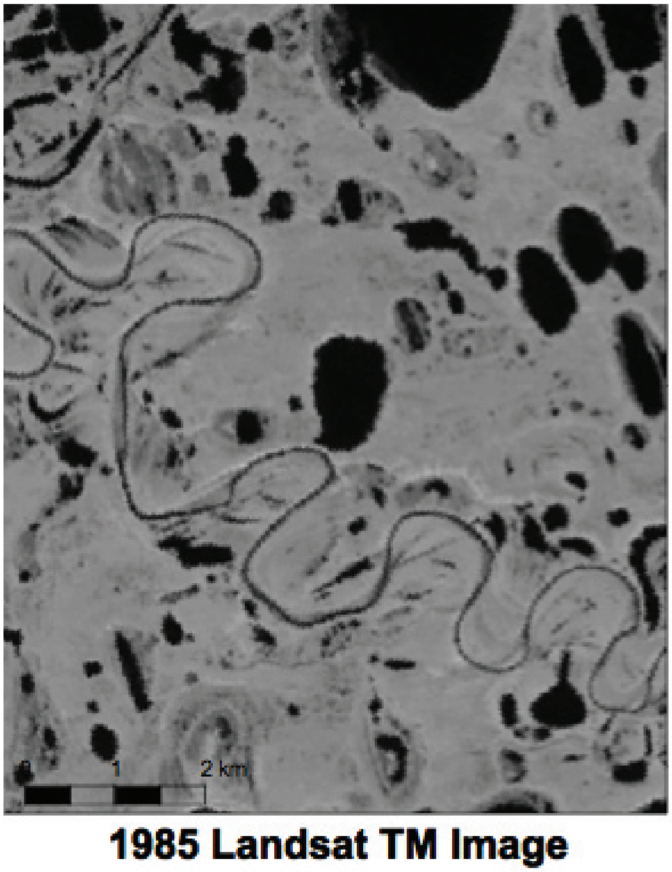
FIG. 3. Frequency diagram showing the general classification, derived from the primary division of the six-digit coding protocol, of 260 records from the Iñupiaq Knowledge GIS.

The classification scheme is, of course, imperfect. Observations related to the topic *Language* are not included. Except for place-names, words describing features tend to lack geographic specificity and so could not be geocoded. The same constraint applies to meteorological events and general observations about changes in resources, such as statements about the general health of a caribou herd or the taste of fish.

Further, the simple location of features may hide a deeper meaning or significance. Large boulders, for example, are unusual on the Coastal Plain. Owing to their size, they are visible year round from long distances and serve as navigation aids. When located near dynamic landforms such as shorelines, boulders provide a visual reference for monitoring shoreline migration. Coastal erosion is indicated when ancient landmarks such as these are removed by encroaching seas, as noted by several respondents.

Examples Using Indigenous Knowledge to Understand Landscape Processes and Events

All of our interviewees worked with us attentively, showed great patience and generosity with their time, and evidenced a remarkable knowledge of their environment. To demonstrate the interviewing process and the utility of Iñupiaq knowledge in terms of our scientific objectives, we present excerpts from interviews with Thomas Brower, Jr., Flossie Itta, and co-author Ronald Brower, Sr. These examples represent the range of experiences and knowledge accessible through the collaborative interview process.



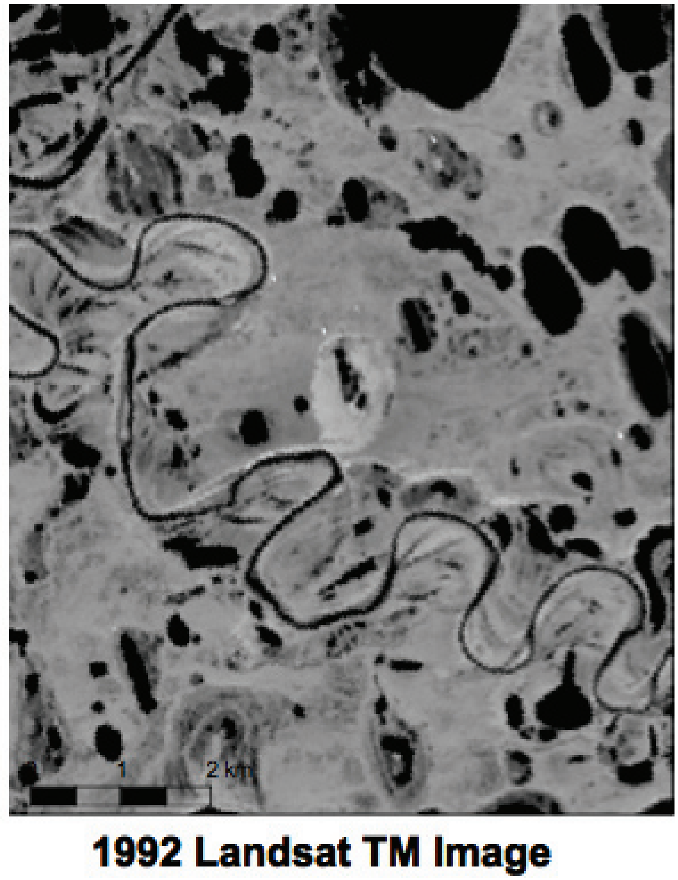


FIG. 4. Satellite images before and after the lake drainage event that Thomas Brower, Jr. witnessed while fishing. The breaching resulted from stream meandering.

Thomas Brower, Jr.

Lake drainage events were specifically of interest to us. These tend to be rapid, episodic, and catastrophic events with important implications for those who travel, fish, and hunt in the tundra. Recently drained lakes are relatively easy to identify on remotely sensed images because water is converted to exposed lake bottom sediments that have an obvious and unique spectral signature (Frohn et al., 2005). Our informants' accounts of drainage have not only been valuable and highly accurate in pinpointing the timing of these events, but also provided insights into the process of lake drainage (Hinkel et al., 2007).

Thomas Brower, Jr. (now deceased) was in his mid-70s when we interviewed him, still actively hunting and fishing, and a keen observer of his environment. The grandchild of famed Barrow trader and settler Charles D. Brower, he was raised by his Iñupiat grandparents (Andrew and Cora Ungarook), and a conscious decision was made to bring him up to be well-versed in Iñupiaq culture, especially in regard to hunting and survival. Brower spent much of his youth working with his uncles at Alaqtaq (Half Moon Three), which was an important reindeer-herding ranch between 1930 and 1950. He described a lake drainage event that he actually observed while fishing from his boat on the Usuktuk River. Initially, he noted that water was seeping from the cut bank of the river, and the subsequent drainage event happened extremely rapidly. The Usuktuk River had meandered to the lake edge and caused breaching (T. Brower, pers. comm. 2005). The extended interview and further analysis of this event are reported in Hinkel et al. (2007). Our analysis of satellite images bracketed the time of drainage to the period between 1985 and 1992, but Tom was able to pinpoint drainage to the early summer of 1989 (Fig. 4).

Flossie Itta

We began our work in Atqasuk by presenting our research and aims to the community at a public meeting, which was attended by over 30 residents. Participants were interested and welcoming, and community consensus as to whom we should interview was very specific and unanimous. The person who knew this region over the longest period of time, all agreed, was Mrs. Thomas (Flossie) Itta. Flossie's special status is derived from the fact that, although she was born in Barrow, a family decision was made to give her a traditional upbringing. Her grandparents, Owen and Fannie Keerik, brought her as a very young child to Atqasupiaq, the original Iñupiaq settlement on the high bluffs overlooking the Meade River. Thus, Flossie's memories of the region go back to the 1930s, and her memory of environmental change includes a wide variety of landscape and atmospheric indicators.

Flossie used the traditional method to describe the transformations undergone in the Meade River region: she told us a story (Cruikshank, 1990; Fair, 1997), using her memory and her remarkable story-telling abilities to illustrate those changes. Today, the bed of the Meade River is sandy and relatively flat. Decades ago, however, the streambed along sections of the Meade was characterized by cobbles and boulders. As an example of Flossie's story telling, we offer an anecdote regarding this change.

> And when I was small, I was teenager too, like 13, 14 years old, 15 years old, 16 years old, every year we always go [travel between Atqasuk and farther inland, toward Sangyak River]. We see the round rocks [using her hands to trace a one-meter diameter circle], in there in the river, on the water. And my grandma and my grandpa, I dragging them with a rope [Flossie was towing the boat from the bank], you know, with them staying in the boat. And that [boat] climb up on the rock, the boat is going like this [Flossie rocks her arms up and down showing the swaying boat deck] and my grandma suddenly says, "AAAHHH!" [laughing] I never see it anymore after I go back to Atqasuk.
>
> (F. Itta, pers. comm. 2004).

This video clip can be viewed online at http://www.geography.uc.edu/~kenhinke/DTLB/.

Flossie said that the boulder bed in the Meade River had disappeared by the time she and her husband returned to the area to settle in the newly established village in the 1970s. The large boulders that lined the streambed of the Meade about 60 years ago are now buried beneath a layer of sand, suggesting that channel sedimentation has occurred along this stretch of the river.

Ronald Brower, Sr.

Ronald H. Brower, Sr. is an active hunter and an expert in the Iñupiaq cultural heritage. His childhood circumstances predisposed him toward an interest in his culture's traditional knowledge.

> We lived in a small sod house there and were frequently cared for by our elderly neighbors while my father and his brother Arnold Brower, Sr. [sons of the afore-mentioned Charles Brower] tended to their trap lines. As a child disabled by rheumatic fever, I listened and learned many Iñupiat myths, legends, histories and stories from elders that frequented my parents' home. I would also be invited by elders to listen and learn my people's history and life experiences so I may be useful to our community in my adult years. (Brower, 1998)

During our interviews, Ron made a highly provocative connection between traditional knowledge and landscape processes. Many of our informants pointed out a site where people have been warned not to spend the night, telling us, "If you go to sleep there, you will never wake up." These sites, we were told by several elders and hunters, are often places where shamans are buried or where spirits dwell. Ron suggested that they are often areas where methane or CO_2 outgassing occurs, making them hazardous during calm conditions. He also identified a location on the shores of a lake that caused much confusion for travelers between Barrow and inland hunting sites. In the winter, hunters are reportedly attracted to a "luminescent glow" that they would tend to mistake for lights of the village of Wainwright, thus navigating to an erroneous point.

Ron also took us to a site on the Meade River delta to show us where his cabin had to be relocated because of stream bank erosion. As we viewed the collapse of his property along the edge of the river bluff, Ron explained: "This side melted most rapidly because there is an ice-lens underneath. This whole area melted pretty rapidly in the last two or three years." The video clip of his explanation can be viewed online at http://www.geography.uc.edu/~kenhinke/DTLB/.

Presentation and Explanation of the Iñupiaq Knowledge GIS

The tangible product of this research is the GIS database, which consists of the base map and associated data layers. Figure 5 displays a layer representing drained lake basins identified by our Barrow and Atqasuk informants. As noted earlier, Hinkel et al. (2007) used satellite imagery to show that 50 lakes completely or partially drained over a 25-year period. Our informants identified 21 of these lakes, all of which were located within 50 km of their home villages or summer camps. Lakes not identified were typically smaller lakes or those that only partially drained. Further, they pointed out several DLBs. However, the fact that we could not find corroborative evidence from either satellite or aerial photos that these were the result of recent drainage suggests that geographic knowledge is spatially restricted, and that verification of verbal accounts is a necessary precaution.

Two drained basins identified by the elders evidence very different causes of lake drainage. Ikkalguruak Lake drained between July 1984 and August 1985: this was a natural and catastrophic drainage event that six informants recalled very well since it is along a well-traveled route to the interior. Local people recognized that this event was caused by bank overtopping and degradation of ice wedges at the southern margin of Ikkalguruak Lake. The subsequent formation of a gully triggered its catastrophic drainage into a previously drained basin north of the Inaru River (Fig. 6). One elder, Mary Lou Leavitt, described a situation in the early spring with ice piling up before the drainage event. She explained that a "crack" was found in the tundra that was more than 30 cm wide, which was believed to be the initial outlet. We were able to bracket the timing of the drainage using Landsat imagery; and we can also see that since August 1985, much of the basin has been revegetated (Jones, 2006).

Another lake drainage event was identified by three informants as occurring because of unintentional

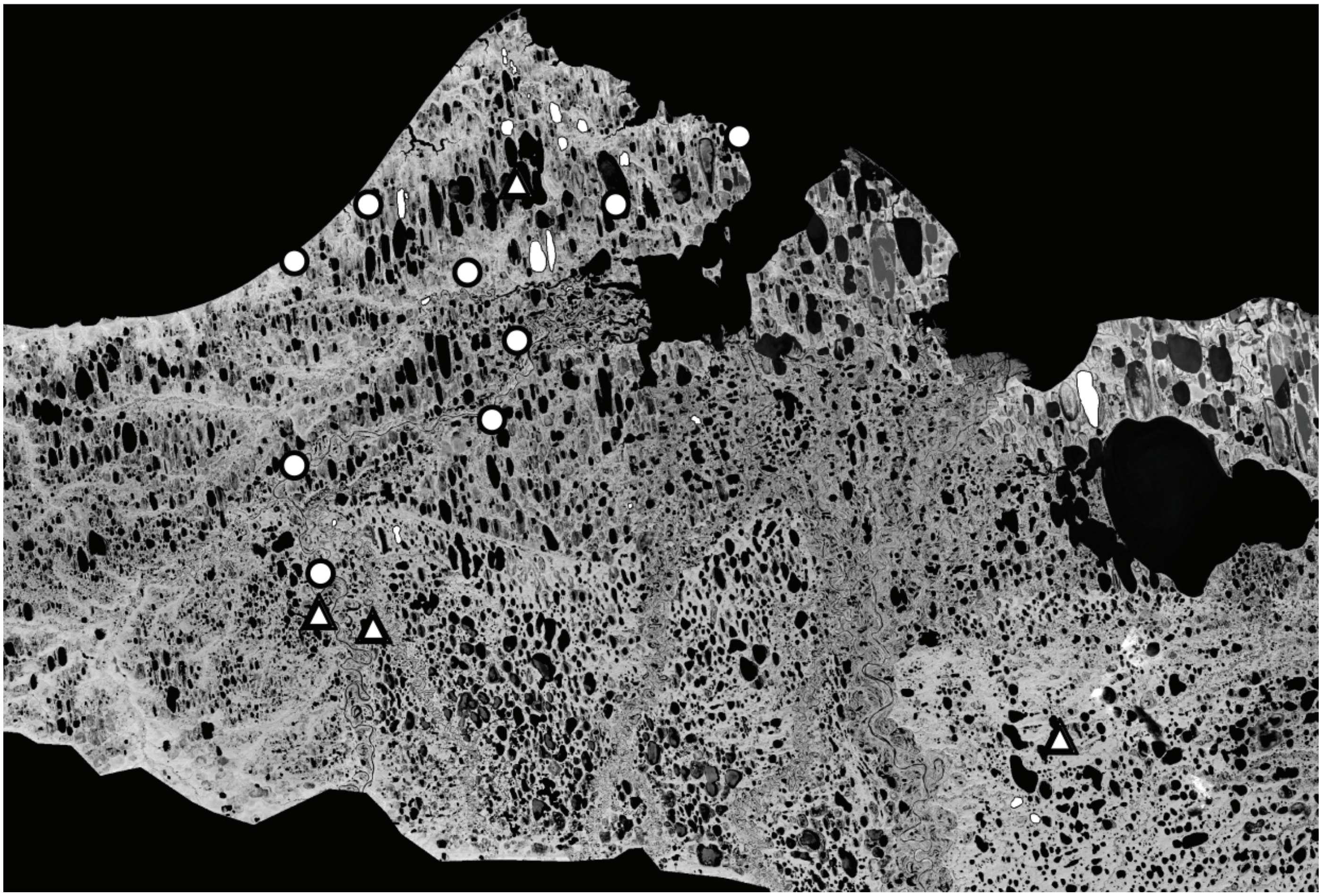


FIG. 5. A layer of the Iñupiaq Knowledge GIS showing drained lake basins identified by elders (white areas), terrestrial gas seepage or dangerous sites (circles), and gas efflux lake sites (triangles).

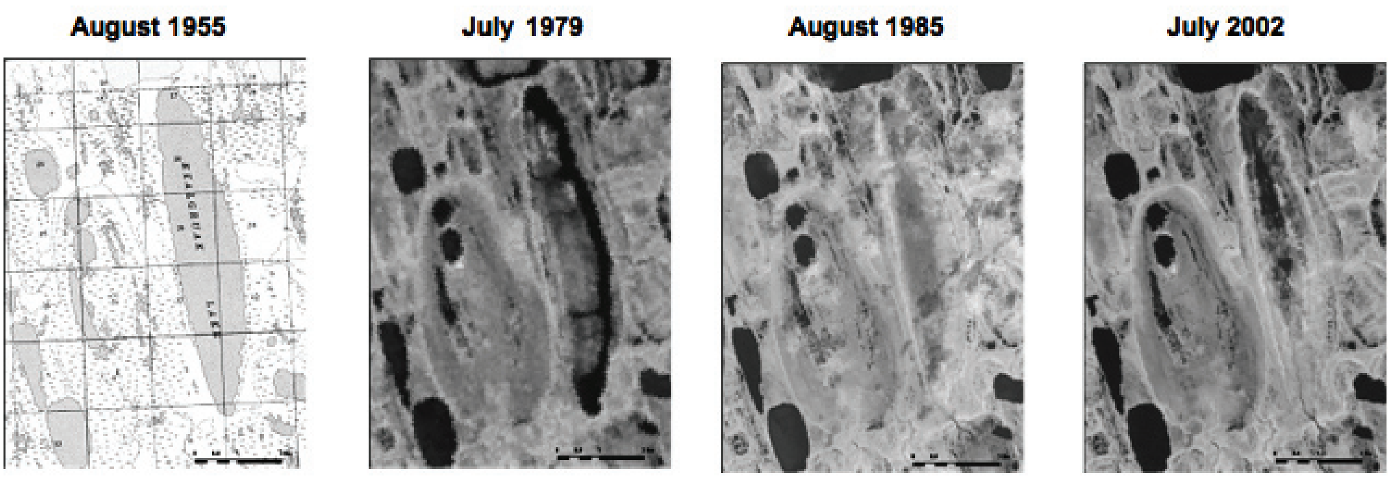


FIG. 6. USGS map and three chronological satellite images showing original lake (1955 and 1979), drained lake basin (1985), and basin revegetation (2002).

interference with the local hydrology. A seismic survey vehicle had been used to access a local lake to obtain potable water, and the resulting linear depression became a lake drainage channel. As was common during the late 1940s and early 1950s, these tracked vehicles left deep ruts in the tundra surface that subsequently resulted in severe thermokarst. Aerial photography has helped to corroborate several of the elders' accounts; the unusually straight outlet channel at the northern end of the drained lake is clearly visible in the 1979 image (Fig. 7).

Elders and active hunters identified sites that were in some way unsafe and therefore to be avoided. It is not clear

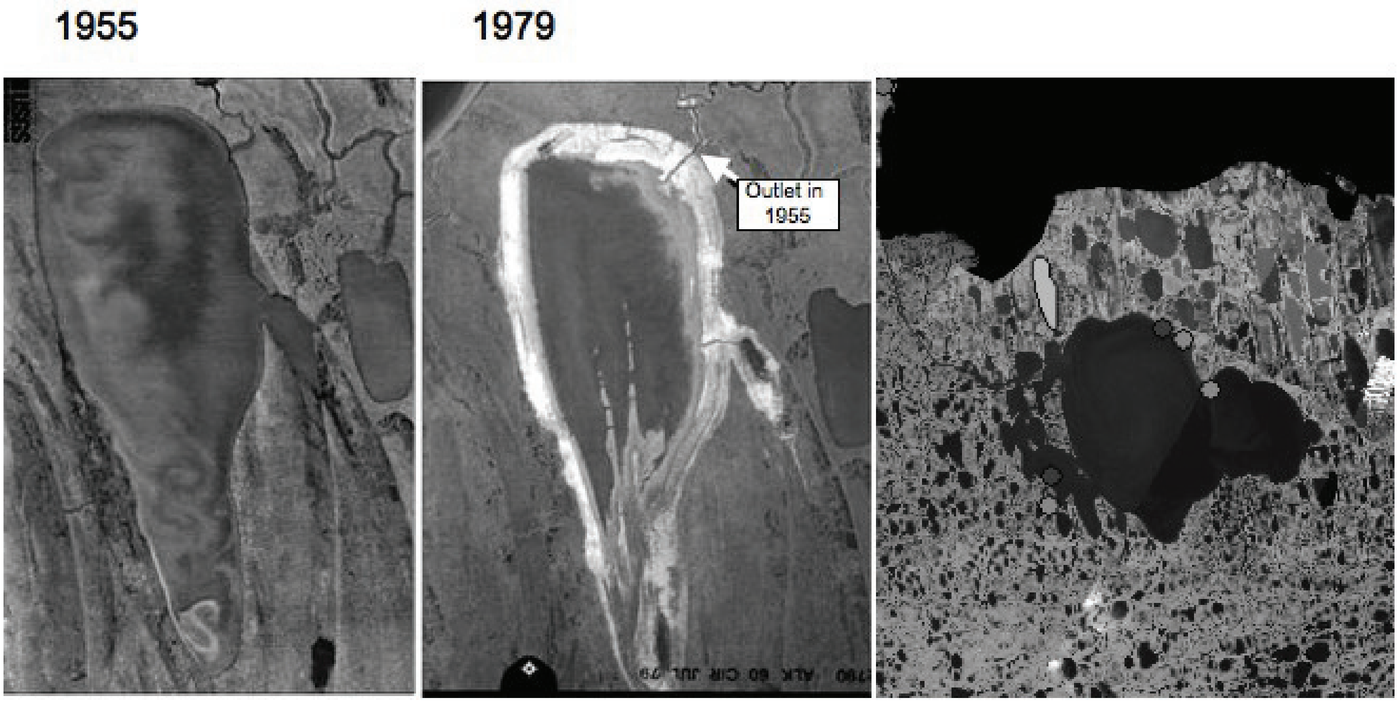


FIG. 7. Lake identified by our informants as having drained because of vehicular traffic and resulting thermokarst. Image on right shows regional context of lake (white polygon above northwest edge of large lake [Teshekpuk Lake]).

whether all these sites form a coherent category: some were obviously sites of natural gas seepage, while others were exclusively associated with shamans, ghosts, or devils. At a gas seepage site, Ron Brower said: “So, this area was called “Sinniqtagnailaq,” and on calm days you don’t want to be here” (it was a windy day when we visited the site). “I wish we could pinpoint the spot where the methane comes out.” Brower knew of several hunters from Barrow who had experienced hallucinations from breathing the air around these gas seeps. When they were found, they appeared to have impaired cognitive skills and were often confused as to their whereabouts even though there were trails nearby to guide them home. “They took off in the opposite direction or followed the wind. That’s why you don’t want to camp there. Otherwise you may not wake up again.” We have isolated those sites that fit into the general category of places not to spend the night or to avoid. These are mapped in Figure 5.

Seven interviewees identified specific sites where sleeping or camping was dangerous: these were sometimes identified as sites where shamans were buried and would result in symptoms similar to those experienced at the gas seep sites. Ron Brower said that “hallucinations result from breathing whatever is coming out of the ground at those sites, and this is attributed to the power of the shaman still exerting its force on humans and animals alike.”

Ron explained the phenomenon further: “The luminescent glow is often visible when the weather gets cold but the ground below is still warm. It looks like a pillar described in the Bible because it glows from the moon shining on it. On some calm days, the lake will fill with a low cloud to its brim. You can stand there and feel the cold gas overflowing from the lake. It is colder than the surrounding air. You don’t want to go into the cloud because you may not come out again. You just have to get away from it. That’s why we call it *Sinniqtagnailaq*.”

Several other points are worth mentioning in regard to gas effusion. Another active hunter, Roy M. Nageak, Sr., identified a site (which he also named *Sinniqtagnailaq*) approximately 16 km south of Ron Brower’s site that had the same sinister reputation. Roy elaborated: “The low-lying land over the ridge is also called *Sinniqtagnailaq*. This particular site is where a man will suddenly appear, then quickly vanish when approached. He then appears in a different location and has caused several local residents to become lost. This site is also where a moving lantern or bright light will be seen, especially in winter, distracting travelers, and causing several local residents to become disoriented as to their whereabouts.” Our liaison and interpreter, Lollie Hopson (pers. comm. 2008) explained that the word *Sinniqtagnailaq* means “should not camp (stay, or sleep) there,” and corroborated that more than one place could have the same name.

Another category of sites identified was places with gas efflux from lakes. Only four such lakes have been identified, and it is interesting that these sites were generally not thought to be dangerous or areas to avoid (Fig. 5). The only warning related to these lakes was that they might not completely freeze over during winter, and thus caution should be exercised when crossing them with snow machines.

Although many of our informants were extremely knowledgeable about changes in the landscape, survival strategies, and understanding landscape processes, several limitations were apparent. People that travel the tundra today do not range as far afield as their predecessors did, nor do they spend as much time in remote areas (Eisner et al., 2008). During interviews, they often lamented that nowadays, traveling in ATVs or snow machines, they move too quickly over the tundra to notice details. This same limitation was a central theme identified by the community of Kinngait, Baffin Island, Canada, where residents said that modern snow machine use discouraged one from learning the landscape (Henshaw, 2006). Most of the geographical data provided by our informants is confined to areas near villages or hunting camps and cabins. Furthermore, we have not yet been able to access information about lake drainage events that took place prior to the lifetime of our informants. Possibly this information is unavailable because of the social and cultural disconnect associated with changes the Iñupiaq culture has endured. Alternatively, this kind of information may not be considered useful or relevant to pass on to the younger generation, especially if it does not directly affect travel routes or resource use.

Thus, the knowledge of the informants was limited by where they lived, the routes by which they traveled inland, their mode of travel, and the locations of their camps and cabins. The greatest density of data points on the GIS is in the vicinity of villages, near camps and cabins, and along travel routes. We are continuing to analyze the spatial distribution of environmental knowledge in relation to changing travel and occupation patterns.

Place-Names as a Source of Environmental Information

A number of ethnographic studies in the Canadian and Alaskan Arctic have focused on place-names (toponyms) and have demonstrated that generally these names are highly descriptive of the landscape or record particular activities or historic events that occurred there (Fair, 2004; Henshaw, 2006; Carmack and MacDonald, 2008). Thus, place-names are an essential element in the Iñupiaq oral tradition (Collignon, 2006). Place-names often describe physical characteristics (for example, Ikkalguruak, 'huge shallow lake'), but may also describe other qualities of a site ('a good place to make a camp') or ('a good place to to avoid'). For researchers working in Arctic communities, attention to place-names is especially warranted regarding lakes. Traditional Iñupiaq environmental knowledge has singled out lakes as highly significant, and this focus probably has ancient roots. In an extensive study of Inuit place-names and sense of place, Collignon (2006) collected a total of 1007 Inuit place-names from northern Canada. She found that lakes were named more frequently than any other landscape category: more often than coastline features, islands, waterways, or any other landform.

Elders clearly found the telling of Iñupiat place-names to be an important part of our interviews. They often related the original Iñupiaq name for a particular geographic feature and were careful to make certain that we recorded these properly. It was not unusual during an interview for the interviewee to engage in a lively discussion with the translator and other members of the household to establish the precise meaning, spelling, and pronunciation of Iñupiat place-names.

Nonetheless, for researchers who are not fluent in the Iñupiaq language, responsible recording of place-names and other information in a different language can be quite challenging. As discussed earlier, two different people described the location "*Sinniqtagnailaq*" similarly, but they selected different locations on the map. Further, the "official" local Iñupiaq map did not include this place-name. Corroboration and accurately locating *Sinniqtagnailaq* therefore became unexpectedly complex. In such situations, there may not be a single authoritative source to consult, and it would be irresponsible for researchers from outside to make independent decisions about how to label such a site within the GIS, or to adjudicate between competing accounts among recognized local experts. In a different scenario, one of the identified DLBs is named "Imagruak," ('big or huge water'), but another lake (this one near Atqasuk) also has the same name. Local traditions of naming may not always clearly conform to scientific needs and norms, but the importance of recording and preserving those traditions calls for good communication with multiple local parties to ensure that a suitable effort has been made to represent local knowledge accurately.

Intersection of Environmental Change and Indigenous Knowledge

During the course of interviewing, we discovered that by focusing most of our questions on lakes, we made our research goals more accessible to our Iñupiat collaborators. Scientists and community members were able to communicate about topics of mutual concern—specifically lake changes, and more generally, landscape changes—and discuss these changes as equal partners. Although our primary goal was to access information on environmental change, we invited our collaborators to add insights into their culture on the understanding that cultural insight was not the main aim of the interview. Placing environmental change in the forefront rather than studying Iñupiaq culture as an end unto itself helped to create a relationship of cooperation to identify causal processes, as opposed to one that establishes a dichotomy between the researcher and his or her subject (Berkes, 1999; Huntington, 2000; Cuomo et al, 2008).

It should be reiterated that Iñupiaq knowledge has its own set of limitations. As noted earlier, at times there may be discrepancies regarding place-names and locations. Indigenous knowledge can be applied as a source of information to scientific research, but this is not the purpose for which it was originally intended. The researcher should consider the ways in which the knowledge was acquired and conveyed through subsequent generations (Huntington and Fox, 2005). Similarly, explanations and interpretation of causative processes may differ between observers. For example, Hinkel et al. (2007) noted that Iñupiat collaborators suggested increased lake drainage when there were strong and persistent winds from the north. Presumably, such winds generate a storm surge, which causes bank overtopping and drainage channel development on the southern shore. This hypothesis has not appeared in the scientific literature, but it appears feasible since the fetch on these NNW-oriented, elongated lakes is appreciably greater in the north-south direction (on average, about three times the fetch in the east-west direction), and there is evidence of wind-induced storm surges in the form of strand line debris. Other Iñupiaq knowledge holders, however, dismiss this explanation. Western scientific methods can be used to develop critical field, laboratory, or modeling experiments to test the veracity of this model.

CONCLUDING REMARKS

We began our research with the assumption that place-based Iñupiaq knowledge has the potential to reveal a new understanding of landscape changes on the Arctic Coastal Plain in general, and on lake processes in particular. This research has already provided critical information on lake process studies (Hinkel et al., 2007) and generated data needed to assess the environmental impacts of overland travel routes on the Arctic Coastal Plain (Eisner et al., 2008). We have also presented this information in more qualitative terms, focusing on our informants' concerns regarding climate change, subsistence, community values, and the role of women (Cuomo et al., 2008).

The three case studies described above are all related either to episodic events (the abrupt and rapid draining of a lake) or to local, specific observations (the change in the bottom sedimentation of a river or the ephemeral accumulation of gas). This is not surprising, as many of our interview questions focused on events and novel occurrences. Other scholars have noted that indigenous knowledge may give more weight to anomalous or extreme events and is generally more focused on local processes (Huntington and Fox, 2005). This attention to detail is a potentially powerful asset in studies of environmental change. Incorporating place-based information provides a way to recognize the perceptions, experiences, and culturally relevant events that are associated with a particular location. Because local-scale, place-based, or experiential knowledge is often relevant and unique, it is arguably necessary for understanding the complexity inherent in environmental change (Cruikshank, 2001; Berkes, 2002).

Although regional climate models predict enhanced warming in the Arctic, it is not clear how this will be actually manifested on the landscape over time. What is clear is that indigenous communities of the Arctic are stakeholders whose amassed knowledge of ecological processes constitutes a powerful tool for integrated management of ecosystems, which Berkes et al. (2007) call "community-based monitoring." Studies have pointed out that traditional methods of monitoring resources, such as caribou health and migration patterns, may be crucial for dealing with uncertainty and resource management in the future (Parlee et al., 2005). The efficacy of environmental research conducted in partnership with the Iñupiaq community of Barrow has been noted by others (e.g., Norton, 2002). In our work, local and indigenous knowledge has served as a means of ground-truthing and a mechanism for refining our rather general and regionally specific thaw-lake model. Elsewhere in the Arctic, natural scientists are finding that partnerships and collaborative research with local residents not only shed light on our understanding of ecosystem processes, but also reveal new ways of approaching resource management and impacts of environmental change on infrastructure (Wolfe et al., 2007). Our research also indicates that including local knowledge can help develop new research questions and explanatory hypotheses, and so the benefits of such collaborations are epistemic as well as practical.

Although climate change is potentially of concern to every community on the planet, Arctic communities have a particularly urgent interest in understanding and addressing potential changes. The Iñupiat have observed gradual, rapid, and catastrophic natural changes in the landscape during their lifetimes. Local knowledge has been demonstrated to be highly valuable in identifying specific events and causative processes, and it can be used to separate natural events from those induced by direct human activities. Beyond its usefulness for contributions to scientific knowledge, community-based Arctic research should also demonstrate usefulness and relevance to local communities (Gearheard and Shirley, 2007). As stated in the Introduction, we are committed to developing methods of sharing information and fostering opportunities for collaboration. The Iñupiaq Knowledge GIS and sophisticated mapping tools presented here are ideal tools for displaying integrated indigenous and scientific knowledge, and for making that knowledge accessible to both the local and scientific communities. It is our hope that the Iñupiaq Knowledge GIS will facilitate submission of geocoded data, information retrieval, and mapping. This will enable the community and scientists to use these tools for environmental assessment, education, and planning.

Incorporating Iñupiaq knowledge into our research was the initial objective of this project; however, in bringing Iñupiaq knowledge to the forefront of this study, we have developed collaborative methods and obtained material that greatly exceeds the original scope of the project. We have collaborated with North Slope communities to develop a GIS database that we hope will preserve the knowledge of elders and local experts and contribute to ongoing observation, monitoring, and collaborative research on the North Slope of Alaska. In addition, our study of environmental change includes the documentation of life stories and cultural histories, analyses of human impacts on the land, and attention to environmental ethics. The wealth of relevant and unique information provided in interviews by Iñupiat elders helps illustrate the epistemological significance of local knowledge about environmental processes and changes. In spite of the challenges of this sort of research, we hope that our project helps convey the practical possibility of community-oriented scientific research and mutually beneficial collaborations with local long-term stakeholders.

ACKNOWLEDGEMENTS

This research was supported by the U.S. National Science Foundation under grants OPP-0240174, OPP-0539167 and BCS -0548846 to Wendy Eisner, OPP-0094769 and OPP-0713813 to Kenneth Hinkel, and ARC-0641623 to Richard Beck. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF. We are grateful for support from the Barrow Arctic Science Consortium and the Ukpeagvik Iñupiat Corporation. We thank our Iñupiat collaborators, especially Thomas Itta, Sr. (deceased), Flossie Itta, Roy Nageak, Sr., Thomas Brower, Jr. (deceased), Virginia Brower, and our translators and community liaisons Lollie Hopson and Ethel Burke. Richard Beck, James Bockheim, Kim Peterson, William Mellman, and John Hurd also assisted in this study.

REFERENCES

Alaska Native Tribal Health Consortium. 2001. Alaska native mortality, 1980–1998. Anchorage, Alaska: Alaska Area Native Health Service, Division of Planning, Evaluation, and Health Statistics. 27 p. http://www.anthc.org/ref/hs/docs/index.cfm.

Albert, T.F. 2001. The influence of Harry Brower, Sr., an Iñupiaq Eskimo hunter, on the Bowhead Whale Research Program conducted at the UIC-NARL facility by the North Slope Borough. In: Norton, D., ed. Fifty more years below zero: Tributes and meditations for the Naval Arctic Research Laboratory's first half century at Barrow, Alaska. Calgary and Fairbanks: Arctic Institute of North America. 265–278.

Berkes, F. 1999. Sacred ecology: Traditional ecological knowledge and resource management. Philadelphia: Taylor & Francis.

———. 2002. Epilogue: Making sense of Arctic environmental change? In: Krupnik, I., and Jolly, D., eds. The Earth is faster now: Indigenous observations of Arctic environmental change. Fairbanks: Arctic Research Consortium of the United States. 334–349.

Berkes, F., Berkes, M.K., and Fast, H. 2007. Collaborative integrated management in Canada's North: The role of local and traditional knowledge and community-based monitoring. Coastal Management 35(1):143–162.

Bernard, H.R. 2002. Research methods in anthropology, 3rd ed. Walnut Creek: AltaMira Press.

Blackman, M.B. 1989. Sadie Brower Neakok: An Iñupiaq woman. Seattle: University of Washington Press.

Bockheim, J.G., Hinkel, K.M., Eisner, W.R., Dai, X.Y., and Peterson, K.M. 2004. Carbon pools and accumulation rates in an age-series of soils in drained thaw-lake basins, Arctic Alaska. Soil Science Society of America Journal 68:697–704.

Brewster, K. 1997. Native contributions to Arctic science at Barrow, Alaska. Arctic 50(3):277–284.

Brigham-Grette, J. 2001. New perspectives on Beringian Quaternary paleogeography, stratigraphy, and glacial history. Quaternary Science Review 20:15–24.

Brigham-Grette, J., and Hopkins, D. 1995. Emergent marine record and paleoclimate of the last interglaciation along the Northwest Alaskan Coast. Quaternary Research 43:159–173.

Brower, C.D. 1942. Fifty years below zero. New York: Dodd, Mead and Company, Inc.

Brower, R.H. 1998. Biographies: Ronald H. Brower, Sr. Anchorage: Institute of Social and Economic Research, University of Alaska Anchorage. http://www.alaskool.org/projects/biography/RHBrower.htm.

Carmack, E., and Macdonald, R. 2008. Water and ice-related phenomena in the coastal region of the Beaufort Sea: Some parallels between Native experience and Western science. Arctic 61(3):265–280.

Chance, N.A. 1990. The Iñupiat and Arctic Alaska: An ethnography of development. New York: Holt, Rinehart & Winston, Harcourt Brace.

Collignon, B. 2006. Inuit place names and sense of place. In: Stern, P., and Stevenson, L., eds. Critical Inuit studies: An anthology of contemporary Arctic ethnography. Lincoln: University of Nebraska Press. 187–205.

Cruikshank, J. 1990. Life lived like a story: Life stories of three Yukon Native Elders. Lincoln: University of Nebraska Press.

———. 2001. Glaciers and climate change: Perspectives from oral tradition. Arctic 54(4):377–393.

Cuomo, C.J., Eisner, W.R., and Hinkel, K.M. 2008. Environmental change, indigenous knowledge, and subsistence on Alaska's North Slope. The Scholar and Feminist Online 7.1: Fall 2008 - Gender on Ice. http://www.barnard.columbia.edu/sfonline/ice/cuomo_eisner_hinkel_01.htm.

Eisner, W.R., Bockheim, J.G., Hinkel, K.M., Brown, T.A., Nelson, F.E., Peterson, K.M., and Jones, B.M. 2005. Paleoenvironmental analyses of an organic deposit from an erosional landscape remnant, Arctic Coastal Plain of Alaska. Palaeogeography, Palaeoclimatology, Palaeoecology 217:187–204.

Eisner, W.R., Hinkel, K.M., Jones, B.M., and Cuomo, C.J. 2008. Using indigenous knowledge to assess environmental impacts of overland travel routes, Arctic Coastal Plain of Alaska. In: Kane, D., and Hinkel, K., eds. Ninth International Conference on Permafrost. Fairbanks: Institute of Northern Engineering, University of Alaska. 415–420.

Fair, S.W. 1997. Inupiat naming and community history: The Tapqaq and Saniniq coasts near Shishmaref, Alaska. Professional Geographer 49(4):466–480.

———. 2004. Names of places, other times: Remembering and documenting lands and landscapes near Shishmaref, Alaska. In: Krupnik, I., Mason, R., and Horton, T., eds. Northern ethnographic landscapes: Perspectives from circumpolar nations. Washington, D.C.: Arctic Studies Center, National Museum of Natural History, Smithsonian Institution. 230–254.

Fox, S. 2002. These are things that are really happening: Inuit perspectives on the evidence and impacts of climate change in Nunavut. In: Krupnik, I., and Jolly, D., eds. The Earth is faster now: Indigenous observations of Arctic environmental change. Fairbanks: Arctic Research Consortium of the United States. 12–53.

Frohn, R.C., Hinkel, K.M., and Eisner, W.R. 2005. Satellite remote sensing classification of thaw lakes and drained thaw lake basins on the North Slope of Alaska. Remote Sensing of the Environment 97:116–126.

Gearheard, S., and Shirley, J. 2007. Challenges in community-research relationships: Learning from natural science in Nunavut. Arctic 60(1):62–74.

Henshaw, A. 2006. Pausing along the journey: Learning landscapes, environmental change, and toponymy amongst the Sikusilarmiut. Arctic Anthropology 43(1):52–66.

Hinkel, K.M., Eisner, W.R., Bockheim, J.G., Nelson, F.E., Peterson, K.M., and Dia, X.Y. 2003. Spatial extent, age and carbon stocks of drained thaw lake basins on the Barrow Peninsula, Alaska. Arctic, Antarctic, and Alpine Research 35(3):291–300.

Hinkel, K.M., Frohn, R.C., Nelson, F.E., Eisner, W.R., and Beck, R.A. 2005. Morphometric and spatial analysis of thaw lakes and drained thaw lake basins in the western Arctic Coastal Plain, Alaska. Permafrost and Periglacial Processes 16(4):327–341.

Hinkel, K.M., Jones, B.M., Eisner, W.R., Cuomo, C.C., Beck, R.A., and Frohn, R.C. 2007. Methods to assess natural and anthropogenic thaw lake drainage on the western Arctic Coastal Plain of northern Alaska. Journal of Geophysical Research 112, F02S16, doi:10.1029/2006JF000584.

Huntington, H.P. 2000. Using traditional ecological knowledge in science: Methods and applications. Ecological Applications 10:1270–1274.

Huntington, H., and Fox, S. 2005. The changing Arctic: Indigenous perspectives. In: Arctic climate impact assessment. New York: Cambridge University Press. 61–98.

Jones, B.M. 2006. Spatiotemporal analysis of thaw lakes and basins, Barrow Peninsula, Arctic Coastal Plain of northern Alaska. MSc, Department of Geography, University of Cincinnati, Cincinnati, Ohio.

Kelly, J.J., and Brower, A., Sr. 2001. The NARL and its transition to the local community. In: Norton, D., ed. Fifty more years below zero: Tributes and meditations for the Naval Arctic Research Laboratory's first half century at Barrow, Alaska. Calgary and Fairbanks: Arctic Institute of North America. 259–264.

Norton, D.W. 2002. Coastal sea ice watch: Private confessions of a convert to indigenous knowledge. In: Krupnik, I., and Jolly, D., eds. The Earth is faster now: Indigenous observations of Arctic environmental change. Fairbanks: Arctic Research Consortium of the United States. 126–155.

Parlee, B., Manseau, M., and Łutsël K'é Dene First Nation. 2005. Using traditional knowledge to adapt to ecological change: Denésǫłiné monitoring of caribou movements. Arctic 58(1):26–37.

Schroeder, R.F., Andersen, D.B., Bosworth, R., Morris, J.M., and Wright, J.M. 1987. Subsistence in Alaska: Arctic, Interior, Southcentral, Southwest, and Western regional summaries. Technical Paper 150. Juneau: Alaska Department of Fish and Game. 690 p.

Serreze, M.C., Walsh, J.E., Chapin, F.S., III, Osterkamp, T., Dyurgerov, M., Romanovsky, V., Oechel, W.C., Morison, J., Zhang, T., and Barry, R.G. 2000. Observational evidence of recent change in the northern high latitude environment. Climatic Change 46:159–207.

Spencer, R.F. 1976. The North Alaskan Eskimo: A study in ecology and society. New York: Dover Publications.

U.S. Census Bureau. 2000. Fact Sheet summary file 1 (SF 1) and summary file 3 (SF 3). http://fastfacts.census.gov/home/cws/main.html.

Wolfe, B.B., Armitage, D., Wesche, S.E., Brock, B.E., Sokal, M.A., Clogg-Wright, K.P., Mongeon, C.L., Adam, M.E., Hall, R.I., and Edwards, T.W.D. 2007. From isotopes to TK interviews: Towards interdisciplinary research in Fort Resolution and the Slave River Delta, Northwest Territories. Arctic 60(1):75–87.