A TOTAL ENVIRONMENT OF CHANGE: EXPLORING SOCIAL-ECOLOGICAL SHIFTS IN SUBSISTENCE FISHERIES IN NOATAK AND SELAWIK, ALASKA

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A

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Abstract

Arctic ecosystems are undergoing rapid changes as a result of global climate change, with significant implications for the livelihoods of Arctic peoples. In this thesis, I use ethnographic research methods to detail prominent environmental changes observed and experienced over the past few decades and to document the impact of these changes on subsistence fishing practices in the Iñupiaq communities of Noatak and Selawik in northwestern Alaska. Using in-depth key informant interviews, participant observation, and cultural consensus analysis, I explore local knowledge and perceptions of climate change and other pronounced changes facing the communities of Noatak and Selawik. I find consistent agreement about a range of perceived environmental changes affecting subsistence fisheries in this region, including lower river water levels, decreasing abundances of particular fish species, increasingly unpredictable weather conditions, and increasing presence of beaver, which affect local waterways and fisheries. These observations of environmental changes are not perceived as isolated phenomena, but are experienced in the context of accompanying social changes that are continually reshaping rural Alaska communities and subsistence economies. Consequently, in order to properly assess and understand the impacts of climate change on the subsistence practices in Arctic communities, we must also consider the total environment of change that is dramatically shaping the relationship between people, communities, and their surrounding environments.

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Chapter 1
Introduction: Arctic climate change and research approach

1.0 Arctic climate change and implications for northern communities

It is generally accepted that climate change is occurring and that it is especially evident in high latitude regions (ACIA 2005). The global warming trend of the past century is amplified at high latitudes through snow and ice radiation and other feedbacks (Chapin et al. 2004). Based on a compilation of paleoclimate records from lake sediments, trees, glaciers, and marine sediments, Overpeck et al. (1997) conclude that Arctic temperatures in recent decades are the highest they have been over the past 400 years. Increasing global concentrations of carbon dioxide and other greenhouse gasses due to human activities are projected to contribute to additional Arctic warming of about 4 to7°C over the next 100 years (Corell 2006). Increasing precipitation, shorter and warmer winters, and substantial decreases in snow cover and ice cover are among the projected changes that are likely to persist for centuries (Corell 2006).

Environmental changes observed over the last four decades suggest that the effects of climate change in the Arctic are already recognizable. These changes include melting sea ice, rising sea levels and coastal erosion, permafrost thaw, and the range extension of some fish species (Hinzman et al. 2005). However, detecting change has been significantly hampered by deficiencies in data sets (Overpeck et al. 1997). Terrestrial records for key Arctic monitoring variables such as air temperature, precipitation, glacier mass balance, and permafrost conditions are often short or discontinuous and lacking in spatial extent (Serreze et al. 2000). Limited scientific knowledge of Arctic physical, biological and ecological processes challenges our ability to predict impacts of change.

As the climate continues to change in the Arctic, there will be ecological consequences in the aquatic and marine ecosystems, such as changes in the range and distribution of many species with resulting effects on availability, accessibility, and quality of resources upon which northern human communities rely. General knowledge of the biology of aquatic and marine biota in this region is minimal, particularly with respect to understanding

potential connections between climate drivers and ecosystem structural and functional responses (Prowse et al. 2009). Large uncertainties remain in projecting species and system-specific responses. However, locally adapted Arctic species will likely disappear from certain areas when environmental conditions exceed physiological tolerances. Climate change is predicted to have profound effects on Arctic freshwater and nearshore marine systems, possibly resulting in shifts in ecosystem structure, function, and productivity (Reist et al. 2006). The inherently complex relationship between changing climatic factors, ecosystem dynamics, and effects on fish populations raises concern for management bodies and resources users, who are searching for ways to prepare for and respond to potential changes in the distribution and abundance of key fish species and ecosystem effects (Stram and Evans 2009).

The global phenomenon of climate change and the regional intensity of change in the Arctic have significant implications for the remote, indigenous communities of the North, who are closely tied to their surrounding environment and often lack the resources to respond effectively. There is a recognition among Arctic residents that the regional climate has changed within living memory (Krupnik and Jolly 2002). The basic observations of warmer temperatures, longer growing seasons, and later freeze-up of major waterways have been observed repeatedly by indigenous people throughout the Arctic, even before trends became statistically detectable in instrument records (Hinzman et al. 2005).

Recently, increasing research attention has been given to documenting local observations of climate change to increase the overall understanding of the complexities of ecosystem processes (Moller et al. 2004), and to understand the vulnerability of social-ecological systems to impacts of climate change (Ford et al. 2006). There is a growing recognition within scientific and other research literature that indigenous communities possess a holistic understanding of complex systems based on long term interactions with their surroundings (Berkes et al. 2000, Riedlinger and Berkes 2001). The multi-generational, place-specific, and integrative nature of indigenous systems of knowing can complement

scientific approaches to more completely understand complex processes of change (Berkes 2008).

Despite the unprecedented level of research and media attention paid to climate change, this phenomenon is not the only, nor the most pressing, challenge facing Arctic communities (Fox 2002, Fazzino and Loring 2009). The Arctic's indigenous populations are not inexperienced in dealing with climate-generated stress (Cruikshank 2001, Burch 2006), while other social shifts pose more serious challenges to the persistence of subsistence cultures. Within recent memory, populations in the Arctic have become more sedentary, traditional land-based activities have declined, industrialization and consumerism have been introduced, and management of natural resources has been assumed by outside bureaucratic bodies (Duerden 2004). Understanding and anticipating the consequences of climate change requires knowledge about the interactions of climate change and social, economic and environmental stresses facing communities (Huntington et al. 2007, Forbes et al. 2009).

1.1 Statement of research need

Few studies have specifically addressed the impacts of climate change on subsistence fishing activities in remote Alaskan communities and the perceived importance of these impacts. Given the dependence of communities in northwest Alaska on subsistence fishery resources, it is imperative to better understand the current and potential impacts of climate and other challenges on these fisheries. Active and experienced fishers throughout Arctic Alaska possess a body of knowledge about local fish resources and environmental interactions, referred to in this thesis as traditional ecological knowledge, which is often under-recognized and under-utilized in conventional scientific approaches to knowledge. Understanding and addressing a process as complex as climate change requires the inclusion of these local perspectives. In this thesis I address the need to document Iñupiaq observations and perceptions of climate change and the consequences of these changes on subsistence fishing activities in the communities of Noatak and Selawik, in northwest Alaska.

The findings and ideas presented here are based on firsthand detailed ethnographic research conducted with the residents of two communities who are observing environmental changes and who are also facing many other issues that fundamentally alter subsistence practices. By documenting informants' observations, perceptions and explanations of environmental changes, I demonstrate that local expertise can guide future research and contribute to our understanding of the impacts of climate change to subsistence practices.

1.2 Research context

The work contained in this thesis was made possible through my participation in a project funded by the U.S Fish and Wildlife Service, Office of Subsistence Management (project number 10-152) that seeks to understand current and future impacts of climate change on subsistence fisheries in northwest Alaska. This project was initially proposed by my graduate advisor, Dr. Courtney Carothers. Dr. J. Andres Lopez and Dr. Ellen Lopez are co-investigators of this project (noted as "UAF research team" throughout this thesis). Additionally, we collaborated with David Andersen (Research North) and Caroline Brown and Brittany Retherford (Alaska Department of Fish and Game), who explore climate change implications in the Yukon-Kuskokwim River system (noted as "Yukon-Kuskokwim research team"). I participated as the lead field researcher for the project in northwest Alaska and pursued further independent research and fieldwork in Noatak and Selawik to gain insight into the broader socioeconomic context of the communities and to gain more firsthand knowledge of subsistence fishery practices in each community. This thesis is a product of my experience from May 2010 through September 2011 working with the communities of Noatak and Selawik and the UAF research team.

1.3 Research objectives

This study was guided by three major research objectives:

(1) To document traditional ecological knowledge of climatic changes that affect the harvest, processing, and practices of subsistence fisheries in Noatak and Selawik;

(2) To determine the extent of agreement about observed changes between and among residents of Noatak and Selawik;
(3) To explore the relationship between climatic changes and social, economic, or other cultural shifts that affect subsistence fisheries.

1.4. Traditional ecological knowledge research in the Arctic

Traditional ecological knowledge (TEK) is a term now commonplace in discourse surrounding the management of land and resources across the North American Arctic and Subarctic. Interest in TEK has grown in recent years, partly due to recognition that local and indigenous communities use their knowledge to respond to and manage processes and functions of complex systems to secure a flow of natural resources and ecological services (Berkes et al. 2000). In the past several decades, scientists have increasingly recognized the inadequacy of ecological models that assume static or slowly changing parameters (Dowsley 2009). The integration of different academic disciplines and TEK is increasingly viewed as essential in order to deal with complex environmental problems (Dowsley 2009). There has also been a paradigm shift in ecology towards viewing humans as being embedded in ecosystems and forming a complex social-ecological system (Holling 2001, Berkes 2004). The hope is that by integrating the knowledge of people who have spent their lives out on the land with that of scientific experts, “we will increase our overall understanding of the environment and that this new integrated knowledge will allow improvements in existing processes of environmental impact assessment and resource management” (Nadasdy 1999: 1).

There is no universally accepted definition of TEK and many terms are widely used in the literature to label these types of knowledge systems including traditional knowledge, indigenous knowledge, local knowledge, and local ecological knowledge. For some, “traditional” implies that such knowledge is fixed in the past and not relevant to contemporary conditions, while others argue that “traditional” signifies that the body of knowledge has been gathered over a long period of time (Berkes et al. 2000). While a debate still exists about which label is the most appropriate, TEK has become established

as a commonly accepted term in the scientific literature. TEK is often conceived of as knowledge specific to place, if not also to a particular group of people, and it is differentiated presumably in both form and content from other types of knowledge (Usher 2000).

Many researchers have attempted to dichotomize TEK and western science in terms of their respective ideological underpinnings, substantive content, methods, epistemology, and context (Freeman 1992, Johnson 1992). What is loosely called science (including technology, management, and engineering) in the public policy arena combines a particular set of values with systems of knowing based on empirical observation, rationality, and logic, as opposed to received or felt truths or "lived experience" (Usher 2000). In contrast, TEK refers specifically to all types of knowledge about the environment derived from experience and traditions of a group of people (Usher 2000). However, others have made the point that there are practical and philosophical limits to posing them as pure and isolated systems of knowledge (Agrawal 1995). For this research I use the following definition of TEK developed by Berkes (1999:8): "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment." As well as specific and practical knowledge, TEK embodies specific philosophical perspectives and modes for transmission of information and worldviews (Turner and Clifton 2009).

Researchers have demonstrated the utility of combining TEK and ecological studies to examine Arctic climate change-related issues (Hinzman et al. 2005, Berkes et al. 2007). Traditional knowledge is increasingly seen as both a source of environmental expertise and a means to ensure that research is ethically conducted and socially relevant to communities (Riedlinger 2001). Several studies in the Arctic region have established that indigenous observations can benefit climate change research as a rich source of climate history and baseline data, as a framework for formulating research questions, and as a source of insights into impacts and adaptations (Riedlinger and Berkes 2001, Krupnik

and Jolly 2002, Ford and Furgal 2009). Documentation of local knowledge of climate change in Arctic communities provides a valuable opportunity to develop frameworks and tools for reciprocal communication between many different stakeholders (Fox 2002). Additionally, TEK projects have the potential to result in the creation of rich bodies of text which can potentially serve as lasting documents of cultural traditions and years of accumulated wisdom, for the benefit of both local communities and scholars (Oozeva et al. 2004).

Because TEK embodies such a broad knowledge/practice/belief complex (Berkes 2008), the challenge is to identify and interpret the information of relevance to outside researchers without losing sight of the larger political, spiritual, and epistemological contexts in which that information is developed (Huntington et al. 2006).

1.5 Organization of the thesis

This thesis is organized into seven chapters, including this introduction. Chapter 2 outlines the research and data analysis methods used. Chapter 3 provides background and context for this study through a brief introduction to the communities of Noatak and Selawik. In Chapter 3, I describe the socioeconomic, political and institutional context of the communities of Noatak and Selawik. Here, I also trace the subsistence patterns and practices over time. This historical analysis provides insight into the subsistence activities undertaken today and how they relate to broader patterns of economic, political, social, and other cultural changes. Chapter 4 focuses on knowledge and observations of environmental change in Noatak and Selawik and impacts of environmental change on subsistence fishing activities, based on analysis of interview and observational data. Chapter 5 explores the relationship between socioeconomic forces, changing subsistence practices and the nature of vulnerability to climate change in Noatak and Selawik. Chapter 6 discusses the extent of agreement about observed changes between and among residents of Noatak and Selawik, using cultural consensus analysis methods. Chapter 7 summarizes the main themes that have come out of the research, with concluding comments on the value and relevancy of this research and directions for future research.

Chapter 2
Research methods and data analysis

2.0 Ethnographic approach

Ethnographic methods provide a useful set of tools for studying and seeking to understand TEK. With an emphasis on "being there," ethnographic research provides powerful insights into the holistic and integrated nature of subsistence practices and the factors shaping subsistence economies (Wheeler and Thorton 2005). Ethnographers also have the ability to extend their inquiries beyond the limits of subsistence activities to examine the articulations between subsistence traditions and the broader demographic, political, economic, and other cultural forces at work in Alaska villages today.

The ethnographic research for this project involved both formal and informal interviews and participant observation. I made a total of five trips to the community of Noatak between May, 2010 and June, 2011, totaling over a month of time spent in the community. I made five trips to Selawik between May, 2010 and August, 2011, totaling three weeks spent in the community. On the initial visit to each community, I traveled with Courtney Carothers. We presented an outline of our research ideas to the community leaders and asked for input in refining the project's objectives. Before beginning our fieldwork, we received formal endorsements from Native Village of Noatak and the Native Village of Selawik and approval from the UAF Institutional Review Board (IRB #10-22). I made subsequent extended trips to each community both alone and with an accompanying project team member.

2.1 Semi-structured interviews

We conducted semi-structured ethnographic interviews (Spradley 1979) with expert informants to explore knowledge about climate and ecological changes of concern for subsistence fisheries. Semi-structured interviews enable researchers to utilize an interview protocol, but enable space for the informants to guide the interviews to topics of interest or importance to them. When needed, a local translator from the community was hired to provide Iñupiaq-English translation during interviews. Informants were

identified using snowball sampling, which is a nonprobability sampling method (Bernard 2002). We first asked tribal council members to identify community members who were actively engaged in subsistence fishing activities and had considerable knowledge of environmental conditions and fish life histories and then asked each subsequent person interviewed to list people with knowledge of fishing. In this way, we compiled a purposive list of knowledgeable informants and interviewed those who were available and willing to participate. We conducted formal interviews with 17 informants (11 men and 6 women, aged 40 to 86) in Noatak and 21 informants (9 men and 12 women, aged 40 to 84) in Selawik. The interviews ranged from 30 minutes to 2 hours.

The interviews protocol (see Appendix) followed a seasonal cycle, asking questions about the distribution and abundance of targeted subsistence fish, observations of species-level changes, other ecological changes, and weather and seasonal patterns that may affect traditional processing techniques and schedules. While the focus of this project is climate change-related effects on subsistence fisheries, we noted other challenges and topics of importance to subsistence fishers in the interviews. These broader observations provide an important context with which to evaluate climate change impacts and management implications among a range of current concerns of subsistence-based communities. During the semi-structured interviews we actively avoided asking leading questions about “climate change” as a broad phenomenon, but instead queried people about their observations of changes in environmental and ecological conditions over their lifetime of engaging in subsistence practices. The interview protocol guide used for this project was collaboratively developed with the UAF research team and the Yukon-Kuskokwim research team. We discussed the appropriateness and usefulness of this protocol with local advisors. In addition to taking detailed field notes, we digitally audio-recorded most interviews, with permission of the informants, to produce verbatim transcripts for content analysis.

2.2 Qualitative data analysis

I used an inductive coding process in Atlas.ti, to develop and refine codes and themes during the analysis of interview data and to identify relationships and patterns in the data (Bernard 2002). Coding is a useful process of categorizing interview data into analytic categories with the objective of conceptualizing the data. I did not approach the interview transcripts with a predetermined code list. Rather, I coded themes as they emerged from the interview material. I targeted to develop between 35 and 45 thematic codes. After completing the inductive process, I had created 39 codes. I used the codes to organize the interview data based on subject matter, such as by particular fish species, seasonal conditions, environmental observations, impacts of changing conditions, socioeconomic conditions, responses to change, and sources of information about environmental conditions and to identify patterns within the data.

2.3 Participant observation

In addition to formal interviews, I utilized the signature method of anthropological research, participant observation (Bernard 2002). I spent many hours during my stays in Noatak and Selawik visiting with elders and active fishermen and participating in local activities. I traveled with families to their traditional hunting and fishing camps and spent time boating on the Noatak and Selawik Rivers and connecting tributaries. During the early summer of my first year of fieldwork, I spent a week camping with a Noatak family at Sisualik, the traditional spring fishing and marine mammal hunting grounds for the people of Noatak and others from nearby communities (see map in Chapter 3). I participated in an opportunistic caribou hunt while boating on the Noatak River during the next spring season. During that summer, I stayed with a Selawik family at their fishing camp along the Selawik River for several nights and helped them set their net for whitefish and pike. I also went on several day trips to check nets with three different Selawik families and took a boating trip for berries in August.

These informal interactions were extremely valuable and provided in-depth information about basic fishing practices, community history, relationships among community

members, social changes experienced in Noatak and Selawik over time, and other topics beyond those discussed during formal interviews. A significant amount of my learning took place while cutting fish alongside locals, chatting over coffee, preparing meals with elders, passing otherwise idle time at the local Native stores, and generally participating in community activities. Learning by direct observation and experience provided me a much fuller understanding of the changes experienced in Noatak and Selawik and how the changes are perceived in the context of the Iñupiaq way of life. Additionally, I was able to further explore discussions I had during formal interviews with a broader group of people. By spending significant amounts of time visiting and experiencing daily life in the communities, I was able to build rapport and trust. It was very helpful for me to have direct experience with the phenomena discussed in interviews and these experiences led to more meaningful conversations with informants, who appreciated the fact that I had seen some of the places and participated in some of the activities they mentioned during interviews.

The participatory process of this project involved multiple visits back to the communities to report on results and receive feedback from key informants and make corrections where necessary. I also met with the members of the tribal councils during my trips back to the communities to report on the project's progress and to hear how they thought the project should move forward. I hired local assistants in both communities to provide translation services during formal interviews. In Selawik, a local assistant was very helpful for identifying potential informants and directing me to their houses. I did not rely as strongly on local assistants in Noatak during the interview component of the project since I quickly built close relationships in this community with people who were willing and preferred to assume this role informally. I held public meetings in April 2011 in both communities to share information gained during the research project and to hear input about the project from a broader range of people, including those not identified as expert fishermen. Finally, I spent time at the public school in Noatak, where I presented the research to high school students and inquired about students' experiences fishing and hunting and learning from older generations.

2.4 Cultural consensus analysis

I used cultural consensus analysis (Romney et al. 1986) to assess the degree of agreement among knowledgeable fishermen about climate change observations, subsistence fishery impacts, and recent socioeconomic changes that influence subsistence practices. Cultural consensus analysis is a formal, mathematical model for examining a database consisting of respondents' judgments about a set of propositions concerning a particular domain of knowledge (Weller 2007). In this case, the domain of inquiry is observations of a total environment of change (see Chapter 5), including climate change and socioeconomic shifts, and impacts of these changes on subsistence fishing practices. Cultural consensus analysis is well suited for application in environmental and natural resource anthropology as it can provide an estimation of agreement among and between groups of people, such as between researchers and fishermen, or residents of different communities (Miller et al. 2004). The cultural consensus model is limited to categorical response data. Consensus theory enables the researcher to answer three basic questions (Grant and Miller 2004:6):

1) Is there enough agreement among respondents about propositions to determine that all respondents share a cultural model about the propositions?
2) If respondents do share a single cultural model, what are the response differences between individual respondents or subgroups of respondents?
3) If respondents do share a single cultural model, what are the culturally correct answers to the propositions?

In order to use cultural consensus analysis, three assumptions must be met (Weller 2007). First, informants should provide answers independently from all other informants. This means that informants should not provide answers after consultation with others. Second, the questions should all be on a single topic and level of difficulty should be consistent across items so that if one is knowledgeable about a particular subset of questions, they should be equally knowledgeable about another subset of questions. Third, cultural consensus theory assumes that there is a single set of answers to the questions. This

means that there should be a high level of agreement in responses among a set of informants.

Based upon interview data and participant observation, a list of 44 agree/disagree propositions was developed in order to measure the degree of agreement about observations of a total environment of change and implications for subsistence fishing in Noatak and Selawik (see Appendix). A portion of the propositions (33 out of 44) were shared between Noatak and Selawik; the remaining 11 propositions were specific to each community. The community-specific propositions of the questionnaire were developed in collaboration with the UAF research team and the shared propositions were developed in collaboration with the Yukon-Kuskokwim research team. The shared propositions were developed to measure the degree of agreement about certain observations among a set of informants within and between communities. The community-specific questions were developed to measure the degree of agreement about local observations pertaining to one community. Understanding the level of agreement about observations of change is important to help determine regional trends and local specificities. A mathematical estimation of agreement about observations of change and their impacts can help traverse the gap between studies of TEK and western science because it enables a quantitative measure of agreement about so-called anecdotal accounts. It is, of course, important to keep in mind that these mathematical estimations are just that, estimations, and are no more “real” than anecdotal accounts from which they are derived.

I pilot-tested the survey instrument with local advisors in each community to ensure that the propositions made sense and correctly captured the local observations and views of change that we uncovered during ethnographic research. Three local community experts in Noatak and Selawik were asked to identify respondents likely to have expert knowledge regarding subsistence fishing practices and traditional ecological knowledge of climate change. I limited the sampling frame to those over the age of 40 in order to capture observations of change over the last few decades. I combined the three separate lists of potential respondents provided by the three local experts and selected those

people who had been mentioned by at least two of the three experts. My final sampling frame was 29 individuals for each community. Of the 29 individuals that made up the sampling frame in Noatak, three people refused to participate and another was unavailable when the survey was administered. Of the 29 individuals that made up the sampling frame in Selawik, one person refused to participate and eight others were unavailable when the survey was administered. We implemented the survey in early August, 2011, and many families had already left town for their fall fishing and hunting camps. I returned to Selawik in October, 2011 and implemented surveys with four of the eight remaining individuals in our sampling frame.

In individual, face-to-face interviews, respondents (n=25 in Noatak and n=24 in Selawik) were asked to either “agree” or “disagree” to the 44 statements related to observations of environmental changes and other challenges to subsistence practices based on their own experiences, which were verbally stated. We emphasized that there were no “right” or “wrong” answers and that observations based on individual experience were being sought. Respondents were encouraged to provide additional information pertinent to each statement, or to ask for clarification. We encouraged each respondent to answer every question. Some informants did not offer answers for all questions, so answers to a small number of propositions were left blank (2.4 % in Noatak; 1.0 % in Selawik). Supplemental information was recorded in field notes. All interviews were conducted primarily in English. A local fluent Iñupiaq speaker served as a field assistant and was present at each interview in Noatak. This person provided interpretation when necessary. Unfortunately, due to unforeseen circumstances, a fluent Iñupiaq speaker was not available at every survey in Selawik, but we were assured by a local assistant that those included in the sampling frame were fluent in English.

The data collected during these interviews was reduced to a response matrix with respondent rows and proposition columns. The missing data in the matrix were filled with randomly generated 1s and 0s (Weller 2007). I used cultural consensus tools in UCINET (Borgatti et al. 2002) to assess the degree of agreement among survey respondents. The

ratio of the first and second eigenvalues indicates whether there is a single response pattern present in the data. If there is a unified pattern of answers, despite some variation among individuals' responses, the ratio of the first and second eigenvalues will be large. Generally, consensus eigenvalue ratios above 3.00 demonstrate consensus among respondents (Weller 2007). In addition to determining if there is a single cultural domain among respondents, the model identifies the level of individual agreement with the culturally correct answers to each proposition. Weller (2007) defines individual knowledge scores as the cultural expertise of each individual with regard to a set of questions. These scores are estimated from the pair-wise similarity in responses between all pairs of informants. Answers to questions are estimated by weighting the responses of individuals by the competence scores and then combining the responses. The likelihood of each possible answer to each question is considered and calculated as the sum of the likelihood that each person gave a correct answer (Weller 2007).

With dichotomous (true/false, agree/disagree) responses, which we used in this project, similarity between respondents can be calculated using two different methods, the match coefficient (Romney et al. 1986) or the covariance method (Batchelder and Romney 1988). The covariance method is not sensitive to the presence of response bias (the tendency for respondents to preferentially answer true (or false) when they do not know an answer) when estimating competence. Meanwhile, the match coefficient method assumes that if informants are unsure of an answer, they will not respond preferentially with a particular answer. When a bias is present, the match method will present an inflated agreement and cause competence to appear higher than it really is (Weller 2007). The covariance method is, however, sensitive to the proportion of true and false answers in a set of answers. Weller (2007) recommends that researchers should attempt to balance positive and negative items to somewhere between 70% and 30%. When response bias is present in the data, both the covariance and match methods will have inaccuracies in the estimated answers. It is generally accepted to use both methods when analyzing dichotomous data and comparing the competency estimates (Weller 2007).

I analyzed three different matrices, using both the covariance and matches methods: 1) Noatak respondents and their responses to the total 44 propositions (33 shared and 11 specific to Noatak); 2) Selawik respondents and their responses to the total 44 propositions (33 shared and 11 specific to Selawik); and 3) both Noatak and Selawik respondents and their responses to the 33 shared propositions.

2.5 Conclusion

Documenting local observations and perceptions of environmental changes is an inherently complex and difficult endeavor. For this project, we chose to use a combination of in-depth ethnographic methods and cultural consensus analysis in order to develop a rich and systematic evaluation of changing environmental conditions and locally situated perceptions of those changes. The key strength of this research is that we sought to describe and understand the socioeconomic contexts of Noatak and Selawik, which allows us to more meaningfully understand and describe impacts of changing environmental conditions on subsistence fishing practices.

Chapter 3

Noatak and Selawik: patterns of change and continuity

3.0 Introduction

In this chapter I provide background and historical information about northwest Alaska and the communities of Noatak and Selawik. The brief history provided here is intended to give the thesis a setting and also to begin to make apparent that Noatak and Selawik are experiencing numerous changes, only some of which are related to climate change. After describing the historical context of fishing in these two communities, I summarize typical contemporary subsistence harvest patterns.

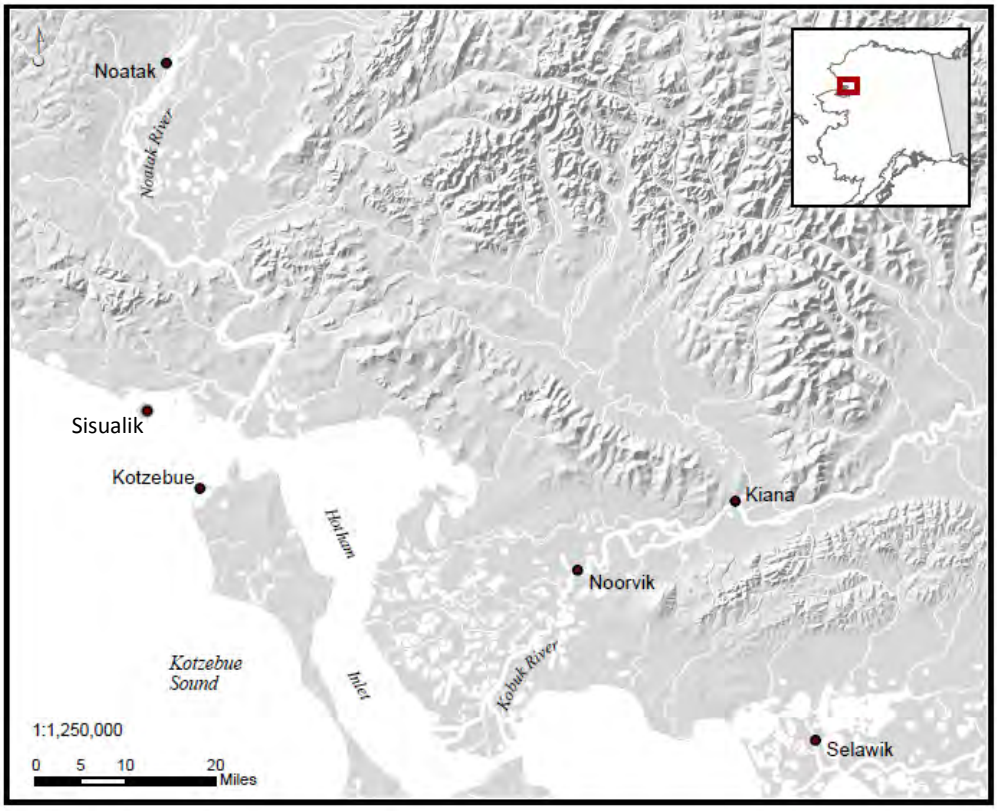

Figure 3.1 Regional map showing Noatak, Selawik, and neighboring communities created by Nicole Braem

Northwest Alaska encompasses roughly 100,000 km^2 and includes both state and federal waters used for subsistence fishing. Within northwest Alaska are the traditional territories of 11 Iñupiaq societies, which coalesced into 11 small, predominately Iñupiaq communities during the early 20th century (Burch 1998). Alaska Natives, including the Iñupiat of northwest Alaska, are among the few indigenous peoples of the world who continue to inhabit their traditional territories, who comprise the majority of the population in their territories, and who continue to rely substantially on hunting, fishing, and gathering for cultural and physical well-being (Magdanz et al. 2010).

The contemporary community of Noatak is located about 120 km upstream from the mouth of the Noatak River and is about 90 km north of Kotzebue, the regional hub of the Northwest Arctic Borough (Figure 3.2). The population of Noatak is about 514 (U.S. Census Bureau 2010).

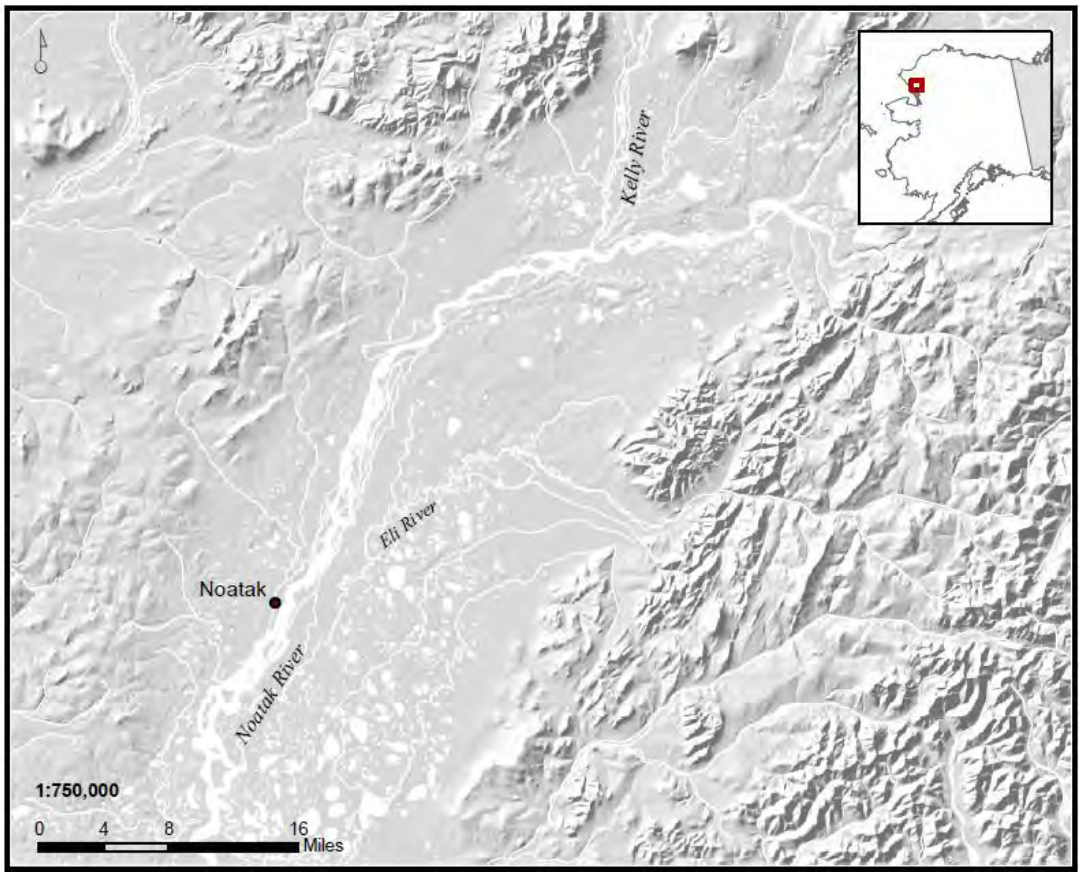

Figure 3.2 Map of Noatak and surrounding waterways created by Nicole Braem

The contemporary community of Selawik is located at the mouth of the Selawik River, about 112 km southeast of Kotzebue (Figure 3.3). Selawik has a population of 829 people, making it the second largest community in the region. Over 90% of residents of both communities identify as Iñupiaq Eskimo (U.S. Census Bureau 2010).

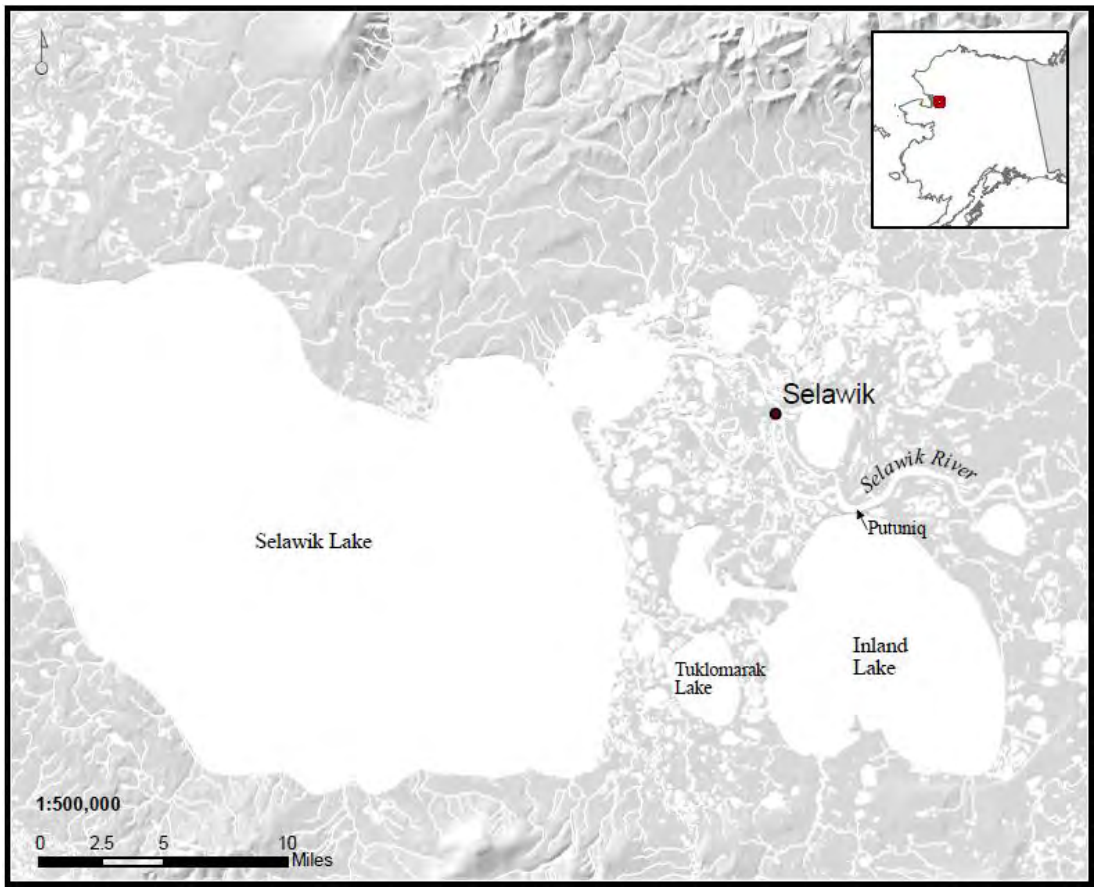

Figure 3.3 Map of Selawik and surrounding waterways created by Nicole Braem

3.1 Early peoples of Noatak and Selawik

The first Westerners to visit Iñupiaq settlements north of the Bering Strait arrived early in the 19th century. They found a country inhabited by widely scattered distinct "nations", made up of several families living in loosely bound, mobile communities. The lower Noatak River, where the modern community of Noatak is now located, was the home of the Napaaqtugmiut (Burch 1998). The neighboring nation, the Nuataagmiut, inhabited the upper Noatak region. Descendents of both ancient societies live in the contemporary community of Noatak (Magdanz et al. 2010). The Siilvikmiut inhabited the Selawik

River, the Selawik Lake area, and connecting tributaries. For these nations, seasonal mobility was the norm as they sought seasonally available resources (Foote and Williamson 1966, Chance 1990). Fish were a vitally important source of food for both people and dogs in all parts of northwest Alaska during the early 19th century due to their reliable presence. After traveling extensively in this region in the 1800s, the explorer Frederick William Beechey (1796-1856) felt justified in characterizing the Iñupiat as being "a nation of fishermen" (Burch 2006:140). As is typical of hunting-and-gathering cultures, the people of the Noatak and Selawik Rivers followed a seasonal pattern that closely reflected the availability of food sources.

The Napaaqtugmuit also followed a seasonal pattern that closely reflected the availability of food sources. Good fishing spots were the primary consideration in the location fall and winter settlements along the lower Noatak River and its tributaries. Large quantities of chum salmon, Dolly Varden char, and grayling were harvested along sloughs and channels connecting the lower Eli and Noatak Rivers. During spring, the Napaaqtugmiut moved to the sea, living in snow houses built on the sea ice. Here, they hunted large bearded seals and remained until the ice began to rot, in mid- to late May. At that point, they moved their camps ashore and continued to hunt on the ice until midsummer (Burch 2006).

In contrast to the Napaaqtugmiut, the Nuataagmiut of the upper Noatak River primarily lived a considerable distance inland. At the time of freshwater freeze-up, usually in late September or early October, the Nuataagmiut settled at favorable fishing and caribou hunting locations along the Noatak River and some of its tributaries and on the shores of some lakes (Burch 1998). Once fish and caribou become less available in winter months, the Nuataagmiut divided into small groups and traveled about in search of food. They took advantage of the northward migration of caribou in March and April, which generally ended a period of late-winter hardship (Burch 2006). As the caribou moved farther north, the people moved back to their fall and winter settlements to await breakup.

After breakup, the majority of the Nuataagmiut traveled all the way down to the delta of the Noatak to hunt beluga (Burch 2006).

During the 19th and early 20th centuries, Siilavingmiit lived dispersed in small family groups along the Selawik River system. They were grouped into two major ethnic divisions: the Qangianatmiit, the upriver people, and the Qitagmiit, the downriver people (Anderson and Anderson 1977). These two groups were distinct bands, to which the people in each were linked by kinship and by a relatively similar way of life. The distinction was not as clear as that between the Nuataagmiut and Napaaqtugmiut of the Noatak River, who even spoke different dialects. Within the Selawik River system, the seasonal rounds can be classed into two general patterns, which correspond to the ethnic groups. Basically, the upriver area was distinguished by a greater number and variety of terrestrial fur-bearing animals and conditions that allowed a longer winter ice fishing season, whereas the lower area had better conditions for spring ice fishing, carried out at Selawik Lake, and a greater accessibility to the coast and its late spring and summer resources (Anderson and Anderson 1977).

The same basic procedures for harvesting, processing, and storing of fish were known by the inhabitants of every region of northwest Alaska, but they were applied in ways that were most suitable to local conditions. As described by Burch (2006) weirs, seines, and gill nets were the most commonly used techniques to catch fish. Several other techniques were employed, including hook and line, spearing, and using a set line with many baited hooks attached to it (Burch 2006).

3.2 Sustained contact and subsequent change

Prior to 1850, western influence in northwest Alaska was minimal. Prior to 1848, there is no evidence to suggest that European diseases had reached northwest Alaska, that westerners had tried to settle there, or that missionaries or other outsiders had attempted to transform Iñupiaq beliefs or behavior (Burch 2006). After 1848, several Euro-American developments initiated western-indigenous contacts at an unprecedented scale. First, the arrival of American whaling ships in north Alaskan waters precipitated drastic

change by decreasing the availability of bowhead whales and walrus for Alaska Native hunters while also introducing a wide array of economic changes (Chance 1990). Caribou was also overhunted for food supplies by whalers, resulting in considerable famine, starvation, and suffering for the peoples of the region, and led to an increase in warfare as desperate groups competed for resources. Secondly, many British Navy ships associated with the massive seven-year search for the missing expedition led by Sir John Franklin visited the region during both the summer and winter and several ships overwintered in the area. These events led to major changes in the Iñupiaq way of life (Burch 2006).

By the 1880s, the indigenous nations of northwest Alaska had incorporated numerous western goods into their daily lives, which they obtained through trade with whalers and the few other westerners who occasionally entered the region. However, trade was not a new enterprise and residents of northwest Alaska had traded furs, reindeer, and other goods with Russians and other indigenous Alaskan groups long before contact with Europeans in the 18th century (Magdanz et al. 2007). The arrival of Yankee whalers meant the availability of new, highly valued trade items and opportunities for cash income. For several years in the late 1890s, it is estimated that as many as half of Alaska's indigenous people north of the Bering Strait were seasonally involved in the whaling industry (Drucker 1996). Access to western provisions drew Alaska Natives from as far as the upper parts of the Noatak and Kobuk Valleys (Drucker 1996). Mining soon reached northwest Alaska; the Klondike gold rush spilled over into the region under the impetus of gold reports from the Kobuk River (Hall 1975). Some prospectors operated along the Noatak River.

Conditions quickly deteriorated for northwest Alaska Iñupiat at the end of the 1800s; whaling decimated an important food resource, the introduction of liquor as a trade item disrupted community life, and the spread of new diseases such as measles, smallpox, and influenza took a devastating toll (Chance 1990). This "period of destruction," aptly labeled by Burch (2006), lasted for about fifty years, during which time epidemics swept across the land and reduced the population of Iñupiat by as much as half (Sprott 1997).

Soon, the precarious condition of the Iñupiat came to the attention of the United States government, which began taking concerted action (Chance 1990).

To counter these developments, the U.S. Bureau of Education recruited missionaries to establish schools and provide healthcare in the 1890s (Chance 1990). In the Kotzebue Sound region, the Friends (Quaker) Church became the dominant missionary influence. The Friends Church erected federally-supported schools along the Noatak and Selawik Rivers in 1907 and 1908 (Drucker 1996). As a result, the previously nomadic and dispersed Iñupiat built permanent homes near the schools, creating villages that still survive (Drucker 1996). Along the Noatak River, the Napaaqtugmiut came first to the school, which was located in the center of their traditional hunting territory, but by 1910 almost all of the Nuataagmiut had also settled in the village (Hall 1975). The receptivity among the Iñupiat to the missionaries and schools at this time is thought to be related to the devastating effect of the epidemics on their traditional culture. Before the 1900s there was a degree of territoriality between different nations and it would have been unthinkable for two nations to move to the same place. That the Nuataagmiut were willing to move away from their roots and into Napaaqtugmiut hunting territory illustrates the degree to social upheaval and even perhaps the deference given to missionaries during this period (Sprott 1997). Faced with the possibility of western education and the material wealth of American society, many parents were swayed to send their children to schools (Drucker 1996). The development of the reindeer herding industry in the 1920s and 1930s, in addition to establishment of schools and churches, further accelerated the move to modern settlements and wage employment, taking people away from subsistence activities (Morseth 1997). School, jobs, and the church restructured daily life and movements for the people of Noatak and Selawik. Seasonal periods of movement became diminished as people began to spend more time in the permanent villages. The increasing availability of commercial goods and foods decreased reliance on the environment to supply nutritional and material needs.

Continuing these cycles of change, within the past fifty years, pronounced social, economic, political, and other cultural changes have radically shaped contemporary ways of life in northwest Alaskan villages. In the 1960s, snowmachines replaced sled dog travel, dramatically decreasing local needs for fish and increasing reliance on fossil fuels (Hall 1971). In the 1970s, the Alaska Native Claims Settlement Act (ANCSA) established indigenous corporations, forever changing tribal resource rights and governance across the state (Case and Voluck 2002). As part of this settlement, regional and village corporations were established and granted legal title to 44 million acres of land across the state. The Northwest Alaska Native Association (NANA) Regional Corporation was established as the for-profit Alaska Native corporation for northwest Alaska to manage tribal lands and resources. Among other things, ANCSA stated that everyone at least one-quarter Alaska Native blood born before December 18, 1971 could choose to be enrolled as a shareholder in one of 13 regional corporations (Anders 1989).

Since the land claims of the 1970s, the conditions of the communities continue to change rapidly, with increasing amounts of infrastructure developed each year. For example, in 1990, 100% of the households in Noatak relied on a “honey bucket” system for sewage disposal and lacked complete plumbing. By 2010, nearly 90% of the homes were served by a centralized water system (U.S. Census 2010). Television now has a ubiquitous presence in rural Alaska villages, causing an inundation of western cultural influences and sedentary pastimes (Seyfrit et al. 1998). Consistent with global trends, an increasingly wider array of technologies is available to residents of rural Alaska such as cell phones, computers, electric appliances, oil-burning stoves, and many others. The cumulative effects of these developments have resulted in significant changes in life-ways of the younger generations across the globe. Several scholars discuss the cultural impacts of such change in Arctic indigenous communities, noting particularly that younger generations now struggle between maintaining their ties to local subsistence resources and “making a living” in the contemporary western sense (Chance 1990, Condon et al. 1995, Sprott 1997).

Despite these and other forces of change, the Iñupiaq peoples of northwest Alaska continue to embrace a life-way oriented towards harvesting local resources. Researchers have advanced the concept of a "mixed" economy to describe the continued coexistence of a pattern of production based on hunting, fishing, and gathering and production based on markets for goods and services (Wolfe and Ellanna 1983, Wolfe and Walker 1987, Buklis 1999). Noatak and Selawik can both be characterized as mixed economies, where locally harvested foods remain a preferred component of diet and people devote much of their resources towards pursuing local foods. Contemporary subsistence users now rely on many modern technologies, such as boat motors, snowmachines, electronic navigation equipment, and commercially manufactured fishing nets. Increasing material needs, high equipment costs, and rising prices for gasoline make it necessary for many households to have at least one wage-earner to support the costs of subsistence activities. Today, the primary employers in both communities are the regional school district, local tribal and city councils, the non-profit Maniilaq Association, NANA Regional Corporation, mining companies operating at the nearby Red Dog zinc and lead mine, and community stores (Magdanz et al. 2010, CIS 2011). Despite measures such as ANCSA, economic opportunities remain limited in northwest Alaska. As noted in interviews and observation for this project, a dearth of job opportunities is a concern for residents of Noatak and Selawik and a high degree of dependence on welfare and subsidies is present in both communities.

These social, economic and political changes have created a complex terrain of life in northwest Alaska. Noted above, the Iñupiat of northwest Alaska, are among the few indigenous peoples of the world who continue to inhabit their traditional territories, who comprise the majority of the population in their territories, and who continue to rely substantially on hunting, fishing, and gathering for cultural and physical well-being (Magdanz et al. 2010). Yet their ways of life, consistently shifting and adapting to past and current challenges, are threatened by numerous forces, including increasing encroachment of land and resource management bureaucracies, a for-profit ideology that necessitates economic development like Red Dog mine at the expense of subsistence

activities, ever-growing ties to a wage economy that occurs largely outside of the region, increasing pressures to adopt western cultural norms and ideas through media and education, and mounting dependence on government support to maintain community functioning. I continue this discussion of contemporary cultural shifts and vulnerabilities in Chapter 4.

3.3 Contemporary subsistence patterns

Residents of Noatak and Selawik harvest various local resources according to their seasonal variability, following a seasonal cycle that in many ways is similar to that of their ancestors. Harvesters generally time their pursuits around the arrival of resources to the area, perceived quality, and the ability to access these resources via boat, snowmachine or four-wheeler (Braund and Associates 2005). A major difference between previous and contemporary subsistence practices is formal work schedule constraints. People often have to take time off work to travel to camps, or their time at camp is limited to only a few days on account their work.

Fish are the most reliable subsistence resource in Noatak and Selawik. Survey data collected in recent years reveal the strong dependence on local fish resources. In 2007, Noatak residents reported harvesting a total of 78,454 pounds of fish, with an estimated per capita harvest of 149 edible pounds (Magdanz et al. 2010). Fish made up 41% of the total subsistence harvest in Noatak in 2007. In 2006, Selawik residents reported harvesting 115,500 pounds of fish, with an estimated per capita harvest of 150 edible pounds (CIS 2011). Similar to Noatak, fish made up 43% of the total subsistence harvest in Selawik in 2006. Fishing and hunting practices in both communities are extremely flexible and dynamic, as people respond to ever-changing conditions and resource needs. Therefore, the following descriptions only provide a general overview of the seasonal round of subsistence activities.

In Noatak, chum salmon[1], Dolly Varden (locally called trout) and several species of whitefish make up the majority of the subsistence fishery catch. Following ice break-up in the spring, around the beginning of June, many residents of Noatak travel to coastal camps by boat to harvest bearded seal, beluga, and several species of whitefish. While there, residents catch whitefish by setting gillnets along the shore near their camps. Closer to the community of Noatak, residents harvest Dolly Varden by rod and reel in the spring and summer months along the Noatak River and its tributaries. Along the Noatak River, runs of chum salmon are strong and many households harvest, dry, and store salmon during the mid and late summer run (Fall et al. 2009). Salmon are generally caught with gillnets. Once the weather cools, people tend to direct their attention to hunting caribou. During the fall months, Noatak residents harvest Dolly Varden and whitefish with rod and reel and seine nets. The fish are left outside in gunny sacks to age and then freeze. Once preserved this way, the fish are eaten later in the winter as frozen *quaq* (Jones 2006). Once the river freezes, ice fishing may begin and continues through the winter. Most ice fishing occurs during the late winter and early spring, between February and April (Braund and Associates 2005).

In Selawik, local harvesters devote much of their effort to catching several species of whitefish, sheefish, and northern pike. There is no salmon run in the Selawik River. In Selawik, major fishing activities occur in both spring and fall during the migration of whitefish into and out of the complex lake systems surrounding the community (Georgette and Shiedt 2005). Spring fishing in Selawik begins once the weather warms and the days lengthen. People use rod and reel to fish for sheefish in the big lakes surrounding Selawik. After ice break-up occurs and water levels drop, families travel to their fish camps to set gillnets for humpback and broad whitefish and pike. Spring is typically drier than fall in the Kotzebue Sound region, and for this reason residents of Selawik prefer to do the bulk of their fishing during this time when rain is less likely to spoil drying fish (Georgette and Shiedt 2005). The spring harvest period lasts for about

[1] Here in the text I refer to fish by common English names for simplicity. Refer to Table 3.1 for scientific and Iñupiaq names.

three weeks beginning after break-up, usually in late May, and ends when the water becomes too warm; once the water warms, fish will spoil if left in the net for even a short period of time. Families pull their nets from the water, return to town, and wait for the water to cool again in the fall. During fall, the same fish are targeted in the same manner as spring. Selawik residents also participate in under-ice fishing for migrating whitefish with gillnets early in winter before the ice becomes prohibitively thick. During fall, Selawik residents hunt for moose and caribou. Arctic grayling, burbot, and several other species of fish are targeted to a lesser degree in both communities.

Table 3.1. English, scientific, and Iñupiaq names for commonly caught fish species (adopted from Georgette and Shiedt 2005, Jones 2006, and ethnographic research)

Common English name	Latin name	Selawik Iñupiaq name(s)[2]	Noatak Iñupiaq name(s)[3]
Chum salmon	*Oncorhynchus keta*	qalugruaq	aqalugruaq
Dolly Varden	*Salvelinus malma*	qalukpik	aqalukpiq
Broad whitefish	*Coregonus nasus*	siyyuilaq qausriluk qalupiaq	sigguilaq qausriluk
Humpback whitefish	*Coregonus pidschian*	qaalgiq ikkuiyiq	qaalgiq iqalupiaq iqalutchiaq
Sheefish	*Stendous leucichthys*	sii	sii
Pike	*Esox lucius*	siilik	sillik
Burbot	*Lota lota*	tiktaaliq	tiktaaliq
Arctic grayling	*Thymallus arcticus*	suluqpaugaq	suluqpaugaq

[2] In Selawik, residents recognize more than one species of broad and humpback whitefish whereas western science recognizes one.
[3] In Noatak, residents use different names of the whitefish species synonymously.

Chapter 4
Observations of climate change and impacts on subsistence fishing

4.0 Introduction

This chapter explores observations of shifting environmental conditions related to climate change and impacts of these changes on subsistence fishing practices in Noatak and Selawik. Largely descriptive, the following analysis presents residents' observations of the environmental changes that they are currently experiencing and perceptions of the importance of these changes on subsistence activities. In order to present informants' observations as accurately as possible, much of this chapter makes use of examples and direct quotes from interviews, allowing local experts to speak for themselves. It is not possible to record the totality of what we learned within this thesis; rather, I focus the discussion on the phenomena that are most noticeable and salient for the communities, which are summarized in Table 4.1. I organize this discussion into three broad themes, including 1) changing weather and physical conditions, 2) ecological changes and fish species, especially as related to fish distribution, abundance, and accessibility, 3) impacts of changes on subsistence fishing and processing. These linked themes are reflective of the way in which informants organized their thoughts during conversations and interviews.

The communities of Noatak and Selawik possess an abundant knowledge base about current and historical weather conditions, ecological conditions related to important subsistence fish species, harvesting and processing of fish, as well as the linkages and relationships between these phenomena. Overall, we found consistent agreement about a range of perceivable environmental changes affecting subsistence fisheries in this region (explored in detail in Chapter 6). However, consistent with literature discussing the varied distribution of knowledge (Ayantunde et al. 2008, Dovie et al. 2008), informants' knowledge of past and current conditions varies based on a multitude of factors, including informants' life experiences, timing of subsistence activities, locations of commonly used fishing spots, and degree of knowledge sharing that occurs between a

particular individual and other active fishers in the community. Hence, interviews and observation reveals that informants' knowledge about, and views of, environmental change varies. Informants from the same community do not always report similar environmental changes. Further, as Noatak and Selawik are located in different ecological zones, residents of each community follow slightly different seasonal cycles of subsistence activities. Therefore, we expect that informants from the two communities have slightly dissimilar knowledge about environmental conditions and may perceive different phenomena associated with climatic shifts. In the following section I note where discrepancies about the observations of particular phenomena arose between and within each community and continue this discussion using cultural consensus survey data in the next chapter.

Table 4.1 Summary of observations of climate change and impacts on subsistence fishing

Physical environmental change	• Less snow in winter • Shallower river water • Fewer high river water events • Melting permafrost increases erosion and drying • Later fall freeze-up; new freeze-thaw cycle • Earlier spring break-up; ice now melts in place
Changes in fish distribution, abundance, and quality	• Less predictable fish movement timing • Increased presence of beaver affect fish • Selawik: less whitefish, more pike • Noatak: less Dolly Varden
Travel and access to resources	• Unpredictable ice conditions hinders winter travel • Lower river and lake levels make boating difficult • Less predictable fish movement timing challenges harvesting practices • Warmer springs cause unfavorable fishing conditions
Unpredictable weather affects traditional fish processing	• Warmer, wetter weather causes spoilage of fish dried in traditional ways • New freeze/thaw cycles during fall challenges traditional fermentation and preservation methods

4.1 Changes related to weather and physical conditions

Changes related to weather and physical conditions are one of the most noticeable areas of change that residents of Noatak and Selawik have experienced in recent years. Weather conditions play an important role in subsistence practices and are constantly monitored, both from living room windows and from direct experience out on the land and water. In this section, I describe the changes related to weather and physical changes within the following subsections: 1) timing of break-up and freeze-up; 2) changing weather conditions; 3) melting permafrost; and 4) water levels.

4.1.1 Timing of break-up and freeze-up

Changes in the timing and rate of freeze-up and break-up are viewed as indicators of changes in the overall weather of the region. These two events mark the end of one season and the activities associated with that season, and a transition to another season and associated activities. In both communities, spring break-up is typically preceded by a period of deteriorating ice conditions, followed by an actual ice break-up event that generally occurs over the course of many hours or a full day, and is proceeded by high water levels in local rivers and streams, which is not conducive for fishing. Freeze-up period is associated with a period of limited travel as the formation of heavy slush ice and shore ice curtails boat travel, and people await the formation of ice solid enough to allow safe crossing of local water bodies by overland transport methods. Overall, informants noted that break-up is happening early and more quickly and freeze-up is happening later and more slowly (often characterized by an abnormal freeze-thaw cycle), with a subsequent longer ice-free season.

Informants consistently discussed changes in the timing and nature of spring break-up. Many informants stated that break-up happens earlier now in both communities compared to about 20-30 years ago. Several informants noted a shift from break-up in early June in earlier decades to a break-up typically occurring now in mid to late May; although other informants note that the timing of break-up has remained about the same. A third comment heard from several informants regarding the timing of spring break-up

was that it varies from year to year so an overall directional pattern is not detectable. The perception that environmental variability is normal and expected in this region is a theme that surfaced frequently during interviews and conversations with local experts in Noatak and Selawik and complicated the documentation of observations of environmental shifts related to climate change. However, over the course of multiple interviews and follow-up community meetings, informants generally indicated to us the specific changes they considered to be unprecedented and the other changes that were considered to be normal variations, which are discussed below.

Consistent with many informants' perceptions of earlier break-up, records show that break-up of the ice on the Noatak River is occurring roughly four days earlier than when records began in 1918 (NOAA River Forecast Center 2011). In Noatak informants consistently noted that there are no longer any "big break-ups; the ice just melts out." In the past, residents of Noatak would gather to listen and watch the large chunks of ice move out down the river, but over the past decade these big break-up events have not been happening. Elders note that the big ice break-up events on the Noatak River are related to the amount of snowfall that accumulates during the previous winter. There is now less precipitation as snow in the winter, according to many informants. High water events associated with spring break-up and melt water flowing from the mountains are less severe than in the past. Consequently, the ice covering the river is not displaced, but instead melts in place. Large ice jams used to hold the water back and cause flooding events, but these are perceived to occur less frequently than in the past. In discussing the changing nature of break-up in the community, some informants noted that the main channel of the Noatak River no longer passes right in front of the village. A high water event over a decade ago caused this channel to shift farther away from the community. When asked about this channel shift complicating observations of break-up characteristics, however, informants still noted a different nature of break-up of the Noatak River in recent years compared to past decades.

> Our weather change from when I was a young kid. When we have break-up here at Noatak, we used to have real high water. Not the way we doing right now. That's low water down there. At that time when we had that high water, oh, I'd say about six, seven miles from here, we could see the ice. Breakup with that high water come down, lot of noise. No more. Everything changed. Don't do that no more. You can see our river right now. It's low water. And no ice -- ice breakup like when I was a kid. -Noatak informant, interviewed June 18, 2010

In Selawik, several informants noted that spring break-up is happening earlier and faster; the ice on the river becomes "rotten" and unsafe for travel at a much faster rate. Some related this to the fact that river ice is now thinner during the winter months and thus melts faster in the spring. Break-up in Selawik is not accompanied by flooding events that are more typical of the Noatak River due to the man-made development of a new channel, circa the 1950s, connecting the Selawik River to a large lake (Inland Lake). The channel is called Putuniq and reportedly eases flooding in the community because it allows a portion of the river to drain into Inland Lake.

> Stuff is starting to change. [Break-up] comes early, comes really suddenly... It used to be a long spring, just melting slowly. Water come up slowly in the edge. Now it won't even do that. Everything just melt. The -- the ice rot real quick and crumble and ready to go. -Selawik informant, interviewed July 19, 2010

Informants in both communities mentioned that the timing of freeze-up is less predictable. Freeze-up tends to occur later now than in the past. Some informants noted that freeze-up may not occur fully until late October, whereas before freeze-up tended to occur in late September or early in October. Several elders noted that freeze-up timing has always varied depending on the weather. Some years fall comes early, and sometimes late. A freeze-thaw cycle now characterizes the freeze-up period, a new phenomenon according to many informants. Many informants cited recent experiences of storing their boats once freeze-up occurred and then later resuming boating once the water reopened in the fall. Others commented that fall temperatures are warmer than the past, causing the

ice to remain thin for a longer period of time. Residents now wait longer before they try to cross water bodies, especially the main river channels.

> Last few years it's been unpredictable in the falltime... when we're going to have freeze-up. We think it's finally here and then it melts again. -Selawik informant, interviewed July 22, 2010

4.1.2 Changing weather conditions

When discussing changing weather conditions, several informants specifically noted that the "sun has gotten hotter." The observation that snow no longer remains on mountains throughout the summer is used as an indicator in both communities of warmer summer temperatures. Informants link warmer temperatures to warmer water conditions. Informants in Noatak cited an example in 2005 of a warm water event that caused chum salmon to have soft, mushy flesh. Warmer weather has been noted in the fall time and freezing temperatures are occurring later, as discussed above. Many informants also noted changes in precipitation, particularly increased variability. Informants in both communities noted that in recent years, the summer months of June and July have been drier.

Informants from both communities consistently commented winters are now milder compared to the past and long stretches of severe cold are much shorter in duration. One informant characterized recent winters as "skinny" - warm weather, fewer storms, and low snowfall. In Selawik, informants often referred to the height of snow banks when discussing snowfall. Several informants noted that based on their observations of the height of snow banks that accumulate in the winter months, Selawik has received less snowfall during recent winters. However, others note that snow bank height is more related to wind direction than snowfall amount and is therefore a poor indicator for changes in snowfall.

4.1.3 Melting permafrost

The Noatak and Selawik basins are underlain by permafrost that is generally continuous (Hamilton 2001). The Kotzebue Sound area is recognized as one of the most ice-rich and thaw-sensitive areas in Alaska, and permafrost temperature monitoring has shown a significant warming trend during the last few decades (Yoshikawa 2010). While it is expected that the active layer, or top layer, of permafrost melts each year and some slumping of the land is normal, thaw slumping on river and lake edges and hillsides is seen as more extensive now. The rate of erosion from one summer to the next is noticeably faster in recent years. Informants in both Noatak and Selawik perceived a connection between warmer air temperatures and melting permafrost. Melting permafrost is described in several ways. One informant noted that "the land is sinking." Another mentioned, "Everything dry up. Even the riverbank slide down into the ground. The permafrost melt and slide out down to the river's edge."

Several informants in Selawik described the disappearance of whole islands that have "sunk" into the water. Selawik informants commonly mentioned that as a result of bank erosion, the Selawik River is getting wider. Many recalled that as children they threw coins to one another across the main channel, which is now impossible because the banks are now much farther apart. Both the Noatak and Selawik Rivers display dramatic evidence of large thaw slumps. The nine-acre wide and eighty-foot high "Selawik Slump," located 175 miles upstream from the village of Selawik, is likely the largest in North America (Rozell 2009). Sediment from the expanding slump may affect sheefish spawning areas.

4.1.4 Water levels

Residents of both Noatak and Selawik constantly monitor water levels of rivers and lakes because they affect both boating and fishing conditions. High water levels are generally not conducive for fishing, where excessive drifting debris can snag nets, swift water makes it difficult to anchor nets, and high sediment loads cloud the water making it difficult to see fish and also preventing fish from biting hooks. High water events also

provide fish with opportunities to enter or exit lakes, streams, and sloughs that are less accessible during periods of low water and also serve to recharge inland ponds and sloughs with fresh water. When water levels drop in the fall, fish often congregate in deep pools along the river channels, making them easier to harvest by seine. However, low water levels can serve as a barrier to accessing certain spots by boat. Because water levels play such an important role in subsistence activities, new patterns of water level fluctuations are perceived to be particularly significant phenomena linked to climate change. In both communities, informants consistently noted lower water levels during the open water season.

> We used to have high water, I know, [but] lately our water don't want to get high. –Noatak informant, interviewed June 18, 2010.

> I think from being too hot last few years, there's less water. We used to be able to boat in and out and [now] we hit ground, or the motor did, and we had to pull the motors up, and use poles to go back to the main river. –Selawik informant, interviewed July 22, 2010.

> It's real shallow. Even in the lakes. There's islands popping out even in the middle. –Selawik informant, interviewed July 19, 2010

A multitude of factors likely contributes to the new phenomena of lower water levels. Some informants linked lower water levels to increasing numbers of beaver dams along the waterways, as discussed below. Others noted that lower water levels in the summer are related to hotter weather and decreasing precipitation. In Selawik, lower water levels were often discussed in relation to permafrost melting and bank erosion. Some informants noted that the water from lakes and streams is flowing out from where it had been previously contained by underlying permafrost. People are concerned that lower water levels hinder fish movement and cause water temperatures to rise, in addition to impeding boat access, which is discussed below.

4.2 Ecological changes and fish species

This section explores ecological changes and observations of change related to fish species that make up a significant portion of subsistence catch. Changes associated with fish species were discussed in terms of fish abundance, fish movement, and the impacts of increasing beaver on fish species. I organize the following discussion around these three themes.

4.2.1 Fish abundance

Informants in both communities reported general declines in the abundance of some species that are important subsistence resources. However, many informants perceived the abundance of fish to naturally fluctuate year-to-year and often hesitated to make broad statements about less or more fish. Many informants noted that they have enough fish to meet their needs.

In Noatak, informants explained that it is becoming harder to catch Dolly Varden than in the past. One elder commented that there are fewer Dolly Varden in the river but they are larger in body size. Several other informants reported that they are noticing a general decline in Dolly Varden and that fishing spots that were reliable in the past no longer produce as many Dolly Varden. This finding is consistent with biological research that indicates the spawner abundance in the Noatak River has declined and a possible change in population structure has occurred (Scanlon 2009). Many informants attributed the decline in Dolly Varden to increasing beaver activity, as discussed below. Another informant described how lower river levels and warmer water temperatures in the summer create unfavorable spawning conditions for Dolly Varden. This informant also related permafrost changes to Dolly Varden egg survival. Based on this informant's knowledge, melting permafrost causes the amount of sediment in the river to increase. The sediment fills the spaces between pieces of gravel on the river bottom, incubation habitat for Dolly Varden eggs. As a result of increasing sediment, the eggs are unable to settle properly and are carried downstream. The subsistence fishery for Dolly Varden is an incredibly important one for the community of Noatak. These fish are a prized

resource locally, and “Noatak trout” are a valued trade resource shared with other communities in the region; informants were especially concerned to understand changes that may affect this species in particular.

In Selawik, informants noted that they are catching less whitefish and more pike than in the past, which may indicate a relatively recent shift towards a greater abundance of pike present in the waterways and fewer whitefish.

> To me, seems like there's more siiliks [pike] and less whitefish…Last three summers, we're waiting for the whitefish to come in, but there's -- there's way less whitefish than we used to have…It seems like there's more siilik in spring than whitefish…We used to get whitefish before the siiliks, but seems like we been getting lot of siiliks from the other ones. –Selawik informant, interviewed July 22, 2010

> I think there's a couple years -- about 35 years …we used to go when we first started, we got a camp over here, about three miles, and when you go camping springtime, we used to get lot of fish, like five, six tubs… Later on, years and years later, you know, when it's going down the line, you start getting fewer and fewer whitefish. Now, last time, last spring, we only get only how many in one setting nighttime, about eight, huh? Or 16? ...Big difference in numbers. – Selawik informant, interviewed July 21, 2010

Informants attributed the decline in whitefish to several factors. Some noted that pike feed on whitefish and increasing pike abundance may be related to a decline in whitefish abundance. One informant described cutting pike and noticing, “The pike, the bigger pike. They always have the whitefish in there (the stomachs).” Others related the decline in whitefish to beaver activity, as discussed below. A few informants mentioned that whitefish movement timing is changing, and perhaps explains the change in catch rates. While we heard from many informants that whitefish abundance has decreased, we also learned that the abundance of whitefish at a particular place is highly dynamic and it is

difficult to make general statements about more or less fish in a given system. One informant explained that the amount of fish present in the waterways where people set their nets is related to the amount of snowfall that accumulated the previous winter. The whitefish travel into little creeks in the fall and spend the winter in ponds. During low snowfall years, the amount of spring melt water is limited and the creeks do not contain enough water to allow the fish to leave the overwintering ponds.

In Selawik, we did not hear any comments about changing sheefish abundance. A few informants mentioned that the good locations for catching sheefish in the spring have changed. Residents of Selawik travel to Inland and Selawik Lakes, which are large, brackish water bodies, to hook sheefish through the ice before break-up (see Figure 3.3). Whereas in the past people would fish in deep places, lately they have been catching sheefish in shallower spots near the mouth of Selawik River. Informants did not offer any reasons that may explain this shift.

Three informants, two in Selawik and one in Noatak, noted that they perceive a decrease in burbot abundance. Burbot are usually caught in the late fall and early spring under the ice by hook and line. They are generally pursued at night, when they are most active. In the past, people used to construct fish traps and catch burbot in large numbers. For the most part, traps are no longer used in Noatak and Selawik, and burbot are caught in fewer numbers than in the 1970s and before. During interviews, people recounted incidences of large catches of burbot shared in the communities, an occurrence that appears less common now. Based on interview and observational data, it seems that fewer people are targeting burbot and they are spending less time pursuing burbot than the past. This subsistence fishery for burbot now usually includes an evening of hooking for burbot, rather than someone setting a burbot trap and monitoring it for a long period of time. So the fact that people are catching fewer numbers of burbot may be more related to changing levels of fishing activity than decreasing abundance. However, a local expert in Selawik who continues to pursue burbot in the fall months on Fish River noted that five

beaver dams are blocking the river and affecting the movement of burbot between important habitat locations, which he relates to decreasing burbot abundance.

4.2.2 Fish movement

Many species of fish that are important subsistence resources display complex seasonal migratory patterns. People time their fishing activities around availability and target particular species when they are moving up or down the waterways in concentrated numbers. I do not go into detail here regarding the seasonal patterns of movement of each species, but instead discuss changes that informants have noticed in the movement timing of particular species. Many people commented that they missed fish runs because the fish moved earlier or later than normal. People have to travel far to reach some important fishing locations, which requires a significant amount of fuel and time, and often do not want to risk missing the fish. For this reason, it may be that some places are used less frequently now because people now cannot ascertain when the fish will be there. Several informants from Selawik stated that humpback whitefish, which are highly valued in the fall when they are full of roe, are becoming more difficult to catch due to changing migration timing. Informants explained that blueberry ripeness generally served as a useful indicator in the fall of when the humpback whitefish will be moving into Fish River, where people catch them with seine nets. For the past couple of years, informants notice that the whitefish had already moved out by the time the blueberries were ripe.

> A couple families still [travel to Fish River], but they said they either miss them, or too early, or late. One never know. Hard to tell anymore too when to get them. [It used to be] about the same time of year, but nowadays it's changed. –Selawik informant, interviewed July 22, 2010

> We don't catch it hardly anymore whitefish. They're -- they're coming in before we go to camp or after. –Selawik informant, interviewed July 20, 2010

Selawik informants noted that during the spring whitefish are now moving before the ice breaks up, which makes it difficult to catch them. Informants explained that they had to

wait for the ice to break-up and then rush out to set their nets before the fish moved into the lakes. When discussing the timing of whitefish movement, one informant surmised, “They’re just early because our spring is early.” Informants also noted that sheefish are moving from Hotham Inlet to the mouth of the Selawik River earlier than in the past.

Noatak informants were less inclined than Selawik informants to discuss changes in the movement timing of fishes. A few informants noted that some Noatak families have recently missed the humpback whitefish run at Sisualik, a spit located on the north shore of Kotzebue Sound (see Figure 3.1). I traveled to Sisualik from Noatak with a family on June 9, 2010. Many in the community thought this date was too early to travel by skiff to Sisualik because of ice conditions at the mouth of the Noatak River. The head of the family who decided to travel on this day was concerned that if they waited any longer, they would miss the whitefish. The head of the household had noticed that the whitefish were moving along the coast earlier in the previous years and responded by heading to camp earlier. We set a gillnet along the coast the first evening we arrived and caught a tub full of humpback whitefish by the next afternoon. This is one of many examples of local experts using their accumulated knowledge and experience to respond to changing environmental conditions.

It appears that the chum salmon run timing up the Noatak River has not changed. Notably, no informants mentioned a change in the chum salmon run timing. The month of July is the general time that they arrive near the village of Noatak as they travel upriver to spawning locations that are located above the village.

4.2.3 Increasing beaver abundance

In both communities, informants discussed the increasing presence of beaver. In Selawik, one informant noted, “I notice that there's tons of beaver where there hardly used to be beavers around, but now there's a house growing like every -- around the bend.” Another explained, “All over they make dam. There are too many… pretty soon we going to have no more fish.” Similarly in Noatak, informants noted that beaver have become increasingly abundant in the area, particularly in the last ten to fifteen years. One elder

said they were so scarce when he was growing up that he did not know what one looked like until he was twelve years old. The reason for this increase is partly related to a decrease in hunting pressure. Beaver trapping used to be an important economic activity in the region when fur prices were high. Informants told us that people no longer pursue beaver for their fur because the pelts are no longer valuable. In Noatak, informants told us that the beaver are expanding their range from the south. We heard about two different large events that informants linked to increasing beaver presence in northwest Alaska. Two informants mentioned that a large wildfire occurred in the interior of Alaska about fifteen years ago and resulted in a large number of beaver showing up in the Noatak area. Another informant linked significant flooding that occurred about twenty years ago to an increase in beaver abundance along the Noatak River.

Some informants related increasing numbers of beavers in the region to changes in fish populations. As one man in Noatak assessed, “Beaver are a menace to the fish.” Another informant in Noatak noticed that the beaver dams have affected the water levels of the Kelly River. In a recent year, he observed Dolly Varden pooling up at the mouth of the river, near his fish camp. The fish could not make it farther out because of the low water levels at the mouth of the Kelly River. In Selawik, several informants noted a possible effect of beaver on whitefish.

> [Whitefish] usually go into the sloughs and go to the lake, but because of beaver they get less. –Selawik informant, interviewed July 22, 2010

> Some of [whitefish] are real sickly.…Because of beavers. Too much beaver dams upriver and they block out the lakes with fish in there. And how we know them is they had red eyes. They've been -- they've been blocked in for year or two in the lake and when they -- when they finally broke through, they went out the beaver dam…That's how we noticed them, through their red eyes. Yeah, they're spoiled. If they're get blocked in...They're barely alive, skinny, and red eyes. And we don't -- we don't even cut them…We noticed that -- her and I noticed them across

> Inland Lake because there's lots of beavers upriver blocking our good fishing area, ruining the lakes. –Selawik informant, interviewed July 21, 2010

In addition to blocking fish movement, informants noted that beaver urine affects the distribution and health of fish. Informants in Noatak explained that Dolly Varden do not like the smell of beaver urine and may not move into an area where beaver are located. Beaver urine in waterways also has implications for human health. One man in Noatak shared that he had been suffering from giardiasis from drinking river water for six years before he was able to determine that the beaver's effect on the water was causing his illness. Many informants described how they now carry bottled water with them on hunting and fishing excursions, whereas before they would drink directly from the river.

4.3 Impacts of changes on subsistence fishing and processing

Many of the weather and seasonal changes noted above affect subsistence fishing and processing activities. In terms of catching fish, the effects of changing environmental conditions on accessing resources are particularly salient. Once fish are harvested, weather conditions play a hugely important role in the processing of fish for storage and consumption. Recent climatic changes challenge both fishing access and fish processing activities.

4.3.1 Fishing access

Changing and less predictable ice conditions on local water bodies at the end and beginning of the frozen season has significant implications for accessing fish resources. Earlier and faster spring break-up limits the amount of time available for spring ice fishing, an activity that provides a desirable source of fresh protein after the long winter. In Selawik, spring ice fishing is done on the Selawik and Inland lakes for sheefish. In Noatak, many people fish for Dolly Varden through the ice along the Noatak River before the ice breaks up. Residents of both communities have noticed that ice conditions become unsafe at a much faster rate than in the past, which limits people's ability to travel for a period of time. Once the ice becomes "rotten" on the water bodies, snowmachine travel becomes unsafe but boating is not yet possible.

> It don't stay safe no more. It's not safe to drive or walk on. It just all crumbled up ice just hold on together. And once you step it, they're just like crystals. They all just falls…Bad for fishing in springtime. –Selawik informant, interviewed July 19, 2010

> And then as soon as the weather starts getting warm, you know, the ice starts thinning…I think it change. You know, I think that global warming or something. It's melting the ice quicker than it usually. Because in a long time -- for a long time we used to have water in the edge and then we go, go, go all over without, you know, bad ice. But now it's real dangerous. Yeah. We've gotten really melt. –Selawik informant, interviewed July 21, 2010

In addition to the challenges associated with changing break-up conditions, late and unpredictable fall freeze-up, as discussed earlier, creates difficult travel conditions. Informants have observed warmer weather continuing into the fall and delayed freeze-up of the waterways, which prevents people from traveling on and crossing water bodies. These conditions can be very dangerous and informants recounted to us incidences of people falling though thin ice in the early winter months. In late November, 1999 three snowmachines went through the ice and into the Tuklomaruk River at Selawik Lake. One person perished and five others were involved in the accident but survived. This incident was mentioned by several Selawik informants as a tragic example of the consequences of increasingly unfavorable fall ice conditions.

> In fall time it don't get too cold. It stay warm, and the ice just freeze, and not getting thick enough to travel on. That's when we really watch the people, too…overnight, we used to go across [the river]. We don't do that no more. It will be too thin. How many days we have to wait now before it thick enough for us to go across? –Selawik informant, interviewed July 19, 2010.

During the open water season, low water levels greatly affect boat travel and access to important fishing locations in both Noatak and Selawik, making it harder to harvest local

resources. The waterways are typically navigable by boat between the months of June and October. Noatak boaters are intimately knowledgeable of the river and rely on an extensive system of side channels to follow more direct paths to target locations. Over the past several years, the river has been too shallow during much of the boating season to use these shortcuts, constraining boating access to the main, meandering channel. The lack of "river shortcuts" makes boating more expensive for subsistence activities because boaters must cover greater distances and burn more gas to get to the same locations. Noatak informants commonly cited incidences in the past ten years when their boat became stuck on a gravel bar or hit rocks while traveling on the Noatak River. Certain fishing areas upriver were noted to be inaccessible in some years, or at certain times of the year. Several informants specifically mentioned the Kelly River, an important fishing destination for Dolly Varden and a tributary of the Noatak River, as a place that has become less accessible due to low water conditions. As in Noatak, low water levels in the rivers, lakes and sloughs near Selawik were also noted to be problematic for boat travel. Changing water levels challenges even those who have spent a lifetime traveling the waterways and developed a deep knowledge of local conditions, as the following example reveals.

> Last -- two summers ago, I think, we went down berry picking. We got some few spots that we always go to. And I know the channel and I know the lake. It's all deep. So I just cruise on. She was sitting in front. And all of a sudden we hit island… There was no island there before. And I talk to these guys and they start telling me these islands are popping out through the lakes…And the land is sinking and the islands are popping up. –Selawik informant, interviewed July 19, 2010

One major consequence of lower water levels is increasing costs of boating. Those who have boats in Noatak and Selawik generally use outboard motors with propellers. We learned that it is becoming increasingly necessary to have a jet unit instead of a propeller on outboards to travel through shallower water. Many in the communities view jet units,

locally estimated to cost approximately $2500 in 2011, as prohibitively expensive. Additionally, broken propellers and ruined lower outboard units are common results of hitting bottom while boating. Both parts are especially expensive to replace in rural communities.

Warmer spring and summer temperatures affect subsistence fishing by limiting the amount of time that people can keep gillnets in the water. This is particularly important in Selawik, where many families travel to spring camps to fish for whitefish and pike. A Selawik informant explained, “The water is too warm. You’d like to stay at camp, like, another couple of weeks, but the sun is too hot. You have to pull out your net because the fish get too soft before you’re even done trying to scale them and cut them. They’re just no good.” The same informant noted that she learned through experience that she could leave her net in the water only for a couple of hours; if she did not pull it, the fish in the net would become “too mushy” and unusable.

4.3.2 Fish processing

Changing fall weather conditions, specifically an increasing occurrence of freeze-thaw cycles, create challenges for traditional fish processing practices. In Noatak and Selawik, a common method for preserving fish in late fall is partially fermenting fish in a shallow pit or on top of the ground, and then allowing the fish to freeze once outside temperatures drop. The fish is then eaten as *quaq* (fermented, frozen fish) throughout the winter. In Selawik broad whitefish is made into *quaq*, and in Noatak Dolly Varden and whitefish are prepared and eaten as *quaq*. Recently, residents of both communities have experienced difficulty preparing *quaq* on account of warm fall weather. Informants told us they are waiting longer for the weather to cool before they harvest fish and put it out to ferment.

> I store away, like about, like two gunny sacks of *qausriluk* or broad fish, whitefish, and it froze in October, and then it thawed, and then it rained, and then it freeze. And that was -- my fish were too stink. My dogs didn't even want to eat

> any of it and I didn't want to eat it either. So I learned from that. –Selawik informant, interviewed July 20, 2010

Informants note changes in temperature and precipitation during both the spring and fall seasons affects traditional fish drying, which is an extremely common method for preserving large numbers of fish. It appears that temperatures are warming faster in the spring in recent decades, which limits the amount of time favorable for fish drying. Informants noted that flies are coming out sooner, which lay eggs on drying fish. One informant in Selawik noted that in both spring and fall, wetter weather also affects fish drying. “Our rains, even those are different. They’re unpredictable. So we could count on it being dry when I was growing up in springtime. And then the same thing in fall time. Sometimes it’d be so wet, the fish can’t dry nowadays.” Some informants explained that they have switched from drying their fish to freezing it in electric freezers.

> Long time ago we hang fish, they dry even though we never really take care of them. Springtime, fall time, September. Here you have to watch them from the sun. Too hot. –Selawik informant, interviewed July 17, 2010

Overall, it appears that drying and aging fish is becoming more difficult as a result of unfavorable weather conditions during periods of the year when good processing weather used to be more predictable. However, it is important to note that before the 1970s, much of each household’s catch went to feeding dogs, whereas now the entire catch is for human consumption. Before snowmachines replaced sled dogs, a batch or two of partially spoiled fish could be fed to dogs and was not wasted. Now there are very few dogs to feed, one or two per household, so if a large number of fish are unfit for human consumption, they are thrown away. Perhaps experiencing periods of poor drying and fermenting conditions is not entirely new, but because spoiled fish are now essentially waste, the consequences of these unfavorable weather windows are different than in the past. Additionally, as a result of increasing participation in the wage economy, some people have a limited window of time to catch and process fish. If a period of bad weather for processing fish coincides with when people can get time off work, the

consequences are significant. Thus, perceptions of changing weather conditions and impacts of these changes is linked to harvesting practices, consumption patterns, and many other complex and interrelated factors. I continue this discussion in Chapter 5, where I explore linked human-environmental changes in Arctic communities.

4.4 Adaptation

Shifts in environmental conditions have prompted residents of Noatak and Selawik to respond adaptively. In response to changing weather conditions, specifically rainy fall weather when the fish are running, people are developing alternative methods for processing their fish. Many now rely more heavily on electric freezers instead of drying the fish outside in the traditional manner. Others put their fresh fish in the freezer and then later defrost and dry them outside when the weather improves. In response to changing fish movement timing, informants noted that they are trying to get to camp earlier so they do not miss the fish. Informants in both Noatak and Selawik noted that people are actively managing beaver activities in order to sustain harvest levels of whitefish (in Selawik) and Dolly Varden (in Noatak) and avoid interruption of boat travel. Elders encourage young hunters to shoot beaver when they are spotted and to tear down beaver dams.

4.5 Summary

Documenting a wide variety of local observations and knowledge of climate change is a difficult task. Changes are relatively recent and local experts' assessments of change are constantly evolving. People's knowledge and perceptions of environmental phenomena are closely tied to daily experiences and their socio-cultural context. Each informant contributed different ideas, observations of change, and thoughts about the implications of these changes to this project. Despite discrepancies in some particulars, we did identify many common themes throughout the data related to recent environmental changes, as discussed above. I explore the level of consensus about these changes in Chapter 6. Summarizing the common observations from the preceding sections, I developed the following statements to represent an overall assessment of local observations of change

for these two communities. These statements emerged from the interview data as the most salient themes discussed by informants, based on the qualitative coding process. Additionally, these statements contain observations of change that were not contradicted within the interview data.

1) The sun feels hotter.

2) While fluctuation and variability are natural aspects of the local environment, the current changes are outside the normal range of variability.

3) Changing weather conditions are most noticeable around the periods of time coinciding with freeze-up and break-up.

4) Seasonal shifts are occurring at a much faster rate (i.e., when fall arrives, the weather turns cold very suddenly).

5) Beaver are increasing in abundance in the waterways surrounding both communities and negatively affect fish health and abundance.

Chapter 5

Climate change in the context of a total environment of change

5.0 Introduction

A number of recent studies have attempted to understand indigenous knowledge and perceptions of climate change, primarily in regions expected to experience pronounced changes (Riedlinger and Berkes 2001, Nichols et al. 2004, Hinzman et al. 2005, Berkes 2008). In addition to this recent interest in indigenous knowledge of environmental change, many studies have sought to understand the impacts of changing weather, travel, and hunting conditions on indigenous communities and their subsistence practices (Hinzman et al. 2005, Ford et al. 2008, Ford 2009). However, indigenous and subsistence-based communities face a whole range of changes, many often more pressing than climate change (Fox 2002).

In this study, while inquiring about observations of climate change and impacts on subsistence fishing practices, we learned that climate change is not viewed by village residents as an especially important driver of change. Rather, changing lifestyles, decreasing interest by younger generations in pursuing subsistence lifestyles, and economic challenges are understood to be pressing drivers of change that are dramatically reshaping subsistence patterns and practices in Noatak and Selawik. Within this chapter, I explore these additional drivers of change that have occurred over the past fifty years in Noatak and Selawik and discuss their impacts on subsistence fishing practices. Using the experiences of Noatak and Selawik as case studies, I suggest that it is ultimately insufficient to try to understand how Arctic communities are experiencing and responding to climate change in isolation from other stressors. Rather, indigenous communities in the Arctic are facing a total changing environment (Garcia-Quijano et al. 2011), or a total environment of change (Moerlein and Carothers 2012). Observations of climate change are clearly perceived and experienced through linked lifestyle and other cultural shifts. To properly assess and understand the impacts of climate change on the subsistence practices in Arctic communities, we must also consider the total environment

of change that is dramatically shaping the relationship between people, communities, and their surrounding environment. The insights drawn here, although based on ethnographic research in two communities, have broad implications for how to better understand local perceptions of climate change in the Arctic and how future research endeavors can best be developed.

In this chapter I first describe the changing socioeconomic conditions that are perceived by Noatak and Selawik residents as major drivers that shape contemporary subsistence fishing practices. Next, I use a vulnerability framework to analyze the ways in which impacts of climate change are tightly linked to the socioeconomic context within which environmental shifts are experienced on a local scale. Specifically, I utilize the vulnerability approach of Ford and Smit (2004) and Ford et al. (2006), which conceptualizes vulnerability to climate change as a function of exposure and adaptive capacity. Exposure relates to the susceptibility of individuals and communities to environmental conditions, and adaptive capacity relates to a community's ability to address and adapt to exposure.

5.1 Shifting socioeconomic and cultural conditions

As described in Chapter 3, pronounced social, economic, political, and other cultural changes have shaped contemporary ways of life in northwest Alaskan villages. Within living memory, the Iñupiaq communities of Selawik and Noatak have experienced major waves of social and economic change, including increasing engagement in wage employment, increasing availability of outside goods and services (e.g., housing, sanitation, motorized transportation), the implementation of a major land claims act, increasing interaction between federal government and residents in the form of monetary transfers and institutional support, and increasing infrastructural development of the communities, among others. These changes are not limited to the communities of northwest Alaska, as similar patterns of change have been experienced in indigenous communities across the Arctic and worldwide (Condon et al. 1995, Ford et al. 2006).

Within the context of interviews and participant observation based on exploring climate change and subsistence fisheries, we heard much about the broader context of change in subsistence livelihoods in this region. While our interview protocol (see Appendix) specifically explored environmental and ecological variables, informants often offered their perceptions of change in their communities more broadly. It is not my intent in the following sections to provide an exhaustive review of the changes experienced in Noatak and Selawik over the past fifty years. Rather, I seek to identify and discuss the main drivers of change that were discussed repeatedly during interviews and participant observation and the effects of these changes on subsistence fishing.

5.1.1 “Easy life these days”

As described by many of our older informants, important differences exist between contemporary living and the lifestyles of their youth. Changing living conditions is an important driver altering local harvesting patterns. Elders from both communities noted that access to a much greater number of conveniences like cell phones, fast transportation, plumbing in the house, and store foods are reshaping the relationships that people have with the environment. Village residents are spending more time indoors. The notion that people live a physically easier life today compared to the past was a consistent observation among elders during interviews. Elders remember hauling water, pulling boats upriver with sled dogs, making fishing nets by hand, and spending significant amounts of time harvesting food for both people and dogs. Today, conveniences like light, heat, water and clothes washing are available at the flick of a button, but were unimaginable only decades earlier. It has only been since the 1990s that most houses in each community were connected to modern water delivery systems. Other informants discussed systems of social support, like food stamps, that have also shifted patterns of food procurement. While many recognize the benefit of these western amenities, others reminisce about the days when community members performed more physical labor on a day-to-day basis and lived more traditionally. When describing the way people lived in Noatak when he was a child, an elder mentioned: “It was harder, but it's better, I think.

Just more clean." Another elder noted that the "easy life" distinguishes lifestyles now from previous generations.

> When we were growing up…we have to get what we get out of the land, you know…(They) don't grow up like we do. You don't -- you don't have to feed your dogs. All you do is just park the snowmachine or 4-wheeler outside the house. You don't -- until you run out of gas. Before, you know, you have to cook for your dogs too, you know. Day in, day out. Busy all the time. You have to go out and get your wood before we start using oil stove… –Noatak informant, interviewed June 18, 2010

5.1.2 Changing food preferences

For many young village residents, food items available at local or regional stores make up a significant portion of their diet at the expense of locally harvested fish and game. Many elders noted that as very few items were available at the local village store during their youth, the majority of food consumed was harvested locally. During our visits to Noatak and Selawik, it was not uncommon to sit at a meal where the elders ate fish or caribou and the children and younger family members ate a prepared frozen meal of pizza or fried chicken. Elders and active fishermen repeatedly noted that the younger generation is less interested in eating "Native food" or "Eskimo food," despite their health benefits and cultural importance. This nutritional transition is not unique to Noatak and Selawik; several studies have documented the negative health impacts of changing dietary habits in Arctic communities (Kuhnlein et al. 2004, Bersamin et al. 2006), and among indigenous populations more generally (Piperata et al. 2011a, Piperata et al. 2011b). Many informants linked increasing rates of diabetes and cancer in the community to the consumption of more store foods today compared to the past. The introduction of welfare checks in the 1950s was noted as a particularly important factor that shifted local food consumption patterns towards more store foods. The following interview excerpts highlight the effects of changing food preferences and food stamp availability on subsistence fishing and Iñupiaq culture.

> [There is] less fishing activity because there's more access to different kinds of food; more heatables, microwaveables, and less interest in our Native food. Lot of children, new generation, I don't think they like our style of food because they grew up with those microwaveables. -Selawik informant, interviewed July 22, 2010

> Lots of young people, families they won't go for fish. There's only a few of us. There's only six families with fish nets and boats. From the whole village.
> *Interviewer: When do you think that started happening?*
> When they start the food stamp, how many years ago? The free -- free money stuff to go store and eat... Usually [the fish was] the only food they have that time. They don't eat from the stores. Just so they have coffee, tea, and sugar, and that's all they need in those days. But they pre-heat and everything today. They are forgetting about the outdoor life and how they could live their life without going to the store. -Selawik informant, interviewed July 19, 2010

> But right now, you know, with this government, I don't know, it messes up. So much easy life now, you know, for a kid, though. Even our kids don't even know how we grow up…It's too easy life right now for these younger people with these food stamp, you know. When we were growing up, we don't have no food stamp. We have to get what we get out of the land, you know. –Noatak informant, interviewed June 18, 2010

5.1.3 Knowledge of younger generations

As the previous interview excerpts disclose, many active fishermen and elders noted that there is a general disconnect between the younger generation and subsistence practices, a trend characteristic of many northern subsistence-based cultures (Condon et al. 1995). Changing social and economic conditions in Noatak and Selawik have made it difficult for the youth to develop comparable hunting and fishing skill sets essential for previous generations. Some children today grow up in homes without active subsistence harvesters and are not taken out on harvesting trips. Other youth in the communities display a

waning interest in learning subsistence practices. I spent time with several families at camp during the spring fishing season and found that often the children would stay inside the cabins while the parents scaled, cut, and hung hundreds of fish. This lack of interest may be related to a general shift in social norms, where it is not expected for the youth to be heavily involved in subsistence activities. Additionally, the youth are increasingly pressured to seek education, training, and employment outside of the rural village communities, which further limits the potential for them to develop the harvesting skills of their parents and grandparents. It is important to note, however, that some families make it a priority to help their children develop the skills necessary for harvesting local resources. During interviews, several informants noted with pride that their children knew how to cut fish and more importantly, enjoyed eating local foods.

5.1.4 Changing technology

An important consequence of “nowadays stuff,” as many informants aptly labeled advanced technology, is that it has become an integral part of modern subsistence practices. Technological advancements have changed the nature of hunting and fishing practices and have also increased the monetary requirements of subsistence activities. One particularly important development was the replacement of sled dogs by snowmachines as the predominant winter mode of transportation around 1975 (Hall 1971, Magdanz et al. 2010). Once dog teams fell out of favor, a heavy burden of feeding many canines throughout the year was lifted and harvest levels, primarily for fish, dropped as a result.

> I notice that people don't put salmon or dried salmon away like they used to when they lost their dog teams. They used to put away a lot of salmon. Like I said, out there they'd make big box and throw all the salmon in and cover them up and use them for dog food throughout the year. And when they're going out, say, caribou hunting they take the dried salmon because of the weight. And when they lost their dog teams, you don't see people hanging salmon or putting them away for the winter. And not only did they put salmon away for the winter in that way, the

> trout and the whitefish were put away also for the dogs in gunny sacks. They don't use trout all that much here. We don't see them putting trout and whitefish away like they used to for the dogs. -Noatak informant, interviewed June 15, 2010

In addition to reducing the amount of fish necessary for harvest, snowmachines significantly decrease travel time. Whereas before people would spend days and weeks camping and traveling by dog sled, they can now reach a particular destination in a few hours, pursue fish or game, and travel home in the same day. Snowmachines are only one example of the many technologies that are now viewed as basic, yet expensive necessities for subsistence activities. Today, the rural subsistence economy is heavily dependent on cash for the purchase and maintenance of boat engines, snowmachines, all-terrain vehicles, ice augers, and commercially manufactured fishing nets.

5.1.5 Economic challenges

An extremely high cost of living is characteristic of contemporary rural Alaskan villages. Residents of the Kotzebue region experience the highest cost of living in Alaska (Fried and Shanks 2011). Economic concerns dominated our discussions with informants about challenges to subsistence practices. Every interviewee stated that he or she worries about the high cost of fuel and equipment (see Chapter 6). Many informants noted that the high cost of gasoline (fluctuating between double to triple the cost of gasoline available in urban areas) often prevents access to hunting and fishing places and a lack of rural employment limits income opportunities. We spoke with numerous people in both communities who cited lack of gas money as the reason they had not been out boating that season. In response to the constraint of high gasoline prices, families often pool their financial resources to travel to hunting and fishing camps together. In Selawik, informants explained that they have begun setting their nets near town rather than traveling to fish camp in order to minimize gasoline usage. The cost of equipment and maintenance was also mentioned frequently by informants in both communities as a barrier to subsistence activity. Informants reported that subsistence fishing trips, or entire seasons of fishing, have been missed because they could not afford parts needed to fix

their boats. With the access to food stamps discussed above, it is often cheaper for families to purchase low quality, packaged food at the store than to go out and harvest local resources.

5.1.6 Participation in the wage economy

In addition to the challenges associated with the high cost of subsistence activities, participation in the wage economy also affects people's ability to spend time hunting and fishing. Many families shape their activities at fish camp in the spring and fall around work schedules, whereas in the past people would spend the entire open water season directing their energies towards harvesting local food. One informant pointed out that nowadays there are "everyday fishermen" who do not hold a regular wage-earning job, and there are "Saturday fishermen," who are only able to go fishing on their days off. It used to be that families traveled to important fishing and hunting locations for weeks to months at a time, but now people travel to distant locations on day-trips or stay only one night at camp due to work constraints. Households must earn enough income to afford gas, equipment, food for camp, warm clothes, and other necessities to maintain successful subsistence harvests, but they also need enough flexibility from work to spend time harvesting. For many, this is a challenging balance to strike.

5.2 Linking social-ecological transitions

As the previous sections suggest, residents of Noatak and Selawik are experiencing a total environment of change, where climate change, socioeconomic transitions, and shifting cultural norms are together reshaping subsistence fishing lifestyles. During interviews and participant observation, we learned that village residents do not perceive the environmental and social change and impacts on local fishing practices separately, but instead possess a holistic view of local conditions and the interacting drivers of change. We find this consistent with the literature on indigenous knowledge systems, where knowledge, practice, and belief are inextricably linked and the false dichotomization of the natural and the social worlds that characterizes western thought does not exist (Berkes 2008). The following interview excerpt begins to reveal the

inseparability of environmental-social change and the perception of village residents that climate change is simply one of many changes that have and are affecting the community.

> *Interviewer: We're trying to learn about environmental change, and if there are any changes going on in Noatak with the weather, with how the seasons are happening, and how that may be affecting subsistence fishing.*
> Informant: Just the weather changed so the – I think the world is changing, that's why. The weather's changing. Getting hotter every year. No more snow. We all move down [to the lower 48] states. We used to have no snowmachine them days. Just dog team. Every household used to have dog teams. -Noatak informant, interviewed June 16, 2010

As we see, this informant, when asked about environmental and weather changes, mentions weather, snow, emigration, and technological shifts all linked into the same train of thought. The swift, unprompted transition that this informant made from changing weather conditions to changing modes of transportation happened with great frequency during interviews and casual conversations. A researcher focused on impacts of climate change may think that the informant is getting off topic and disregard the information given that is seemingly unrelated to climate change or steer the informant back toward the direction of climate change. But in fact the previous excerpt provides insight into the ways in which climate change is perceived and experienced by Noatak fishermen. Climate change is bringing changes, such as hotter weather and less snow. Snowmachines forever changed the way Iñupiaq people traveled in the winter and changed the way they harvested fish. Both are important and both are connected in ways that are difficult to capture in formal interviews conducted by outside researchers who come to communities to study questions pertinent to their distinct disciplines. After spending many hours with elders, knowledgeable fishermen, and other patient teachers in Noatak and Selawik, I have come to learn that it is much more appropriate and locally relevant to discuss observations of climate change within the context of a total

environment of change than to consider the impacts of climate change on subsistence practices alone.

Climate change is not an isolated issue in Noatak and Selawik, but is perceived as only one of multiple linked stressors affecting subsistence practices. In the following section I analyze the interactions between climate change and the socioeconomic and cultural context and the ways in which these interactions shape contemporary subsistence fishing practices in Noatak and Selawik. I use a vulnerability framework to discuss the ways in which many interdependent factors affect the exposure of subsistence harvesters to climatic changes and their abilities to adapt.

5.2.1 Travel conditions

Noatak and Selawik's residents' experiences with changing water conditions provides a particularly poignant example of how the effects of climate change are embedded within and mediated through an existing socioeconomic context. As discussed in Chapter 3, we heard repeatedly from informants that river levels are now lower on average during the open water season; these lower water levels affects transportation and access to important fishing locations. During periods of low water, boaters are constrained to using the main meandering river channel and cannot use shallow side channels that provide shortcuts to various destinations. The lack of "river shortcuts" as a result of lower river levels increases boating expenses for subsistence activities because boaters must cover greater distances and burn more gas to get to the same locations. Furthermore, lower water levels increase the chances that boaters will hit the river bottom, which often causes damage to boats and underwater components of the boat engines. The cost of shipping to Noatak and Selawik is exorbitantly high due to their rural location, and villagers often do not have access to professional mechanics to fix broken parts or perform metal or fiberglass work on damaged boat bottoms. Thus, a damaged boat or outboard has a much larger impacts on daily life in Noatak and Selawik than it would in urban areas. It can potentially include nutritional and psychological effects, in addition to financial concerns. The high cost of parts is a significant factor for the majority of Noatak and Selawik

families, whose paychecks and other forms of income are not adequate to cover the extra expenses. We can suggest that these rural communities are more vulnerable to environmental changes like lower water levels because of the social and economic contexts of the communities. Due to financial constraints and high prices of equipment, residents of rural communities have a low adaptive capacity to respond to changing boating conditions.

5.2.2 Knowledge transfer

As discussed above, an erosion of traditional knowledge and practice has been noted in Noatak and Selawik among the younger generation. The disconnection of youth from subsistence fishing has wide-ranging implications for current and future vulnerabilities to climatic shifts. Traditional ecological knowledge is formed through experiential and dynamic processes, and is continually updated and revised in light of observations, trial and error experience, and the incorporation of non-traditional ways of knowing (Ford et al. 2008). A repository of accumulated experience can be drawn upon by elders and adults to minimize the consequences of unfavorable fishing conditions and maximize opportunities. For example, older generations have more experience dealing with poor fish processing weather conditions and can still get fish stored for the winter despite less than ideal conditions. The younger generations, who have spent significantly less time on the land and observing the environment than their parents and grandparents, do not have the same access to years of accumulated knowledge upon which to rely when dealing with challenging conditions. Additionally, drastic cultural changes over the past fifty years have altered the frequency and effectiveness of knowledge transfer from older generations and the youth. The youth are spending less time out on the land than their parents did when they were young. Informants noted that due to work constraints and financial challenges, families now spend fewer days at fishing and hunting camps compared to several decades ago, which limits the amount of fishing and hunting knowledge that is transferred to the younger generations.

Informants noted many times that younger boaters, with limited knowledge of the river channels, were most vulnerable to low water levels. “You need to know the river,” was the response given frequently when we asked village residents if changing water levels affected boating access. Informants also cited lacking knowledge of good ice conditions for traveling as a particularly worrying consequence of decreasing time spent on the land by younger generations. Informants noted that during fall it is now taking longer for the ice to thicken enough for safe crossing and they are concerned that younger people do now know how to determine when the ice is safe. Along the same lines, early, fast break-ups are particularly dangerous for those who do not know the signs of hazardous ice.

> We've been warning our young people not to go out when the snow start melting… we start explaining to these young people that ice is already rotting. And warned them not to go out. –Selawik informant, interviewed July 19, 2010

In addition to knowledge of travel conditions, knowledge of harvest timing was identified as an area where the younger generation is deficient, making them particularly vulnerable to shifting weather conditions. Informants noted that over the past decade uncharacteristically warm fall weather restricts traditional fish processing methods that require cool, near freezing conditions outside. In Noatak, we heard that village residents lost batches of Dolly Varden and whitefish that they had harvested and placed in gunny sacks outside to ferment. The weather did not cool as expected, causing fish to rot. However, a particularly knowledgeable elder said that one of the reasons why some village residents have lost fish is because they are not using the right indicators to tell when to harvest the fish. This informant told us that he learned to feel the temperature of the river water to know when the weather will turn cold. Younger people do not know to do this, but instead start to harvest fish around the time it is generally predicted that the weather will turn cold. If the weather does not cool as expected, the fish spoil. Together an increasing frequency of periods of warm weather in the fall and a decline in traditional knowledge may make it gradually more difficult for village residents to successfully harvest and process fish resources.

5.2.3 Fish processing

Informants also noted that many village residents do not know how to properly monitor their drying fish, but instead leave it unwatched for days and expect that it will properly preserve. We learned from elders that with adequate knowledge and the proper amount of care, including turning the fish, keeping water away from the flesh, and making a fire to prevent moisture build-up, batches of fish can dry even in unfavorably wet conditions. This is not to say that increasingly unfavorable weather conditions are inconsequential, but rather that a loss of local knowledge regarding traditional fish processing methods amplifies the costs of this change. Thus, individuals' vulnerability to climate change in terms of their ability to process fish is inextricably tied to the transfer of traditional ecological knowledge. Those who, for many possible reasons, do not possess a deep knowledge of local conditions and processing techniques may not have the adaptive capacity to respond to changing climate conditions.

5.2.4 Conflicts between subsistence activities and wage economy

As discussed above, increasing participation in the wage economy has changed the nature of human/environment interactions in Noatak and Selawik over the past fifty years. In most households at least one, if not two, adults work part- or full-time. Many village residents work away from their homes, at Red Dog Mine, in the regional hub of Kotzebue, or elsewhere in Alaska. Work constraints play a major role in the timing, duration, and nature of fishing activities. During my visits to Noatak and Selawik, it was not uncommon to come across families who were waiting for a particular family member to return home from work so that they could leave for fish camp.

Exposure to climate change is affected by reduced time available to spend fishing and processing on account of work schedules. Because many active fishermen only have a limited amount of time off work, concerns of unfavorable weather or poor traveling conditions may be superseded by consideration of time availability when harvesting decision are made. We heard from many informants in Selawik that the water is warming faster in the spring now compared to a few decades earlier, which shortens the window of

time that village residents can set their gillnets for whitefish and pike before warm water spoils the fish. A narrowing window of favorable fishing conditions coupled with an inflexible work schedule creates a challenging situation for families trying to procure fish for themselves and others. Furthermore, heads of household often take time off work to travel to camp during the peaks of fall and spring fishing. Time off work must often be booked in advance. Increasingly unpredictable weather conditions and fish movement timing, combined with increasing participation in the wage economy has narrowed the windows of opportunity for fish harvesting and processing.

5.3 Conclusions

Communities differ in the way their members perceive risk, in the ways they respond to change, and in their abilities to adapt. Given the increasing prevalence of climate change research and its predicted devastating impacts, we find it especially important to put climate change in context, as our informants have done, as one driver of change among a suite of stressors currently being experienced as a total environment of change in Arctic Alaska. Our ethnographic findings demonstrate that the dramatic social transitions taking place in communities in northwest Alaska currently takes precedence over climate change in how they impact the sustainability of subsistence practices and subsistence-based remote villages. However, we must also pay attention to the interaction of various impacts, such as the compounding nature of changing river levels and the social changes that mean the younger generations do not spend enough time boating to learn navigation skills without the complications of changing environmental conditions (Gearheard et al. 2006). As others have argued (e.g., Gearheard et al. 2006), I also find that the coupled human-environment system is too complex to draw neat conclusions about the implications of climate change; much ambiguity remains. Within a science-based way of knowing, ethnographic approaches that engage local perceptions of change are necessary to generate meaningful understandings of total environments of change and to inform effective strategies of response. This research indicates that it is meaningful to turn attention to the total environment of change affecting subsistence practices and culture in Arctic communities. This broader focus on linked social-ecological conditions provides a

better sense of how global phenomena are driving change in place and context. An analysis of the differential social impacts of climate change reveals that a useful investigation of impacts of climate change must be framed by local perceptions and be sensitive to existing socioeconomic conditions that shape human-environment interactions.

Chapter 6

Assessing agreement about observations and perceptions of climate change

6.0 Introduction

To complement the rich and detailed accounts collected through interviews and participant observation, I used cultural consensus analysis methods (Romney et al. 1986) to estimate the level of agreement about observations of climate change and other drivers of change affecting subsistence practices. Within a single community, knowledge and perceptions are not homogenous. Gender, age, education, experience, subsistence practices-- including use of different harvesting locations, species preferences, harvesting methods, level of overall participation-- and innumerable other factors contribute to the knowledge base of an individual (Turner et al. 2000). As described in the previous chapter, each expert informant contributed his or her unique observations and understandings of the recent environmental changes and other challenges that are affecting subsistence practices. Many observations were shared across a large range of experts, such as the increasing presence of beaver in the waterways, but other observations of change were less frequently recorded, such as increased precipitation during the fall season. Cultural consensus analysis provides a technique for revealing patterns of agreement and disagreement concerning a domain of knowledge among individuals within a particular social setting (Romney et al. 1986). Further, it allows the researchers to infer whether there is either a culturally central or more diversified understanding of the domain (Caulkins and Hyatt 1999). Here, I discuss findings from three separate analyses concerning the domain of observations of a total environment of change and impacts on subsistence fishing: 1) the degree of agreement among Noatak expert informants; 2) the degree of agreement among Selawik expert informants; 3) the degree of agreement between Noatak and Selawik expert informants.

As discussed in Chapter 2, cultural consensus analysis is a formal mathematical model that provides an estimate of the cultural knowledge shared by a set of informants and estimates the culturally correct answer to each question. Based on the ethnographic

interview data described in Chapters 4 and 5, we created a series of propositions, or observations of change. We created 33 propositions that were shared between Noatak and Selawik and 11 propositions that were specific to each community (see Appendix). In each community, every informant in our sampling frame was given the same set of propositions, and they were asked to agree or disagree with the propositions. The data consisted of an informant-proposition matrix, which contained each informant's answers to each of the propositions. In cultural consensus analysis, estimates of individual knowledge or "competency" can be estimated from the agreement between people (Weller 2007). Then, the "culturally correct answers" are estimated by weighting the responses of each informant by their competency and aggregating responses across the group of informants. A general diagnostic test is to examine the ratio between the first and second eigenvalues, based on a factor analysis of the agreement matrix, to determine the dimensionality of the solution. When responses are homogenous across informants, the eigenvalue ratio will be high and this indicates that there is only a single dimension in the data. Generally, an eigenvalue ratio greater than 3.00 demonstrates consensus among respondents (Weller 2007).

6.1 Community specific analysis: Noatak

Consensus analysis of observations of a total environment of change and impacts on subsistence fisheries in Noatak based on the covariance method resulted in an eigenvalue ratio of 5.831, which indicates consensus among informants (n=25). For the match coefficient method of measuring agreement among informants, the ratio of the first eigenvalue to the second is 6.915. Both methods produced the same estimated answers to the propositions. Because the covariance method is not sensitive to the presence of response bias when estimating competence, I use the results from the covariance method in the subsequent analysis and interpretation. Following Weller (2007: 353-354), I considered an average competency score above 0.5 to indicate moderate agreement about an underlying model of shared knowledge. Analysis shows the average estimated competency of the informants in Noatak to be 0.603 (SD=0.21). I did not find any correlation between individual knowledge score and age or individual knowledge score

and number of years spent as an active fisher, using Pearson's correlation coefficient. There is also no correlation between individual knowledge score and gender, using a one-way ANOVA. The lack of correlation between demographic information of respondents and individual knowledge scores indicates that there are no easily identifiable subgroups of people that show systematic differences in responses. Our sampling frame included those in the community who were older (over 40 years) and experienced fishers, so the lack of subgroups here is expected.

Although there is an overall consensus among informants about observations of a total environment of change and impacts on subsistence fishing practices in Noatak, we found some differences in response patterns. One informant had a particularly low knowledge score (0.016 on a 1-0 scale), which indicates that this person has a slightly different knowledge body than the rest of the sampling frame. It is important to note that this particular informant hesitated to agree to any statement when the survey was conducted, repeatedly stating that he did not notice any change. His response pattern was different than any other informant, and I knew before analysis of the data that he would be an anomaly. The removal of this respondent from the matrix results in an eigenvalue ratio of 7.39 and a group average individual knowledge of 0.62.

The estimated answers to the propositions and the frequency of response are presented in Table 6.1. Cultural consensus analysis reveals that local experts in Noatak agree about many observations of changing environmental conditions over the past several decades. Over 80% of informants agreed that compared to twenty to thirty years ago the nature of spring break-ups is changing (C3), there is more erosion of the river banks (C6), beaver are increasing and affecting fish movement and water quality (C8-10), permafrost is thawing (C13 and C14), lakes are drying (C15), winter weather is warmer (C18), and there are now thaw slumps on the Noatak River (N44). We also found significant agreement about changing water levels. All informants (100%) agreed that river water levels are shallower now compared to twenty to thirty years ago (C4) and 76% of informants agreed that changing water levels affect access to fishing spots (C7).

In addition to observations of environmental change, we also found significant agreement about socioeconomic factors affecting subsistence practices. All informants (100%) agreed that high food and fuel prices increase the need for subsistence foods for Noatak residents (C33). All informants (100%) also agreed that they worry about the high prices of gas and equipment (C32). The majority (92%) of informants also agreed that access to store foods negatively affects how much Native food people eat in Noatak (C30).

Table 6.1 Estimated answers to propositions with frequency of response among Noatak informants

#[4]	Propositions	Culturally correct response	Frequency of response (%)
C1	Spring floods are less common now than they were 20 to 30 years ago.	agree	60
C2	Break-up usually happens earlier now than it used to happen 20 to 30 years ago.	disagree	68
C3	Big break-ups don't happen as much now; the ice just melts out.	agree	88
C4	The rivers are shallower now than they were about 20 to 30 years ago.	agree	100
C5	The number of sandbars in the river has not changed over the past 20 to 30 years ago.	disagree	84
C6	There is more erosion of the river banks now than there was 20 to 30 years ago.	agree	88
C7	Changing water levels make it more difficult to access fishing spots.	agree	76
C8	There is the same number of beavers here now than there was 20 to 30 years ago.	disagree	96
C9	Beaver dams interfere with fish movement more now than they used to.	agree	88
C10	The presence of beavers does not affect water quality.	disagree	92
C11	Summers are cooler now than they were 20 to 30 years ago.	disagree	96
C12	During the summer, it tends to rain more now than it did 20 to 30 years ago.	disagree	100
C13	The permafrost is thawing more now than 20 to 30 years ago.	agree	96
C14	Thawing permafrost affects the land, river banks and lake edges.	agree	96
C15	Lakes and sloughs are drying.	agree	84

[4] Propositions labeled with a C indicate the set of combined propositions. These were asked to both Noatak and Selawik informants. N is used to label Noatak-specific propositions.

Table 6.1 continued

C16	The river and lake water is colder now than it was 20 to 30 years ago.	disagree	76
C17	It usually rains more in the fall now than it did 20 to 30 years ago.	disagree	60
C18	Winters are usually warmer now than they were 20 to 30 years ago.	agree	84
C19	On average, there is less snowfall during the winter as there was 20 to 30 years ago.	agree	72
C20	I have not noticed any changes in ice thickness on the lakes and rivers over the last 20 to 30 years.	disagree	72
C21	Overall, the ice is thinner on the lakes and rivers now than it was 20 to 30 years ago.	agree	72
C22	Fall freeze-up tends to happen later than it did 20-30 years ago.	agree	80
C23	It is harder to predict the weather now than it was 20-30 years ago.	agree	72
C24	We catch more fish now that are diseased or deformed than we did 20 to 30 years ago.	agree	56
C25	It is harder to know when fish will move now than it was 20 to 30 years ago.	agree	68
C26	I am able to harvest enough fish to meet my needs and the needs of others I share with.	disagree	80
C27	The average size of fish I catch has not changed over the last 20 to 30 years.	agree	64
C28	There are as many fish in our waterways now as there were 20 to 30 years ago.	disagree	72
C29	Climate change is affecting the way we live.	agree	88
C30	More access to store foods decreases how much native food people in Noatak eat.	agree	92
C31	I worry about the changes I am noticing in the environment.	agree	88
C32	I worry about the high costs of gas and equipment.	agree	100
C33	The high cost of food and fuel increases our need for subsistence foods.	agree	68
N34	The abundance of trout in the Noatak River has not changed much over the past 20 to 30 years.	disagree	80
N35	There are fewer trout in the Noatak River now than there were 20 to 30 years ago.	agree	80
N36	Late fall freeze-up causes difficulty for aging fish outside.	agree	80
N37	Dirty water in the spring doesn't last as long as it did 20 to 30 years ago.	agree	64
N38	There are more whitefish (iqalupiaq) in the Noatak River now than there were 20 to 30 years ago.	agree	80
N39	The Kelly River is drier now than it was 20 to 30 years ago.	agree	72

Table 6.1 continued

N40	Beaver block the movement of trout to lakes and streams where they spawn.	agree	88
N41	The amount of open water on the river in winter has not changed over the past 20 to 30 years.	disagree	72
N42	More boats run aground on account of low water levels now than they did 20 to 30 years ago.	agree	84
N43	People now travel farther to find good fishing spots than they did 20 to 30 years ago.	agree	68
N44	There are now more thaw slumps on the banks of the Noatak River than there were 20 to 30 years ago.	agree	88

Some observations of change are less widely shared. In particular, less than half of the informants agree that it rains more in the fall than it did twenty to thirty years ago (C17). During semi-directed interviews several of our key informants described increasingly rainy fall weather and the effects of this change on drying salmon, but we find that this observation is not widely shared, suggesting that individuals have experienced variation with fall precipitation patterns. Perhaps those who do not regularly dry salmon in the fall do not notice a shift in weather conditions. It could also be that rainfall patterns in the fall months have varied over the years, and an overall pattern of change is difficult to detect. Observations of earlier break-up were mentioned often during semi-structured interviews, but cultural consensus analysis reveals that overall, informants disagree that break-up is earlier (C2). Ice records show breakup of the ice on the Noatak River is occurring roughly four days earlier than when records began in 1918 (NOAA River Forecast Center 2011). Perhaps the change in timing is so slight that it is not yet detectable by the majority of local observers while the nature of break-up being different (C3) is more widely observed.

6.2 Community specific analysis: Selawik

Analysis of the Selawik response matrix showed a more marginal fit to a consensus model than Noatak. For the covariance method of measuring agreement among informants (N=24), the ratio of the first eigenvalue to the second is 2.68. Consensus analysis based on the matches method showed a better fit to the consensus model with an

eigenvalue ratio of 3.81. There are a high proportion of "true" responses in the matrix and a high proportion of estimated answers classified as true (0.77). Therefore, for subsequent analysis and interpretation of the Selawik response matrix, I use the results from the matches method, given the covariance method's sensitivity to the underlying proportion of true answers. Both methods resulted in the same estimated answers, except for C11. The estimated answers based on the matches method are presented in Table 6.2. The average individual knowledge score of Selawik informants is 0.58 (SD=0.19), which indicates moderate agreement about an underlying model of shared knowledge (Weller 2007). As with Noatak, I did not find any correlation between individual knowledge score and age or individual knowledge score and number of years spent as an active fisherman, using Pearson's correlation coefficient. There is also no correlation between individual knowledge score and gender, using a one-way ANOVA. This indicates that there are no easily identifiable subgroups of people that show systematic differences in responses. Again, the lack of sub-groups is expected since our sampling frame included those in the community who were older (over 40 years) and experienced fishers.

Table 6.2 Estimated answers to propositions with frequency of response among Selawik informants

#[5]	Proposition	Estimated answer	Frequency of response (%)
C1	Spring floods are less common now than they were 20 to 30 years ago.	disagree	54
C2	Break-up usually happens earlier now than it used to happen 20 to 30 years ago.	agree	67
C3	Big break-ups don't happen as much now; the ice just melts out.	agree	83
C4	The rivers are shallower now than they were about 20 to 30 years ago.	agree	71
C5	The number of sandbars in the river has not changed over the past 20 to 30 years ago.	disagree	75
C6	There is more erosion of the river banks now than there was 20 to 30 years ago.	agree	100

[5] Again, propositions labeled with a C indicate the propositions asked to both communities and S is used to label Selawik-specific propositions.

Table 6.2 continued

C7	Changing water levels make it more difficult to access fishing spots.	agree	67
C8	There is the same number of beavers here now than there was 20 to 30 years ago.	disagree	96
C9	Beaver dams interfere with fish movement more now than they used to.	agree	96
C10	The presence of beavers does not affect water quality.	disagree	96
C11	Summers are cooler now than they were 20 to 30 years ago.	agree	50
C12	During the summer, it tends to rain more now than it did 20 to 30 years ago.	agree	63
C13	The permafrost is thawing more now than 20 to 30 years ago.	agree	96
C14	Thawing permafrost affects the land, river banks and lake edges.	agree	100
C15	Lakes and sloughs are drying.	agree	83
C16	The river and lake water is colder now than it was 20 to 30 years ago.	disagree	75
C17	It usually rains more in the fall now than it did 20 to 30 years ago.	agree	63
C18	Winters are usually warmer now than they were 20 to 30 years ago.	agree	83
C19	On average, there is less snowfall during the winter as there was 20 to 30 years ago.	agree	58
C20	I have not noticed any changes in ice thickness on the lakes and rivers over the last 20 to 30 years.	disagree	96
C21	Overall, the ice is thinner on the lakes and rivers now than it was 20 to 30 years ago.	agree	88
C22	Fall freeze-up tends to happen later than it did 20-30 years ago.	agree	54
C23	It is harder to predict the weather now than it was 20-30 years ago.	agree	67
C24	We catch more fish now that are diseased or deformed than we did 20 to 30 years ago.	agree	71
C25	It is harder to know when fish will move now than it was 20 to 30 years ago.	agree	75
C26	I am able to harvest enough fish to meet my needs and the needs of others I share with.	agree	79
C27	The average size of fish I catch has not changed over the last 20 to 30 years.	agree	58
C28	There are as many fish in our waterways now as there were 20 to 30 years ago.	agree	71
C29	Climate change is affecting the way we live.	agree	83
C30	More access to store foods decreases how much native food people in Selawik eat.	agree	88

Table 6.2 continued

C31	I worry about the changes I am noticing in the environment.	agree	79
C32	I worry about the high costs of gas and equipment.	agree	96
C33	The high cost of food and fuel increases our need for subsistence foods.	agree	96
S34	The abundance of qalupiaq (whitefish) in the Selawik area has not changed dramatically over the past 20 to 30 years.	disagree	50
S35	There are less qalupiaq (whitefish) than there were about 20 to 30 years ago.	agree	50
S36	Late fall freeze-up causes difficulty for aging fish outside.	agree	79
S37	In the spring, the water tends to gets too warm to keep fishing earlier now than it did 20 to 30 years ago.	agree	79
S38	The timing of qalupiaq (whitefish) movement has not changed over the past 20 to 30 years.	disagree	58
S39	It is getting harder to predict when the qalupiaq (whitefish) will show up.	agree	63
S40	Beaver block the movement of qalupiaq (whitefish) to lakes and streams.	agree	96
S41	The amount of open water on the river in winter has not changed over the past 20 to 30 years.	agree	88
S42	More boats run aground on account of low water levels now than they did 20 to 30 years ago.	agree	79
S43	Break-up is less predictable than it was 20-30 years ago.	agree	79
S44	I have not noticed any changes in the weather over the past 20 to 30 years.	disagree	75

While Selawik displays slightly less agreement overall to the 44 propositions concerning observations of climate change, additional important drivers of change, and impacts on subsistence fishing practices, we can see strong patterns of agreement about certain observations (Table 6.2). Specifically, there is 100% agreement that there is more erosion along the river banks now compared to twenty to thirty years earlier (C6) and that thawing permafrost is affecting river banks and lake edges (C14). There is over 90% agreement about observations of increasing beaver abundance and the impacts of beaver on water quality and fish movement (C8-10 and S40). There is also over 90% agreement that the economic challenges of purchasing gas and equipment are worrying and the expense of store foods increases people's reliance on local food (C32 and C33). We also

found significant agreement that thawing permafrost and thinner ice conditions are being observed by resource users in Selawik (C13, C20, and C21).

For some propositions we found marginal agreement among Selawik informants. In particular, only 50% of the responses observed changes in whitefish abundance (S33 and S34). During interviews, informants frequently noted that they struggled to catch whitefish when setting nets in the spring and fall at their fish camps. Informants suggested that whitefish abundance around the Selawik area was decreasing. Based on the cultural consensus data, however, there is not agreement about an overall decrease in whitefish abundance in the Selawik area. When answering the propositions, informants described what they noticed in the waterways around their family's traditional fishing camp. It appears that the lack of agreement about changing whitefish abundance is related to the fact that residents of Selawik are harvesting fish at disparate locations and observing different patterns of change at those locations. This subsistence pattern contrasts with Noatak's, where fishermen harvest Dolly Varden in a few shared locations and there is agreement about decreasing abundance.

There is less agreement in Selawik about observations of changing weather conditions compared to Noatak. For example, 50% of respondents agreed that summers are cooler now compared to twenty to thirty years ago (C11) whereas in Noatak 96% of informants disagreed. Similarly, 58% of Selawik respondents agreed that there is less snowfall on average now compared to twenty to thirty years ago (C18) whereas in Noatak 84% of informants agreed. While conducting the surveys in Selawik, we found that some respondents referenced the seasonal conditions of recent years when forming their response. For example, respondents would commonly mention that Selawik experienced heavy snowfall last winter and therefore, they disagreed with C18. When conducting the survey, we frequently reminded informants that we were asking about overall patterns of change during a twenty to thirty year period, but some informants would revert back to referencing particular years. We did not find this to occur to such an extent in Noatak.

Therefore, we suspect that weather conditions during the recent seasons more heavily influenced the data collected in Selawik than in Noatak.

We also found marginal agreement about the frequency of spring floods and changing timing of fall freeze-up (C1 and C22, respectively). When we asked informants if they thought spring floods are less common now compared to twenty to thirty years ago, some noted that a man-made channel constructed in the 1960s has reduced flooding and agreed with the proposition. Others noted that there was particularly high water this past spring and disagreed with the proposition. Overall, 54% of the informants disagreed that spring floods are less common, which indicates that there was no consensus about this particular observation. We also found that there was no consensus about changes in the timing of fall freeze-up. Just over half (54%) of the informants agreed that fall freeze-up is now later than it was twenty to thirty years ago. Several informants noted that the timing of the first ice formation on the river is about the same, but the ice is taking longer to thicken. Others mentioned that the timing of the first freeze-up is about the same, but in recent years the ice has melted later in the fall after the initial freeze-up, which is a new phenomenon. A third group of informants noted that the timing of freeze-up is always variable, depending on water level, temperature, and wind patterns.

Overall, we found there is consensus among Selawik respondents about observations of a total environment of change and impacts on subsistence fishing practices. However, it appears that there is less agreement among Selawik respondents compared to the level of agreement among Noatak respondents. A variety of factors may explain this discrepancy. First, we found that Selawik fishermen are harvesting resources in very disparate locations and their responses were often based on observations of change at particular locations. Second, we found that some Selawik respondents tended to focus on recent weather conditions when forming their responses while others focused on overall patterns of change, which affected the level of agreement about particular propositions. We did not see this pattern among Noatak informants.

6.3 Combined analysis: Noatak and Selawik

An analysis of the response matrix containing Noatak and Selawik informants' responses to 33 shared propositions reveals the two communities have a high level of agreement about observations of total environment of change and impacts on subsistence practices. Both the covariance method and the matches method showed a good fit to the consensus model, which eigenvalue ratios of 4.7 and 5.6, respectively. Using the covariance method, we found an average competency of 0.56 (SD=0.17). Using the matches method, we found an average competency of 0.61 (SD=0.18). Average competency scores over 0.5 indicate moderate agreement about an underlying model of shared knowledge (Weller 2007). The two methods produced the same estimated answers, except for C2 and C17. The description of analyses below uses results from the covariance method. Both methods indicate a good fit of the Noatak and Selawik combined data to the consensus model, but I chose to focus on the covariance method because the matches method is more sensitive to response bias and our data have an appropriate balance between positive and negative items (67% agree and 33% disagree in estimated answers) for the covariance method (Weller 2007). The answers to the propositions estimated by the covariance methods are presented in Table 6.3, along with the frequency of response.

Table 6.3 Estimated answers to propositions with frequency of response among Selawik and Noatak informants

#	Proposition	Culturally correct response	Frequency of response (%)
C1	Spring floods are less common now than they were 20 to 30 years ago.	agree	53
C2	Break-up usually happens earlier now than it used to happen 20 to 30 years ago.	disagree	51
C3	Big break-ups don't happen as much now; the ice just melts out.	agree	86
C4	The rivers are shallower now than they were about 20 to 30 years ago.	agree	86
C5	The number of sandbars in the river has not changed over the past 20 to 30 years ago.	disagree	80
C6	There is more erosion of the river banks now than there was 20 to 30 years ago.	agree	94

Table 6.3 continued

C7	Changing water levels make it more difficult to access fishing spots.	agree	71
C8	There is the same number of beavers here now than there was 20 to 30 years ago.	disagree	96
C9	Beaver dams interfere with fish movement more now than they used to.	agree	92
C10	The presence of beavers does not affect water quality.	disagree	94
C11	Summers are cooler now than they were 20 to 30 years ago.	disagree	73
C12	During the summer, it tends to rain more now than it did 20 to 30 years ago.	disagree	69
C13	The permafrost is thawing more now than 20 to 30 years ago.	agree	96
C14	Thawing permafrost affects the land, river banks and lake edges.	agree	98
C15	Lakes and sloughs are drying.	agree	84
C16	The river and lake water is colder now than it was 20 to 30 years ago.	disagree	76
C17	It usually rains more in the fall now than it did 20 to 30 years ago.	disagree	49
C18	Winters are usually warmer now than they were 20 to 30 years ago.	agree	84
C19	On average, there is less snowfall during the winter as there was 20 to 30 years ago.	agree	65
C20	I have not noticed any changes in ice thickness on the lakes and rivers over the last 20 to 30 years.	disagree	84
C21	Overall, the ice is thinner on the lakes and rivers now than it was 20 to 30 years ago.	agree	80
C22	Fall freeze-up tends to happen later than it did 20-30 years ago.	agree	67
C23	It is harder to predict the weather now than it was 20-30 years ago.	agree	69
C24	We catch more fish now that are diseased or deformed than we did 20 to 30 years ago.	agree	63
C25	It is harder to know when fish will move now than it was 20 to 30 years ago.	agree	71
C26	I am able to harvest enough fish to meet my needs and the needs of others I share with.	disagree	51
C27	The average size of fish I catch has not changed over the last 20 to 30 years.	agree	61
C28	There are as many fish in our waterways now as there were 20 to 30 years ago.	disagree	51
C29	Climate change is affecting the way we live.	agree	86
C30	More access to store foods decreases how much native food people in (Selawik or Noatak) eat.	agree	90

Table 6.3 continued

C31	I worry about the changes I am noticing in the environment.	agree	84
C32	I worry about the high costs of gas and equipment.	agree	98
C33	The high cost of food and fuel increases our need for subsistence foods.	agree	98

We can see there is very strong agreement between informants in Noatak and Selawik about certain observations of change (Figure 6.1). In particular, there is over 90% agreement among all the informants in Noatak and Selawik that there is more erosion of the river banks now compared to twenty to thirty years ago (C6), abundances of beaver are changing and these changes affect fish movement and water quality (C8-10), and permafrost is thawing more now compared to twenty to thirty years ago which has implications for river banks and lake edges (C13 and C14). A majority (80%) or more of the informants agreed to the following observations of changing environmental conditions: big break-up events are less frequent (C3), river water levels are shallower (C4), lakes and sloughs are drying (C15), winter temperatures are warmer (C18), ice is thinner on the lakes and rivers (C21), and climate change is affecting people's lives (C29).

Observation	Noatak (% agree)	Selawik (% agree)
Changing nature of break-up	88	83
Shallower river level	100	71
Increasing erosion	88	100
Changing beaver abundance	96	96
Thawing permafrost	96	96
Warmer winter temperatures	84	83
Drying lakes and sloughs	84	83
Worry about environmental changes	88	79
Worry about high cost of gas and equipment	100	96

Figure 6.1 Observations of change with a high level of agreement among Noatak and Selawik informants. Large circles represent high agreement (above 80%) and medium-sized circles represent moderate agreement (51-80%).

We also found significant agreement about additional drivers of change affecting subsistence practices. A large majority (90%) of informants agreed that increasing access to store foods is related to decreasing consumption of local foods (C30). We also found that there are a larger proportion of informants (98%) who worry about the high cost of gas and equipment than who worry about the changes they the noticing in the environment (84%). This last finding further supports the ethnographic data demonstrating that socioeconomic factors currently play a stronger role than climate change in terms of impacting the sustainability of subsistence practices and subsistence-based remote villages. While interview data and cultural consensus data support the conclusion that residents may be relying less on subsistence foods today compared to the past, we found that high costs of living in these rural communities is perceived to increase people's need for subsistence foods (C33).

While the data support the conclusion that there is overall consensus among active and knowledgeable fishers in Noatak and Selawik, some observations of change were not

widely shared (Figure 6.2). We did not find consensus about the timing of spring break-up (C2) and the frequency of spring floods (C1). Both community specific analyses revealed marginal consensus about these propositions, so it is expected that the combined data also show a lack of agreement. We also found a lack of agreement about observations of changing precipitation patterns. In Noatak, informants noted that summers are drier now compared to twenty to thirty years ago, and 100% of the informants disagreed that it tends to rain more in the summer (C12). In Selawik, recent rainy summers influenced informants' answers, and 63% agreed that it now tends to rain more in the summer compared to twenty to thirty years ago. While Noatak informants clearly shared the observation that summers are drier now compared to the past, we did not find a clear agreement in Selawik. There was also a lack of agreement about increasing rain during the fall months (C17). In Noatak, the majority of informants disagreed that it now rains more in the fall, while in Selawik the majority of informants agreed that it now rains more in the fall. The lack of agreement between the two communities could be related to regional differences in weather patterns. It may also be related to the fact that it is difficult for people to correctly detect changing average rainfall patterns over a period of several decades or that there is so much variation that "averages" are difficult to perceive. As discussed above, we found that some informants in both communities, but particularly in Selawik, based their responses to propositions about precipitation on memories of conditions in particular years instead of overall patterns.

Observation	Noatak (% agree)	Selawik (% agree)
Later fall freeze-up	80	50
Earlier break-up	32	67
More rain during fall months	40	63
Changing fish abundance	72	29
Able to harvest enough fish	20	79
Increasing frequency of disease	56	71

Figure 6.2 Observations of change with low agreement among Noatak and Selawik informants. Medium-sized circles represent moderate agreement (51-80%) and small circles represent marginal agreement (50% and lower).

We also found marginal agreement about changing fish abundance, increasing prevalence of diseased fish, and changing average fish body size (C28, C24, and C27, respectively). In Noatak, informants observed declines in the abundance of Dolly Varden, an extremely important local subsistence resource. In Noatak, 72% of informants disagreed that there are as many fish in the waterways now compared to twenty to thirty years ago. Further, 80% of informants said that they were not able to harvest enough fish to meet their needs (C26). In Selawik, a community located in a different ecological zone, reliant upon different fish species for their subsistence needs, informant responses revealed a different pattern. A majority of Selawik informants (71%) agreed that there are as many fish in their waterways now compared to twenty to thirty years ago. Further, 79% agreed that they are able to harvest enough fish to meet their needs. While some informants noted a localized decline in whitefish, as discussed above, it does not appear that people are noticing an overall decline in locally important fish species in Selawik. The low level of combined agreement about fish disease and changing body size is consistent with our findings of low agreement about these propositions in each community.

6.4 Multidimensional scaling

The agreement matrix that indicates the proportion of similarities between each pair of respondents was submitted to non-metric multidimensional scaling in UCINET (Borgatti et al. 2002) to represent graphically the similarity of response patterns between Noatak and Selawik informants. Figure 6.3 shows the first two dimensions of the multidimensional scaling solution (stress=0.24, iterations=20). The stress indicates the amount of distortion that occurs when the data is represented in a particular number of dimensions. Generally, a stress greater than 0.15 is considered unacceptable (Borgatti 1997). Despite the high stress value, patterns can still be detected in the figure below. The Noatak informants distinctly cluster at the top of the plot while the Selawik informants are generally located at the bottom of the plot. This suggests that Noatak informants responded more similarly to each other than to Selawik informants. We can also see that Noatak informants are clustered more tightly together than Selawik informants, which suggests that Noatak informants have a higher level of agreement among themselves than do Selawik informants. This last point is supported by individual community analyses. As previously discussed, the response matrix from Noatak produced a higher eigenvalue ratio than did Selawik, which indicates more agreement. Although we see the respondents from each community cluster amongst themselves, we also see some overlap. This reflects the overall similarity of their responses.

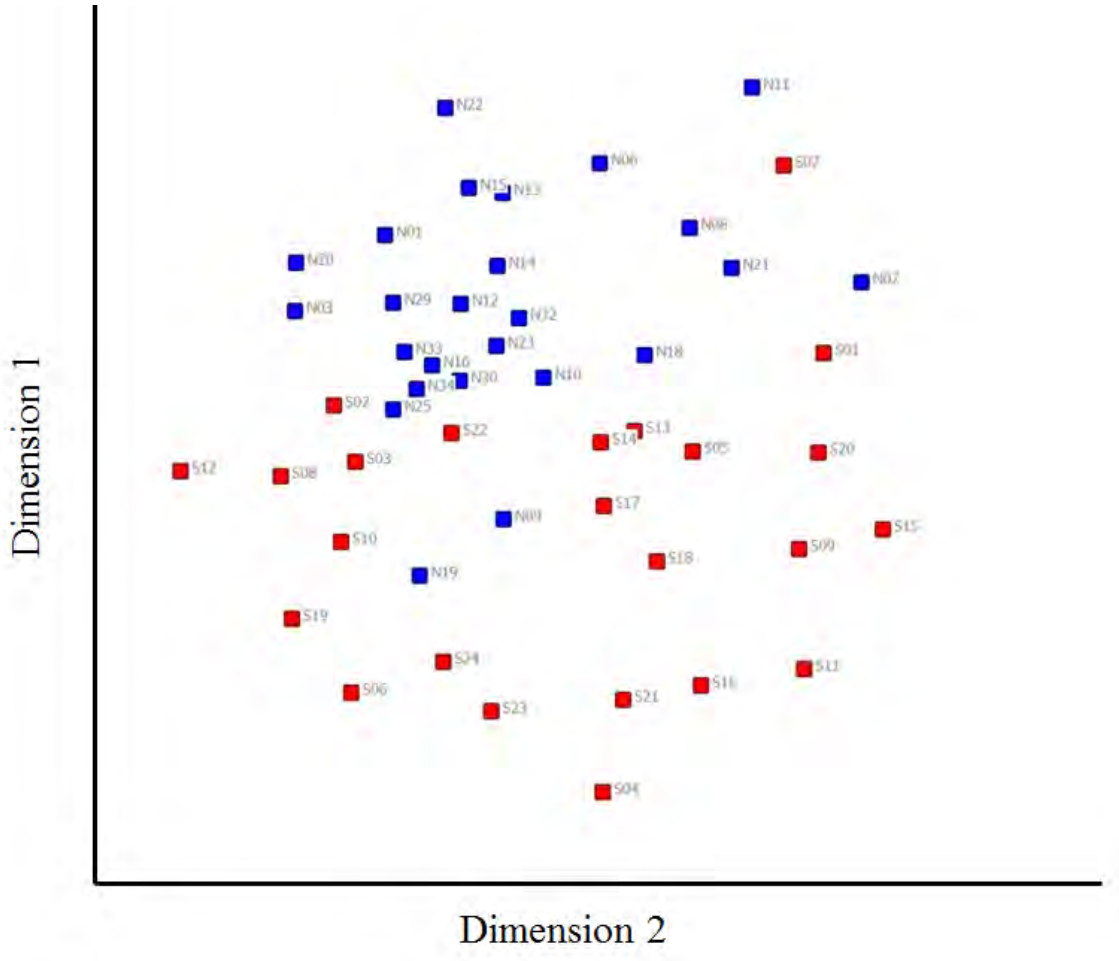

Figure 6.3 Nonmetric multidimensional scaling of Selawik respondents (S; red squares) and Noatak respondents (N; blue squares)

6.5 Conclusions

Cultural consensus analysis is a useful method for systematically seeking regularities in perceptions and knowledge in cross-cultural contexts. Here, we used cultural consensus analysis to measure the degree of agreement among knowledgeable fishers in Noatak and Selawik about observations of a total environment of change and impacts on subsistence practices. We first analyzed the response matrices of the two communities separately. We found that both Noatak and Selawik display an overall consensus about observations of change, but Selawik informants have a more varied response pattern than does Noatak informants. Analysis of all informants' responses to the propositions presented in both

communities reveals that there is an overall consensus about observations of a total environment of change. Based on this information, we can say that many environmental changes, such as thawing permafrost, increasing erosion, and increasing abundances of beaver, are widely perceived across the region and have implications for subsistence practices in many communities. Other changes, such as drier weather, appear to be occurring at a local scale and are perceived differently from community to community.

We found cultural consensus to be a very useful tool for providing a quantitative measure of local perceptions and knowledge of changing conditions, but also confronted several challenges. Cultural consensus analysis assumes that each question is equally difficult (Weller 2007), which means that the likelihood that an informant knows the answer to a proposition should be equal throughout the instrument. Despite careful design and pilot testing, we found that informants faced difficulty answering several particular questions. We asked informants about changing water temperature in both communities (C16). Many told us they do not swim, and thus do not have knowledge of water temperature changes. In the Noatak survey, N39 asked about changing water levels at a particular tributary of the Noatak River (the Kelly River). Those who do not travel to the Kelly River felt that they were unable to answer that question. We also encountered issues with how informants interpreted the questions when we implemented the survey instrument. Some informants tended to focus on recent seasons or particularly anomalous events when answering the propositions, while others seemed to more easily comprehend that we were asking about changes to average conditions (as noted above this occurred more frequently among Selawik respondents). The lack of continuity between how informants interpreted the intent of the propositions may have affected our results. Lastly, it was a challenge when designing the survey instrument to balance the number of positive and negative propositions. As discussed previously, it is desirable to have a roughly 50-50 split between positive and negative propositions, but a 30-70 split is acceptable (Weller 2007). In trying to achieve this balance, we ended up with some awkwardly worded propositions, such as C8 and C10. In the future, it may be wise to use a multiple choice

instead of dichotomous survey instrument to test agreement about observations about environmental change, in order to avoid this issue.

The combination of in-depth ethnographic interviews, which are limited to qualitative analysis, and cultural consensus methods, provides a rich body of information about residents' observations and perceptions of a total environment of change. The cultural consensus analysis component of this project allowed us to explore the observations and knowledge of a broader group of people, beyond those who participated in in-depth interviews. To our knowledge, this is first use of cultural consensus methods to assess agreement about perceptions and observations of climate and related-ecological shifts. As documented in this chapter, these methods are a powerful tool to provide a quantitative assessment of agreement, or disagreement about certain domains of knowledge. Here, rather than a collection of "anecdotal" information that is often dismissed within scientific communities, we provide a robust measure of agreement within and between two communities in the northwest Arctic about climate change and related shifts. Used as one component of a broader ethnographic approach, cultural consensus analysis provides a new direction for exploring traditional ecological knowledge and observations of environmental change.

Chapter 7
Synthesis and future directions

7.0 Arctic communities and scientific inquiry: emerging collaborations

The practice of scientists using indigenous, or traditional, knowledge in their research has emerged as a common endeavor in the Arctic over the past few decades (Huntington 2011). A growing number of studies have attempted to understand indigenous knowledge and perceptions of climate change, primarily in regions expected to experience the most pronounced changes (Riedlinger and Berkes 2001, Nichols et al. 2004, Hinzman et al. 2005, Berkes 2008). Scientists increasingly are finding value in collaborating with active subsistence resource users in the Arctic region, and a growing political awareness has led to increased recognition of local knowledge and ideas. Numerous examples of how such collaborations between scientists and Arctic residents are evident in recent publications. In Sweden and Norway, Sami reindeer herders have worked with scientists to document snow conditions (Riseth et al. 2011). In Sachs Harbour, in the western Canadian Arctic, researchers have sought the expertise of Inuit knowledge holders as a source of climate history and baseline data (Riedlinger and Berkes 2001). Alaska Tlingit communities and elders from Yukon First Nations have provided observations about glaciological conditions to scientists where a written record was limited (Cruikshank 2001). Documentation of Arctic communities' experiences with climate change has lent insight into local level vulnerabilities to changing climatic conditions (Berkes and Jolly 2002). This thesis, following the lead of these and other research projects, focuses on the evaluation of Iñupiaq observations and perceptions of climate change and the consequences of these changes on subsistence fishing activities in the communities of Noatak and Selawik, in northwest Alaska. This endeavor contributes to the ongoing discussion of how best to assess the current and future impacts of climate change in Arctic communities in a way that is both meaningful at a local level and has broader utility to inform scientific inquiry into the global issue of climate change.

7.1 Synthesis

Using in-depth ethnographic interviews, participant observation, and cultural consensus analysis, we explored local knowledge and perceptions of climate change and additional changes facing the communities of Noatak and Selawik. These communities possess an abundant knowledge base about current and historical weather conditions, ecological conditions related to important subsistence fish species, harvesting and processing of fish, as well as the linkages and relationships between these phenomena. We found consistent agreement about a range of perceivable environmental changes affecting subsistence fisheries in this region. Lower water levels hinder boating access to important fishing locations. Unpredictable weather conditions challenge traditional fish processing methods. Increasingly warm fall temperatures and freeze-thaw cycles create dangerous travel conditions and limit mobility. Changing fish abundances and movement patterns undermines the utility of a body of knowledge about local ecological conditions that has developed over generations. Beaver, which are reported to be increasing in abundance around both Noatak and Selawik can dramatically reshape the aquatic environment, with implications for fish health and abundance, as well as human health. Overall, we found a high level of agreement, based on cultural consensus analysis, about the observations of environmental shifts between and among Noatak and Selawik expert informants.

One of the more important findings of this thesis is that these observations of environmental changes are not perceived alone, but are experienced in the context of accompanying social changes that are continually reshaping rural Alaskan communities and subsistence economies. The rate of social, economic, and political change in Arctic communities has had a profound influence upon the way in which communities and individuals interact with the environment (Condon et al. 1995). To properly assess and understand the impacts of climate change on the subsistence practices in Arctic communities, we must also consider the total environment of change that is dramatically shaping the relationship between people, communities, and their surrounding environment. The consequences of climate shifts for community residents are not quantifiable from the physical dimensions of the shifts alone, but require an

understanding of the human dimensions through which they are experienced. Local informants do not identify “the environment” as something that is perceived in isolation of lived experience.

Given the increasing prevalence of climate change research, it is especially imperative to put climate change in context as one driver of change among a suite of stressors currently being experienced in Arctic Alaska. Locally situated ethnographic research in Noatak and Selawik lends insight into the complex interactions between perceptible climatic changes and broad social, economic, and political changes and the combined impacts of these changes on subsistence economies in Arctic Alaska. Our ethnographic findings demonstrate that the dramatic socioeconomic and cultural transitions taking place in communities in northwest Alaska currently take priority over climate change in terms of impacting the sustainability of subsistence practices and subsistence-based remote villages. However, we must pay attention to the linkages between climatic shifts and the socioeconomic conditions facing rural communities. For example, we see the linkage of environmental, economic, and social factors in informants’ discussions of lower water levels in the Noatak River. Lower water levels force fishermen to burn more gas because “river shortcuts” are unavailable. Traveling in shallow water presents risks for damaging boats and engines. Decreasing participation in subsistence practices among younger generation leads to less knowledge transfer. As a result, fewer people know the river system well, further contributing to potential damage incurred because of low water levels. The lack of well-equipped mechanics, low income levels, and exorbitantly high costs of shipping to rural villages often prevents repair or replacement of broken parts, limiting future fishing access. Similarly, seasonal and fish movement shifts demonstrate the linked social-ecological subsistence system experienced in Noatak and Selawik. Less predictable weather and fish movement timing, combined with increasing participation in the wage economy has narrowed the windows of opportunity for fish harvesting and processing.

Within science-based ways of knowing, ethnographic approaches that engage local perceptions of change are necessary to generate meaningful understandings communities' experiences with climate change, and certainly in this case, with a total environment of change. Understanding and anticipating the consequences of climate change requires knowledge about the interactions of climate change and other social and environmental stresses facing communities (Huntington et al. 2007, Forbes et al. 2009). This is particularly relevant in the Alaska context, where rural communities are increasingly inundated with researchers studying various aspects of climate change.

7.2 Moving forward

While conducting fieldwork in both Noatak and Selawik, we came across many researchers from other disciplines at the University of Alaska Fairbanks and researchers from other institutions who were investigating climate change. These researchers often sought input from local residents and experienced subsistence harvesters. On more than one occasion we had to explain to an informant who had recently spoken to a different researcher about environmental changes that we were part of an entirely different research project. With so much attention being paid to climate change in rural Alaska, we have much to gain from developing research projects that are both useful and relevant to community residents. However, the research community must use caution to avoid creating "research fatigue," where scientists are seen as more of a bother than as partners in addressing local environmental challenges.

Documenting local knowledge, observations, and cultural contexts provides a powerful means to begin understanding local concerns. For example, in Noatak, a large number of informants inquired about why they were experiencing decreased Dolly Varden harvests. We also found a high level of interest in both communities about increasing beaver abundances and the effects of beaver on water quality, water levels, and fish health. While this project was not intended to explore the biology of Dolly Varden nor document the population dynamics of beaver in northwest Alaska, it provided an opportunity for local resource users to voice their concerns and desires for future research endeavors. As

researchers, we need to listen to the concerns that locals raise even if they extend beyond the narrow focus of the current research. It is our responsibility to spread these concerns to a wider audience so that future research can focus on answering locally raised questions.

A necessary but often lacking component of research conducted in rural Alaska communities is the sharing of information to local residents in a way that is relevant and useful. Based on my experience in northwest Alaska communities, I found a significant disconnect between management and research entities and local resource users in terms of reporting research findings. I heard mention of many research projects, both past and present, of which local residents knew the general questions, but felt unsure of the outcomes of the research. For example, in Selawik, many active fishermen noted that pike in the Selawik area contain high mercury levels. During interviews, informants described a researcher who traveled around the Selawik area measuring mercury levels in pike. It became apparent that the data gained from this project was not adequately shared with resource users. As a result, I was left with the impression that an idea had been instilled that consumption of pike was a potential health hazard, but there was lacking follow-up and local residents were left without sufficient information to make informed decisions about safe consumption levels. Since pike is a highly significant subsistence resource and consumed widely in the community, it is imperative that information like mercury levels be easily accessible to community residents. Many informants voiced their frustration with the way in which researchers have conducted projects in and around rural communities and have inadequately shared research findings. I began to address this concern by holding community meetings to share my research findings and also took the time to share my research findings with community members in individual conversations.

The increasingly collaborative nature of scientific projects, where local resource users play an active role in the research process, provides an opportunity to mitigate the issue of a lack of information sharing between researchers and local residents. By including local people in the data collection and interpretation phases of research projects,

researchers can also potentially circumvent the issue of using information in a way that is undesirable and unacceptable to local knowledge holders. True collaboration during the data interpretation and transformation phase involves conversations between local community members and researchers about how final products should look, what information they should include, and how the information should be represented, much before the final phase of publication.

7.3 Concluding comments

In this thesis, I explored two communities' assessment of a total environment of change and the impacts of changing conditions on subsistence fishing practices. The communities shared this knowledge during a series of interviews, cultural consensus surveys, and the additional time I spent in the communities participating in subsistence activities and learning from elders and others. As the project developed, we found that our initial research focus on observations of climate change was insufficiently narrow in scope. Even in our attempts to limit our discussion to observations of "environmental change," informants consistently discussed wide-ranging shifts in ecological, social, cultural, political and economic realms as they are experienced together. Our study that started as a study of climatic and related ecological shifts necessarily grew to explore the total environment of change that is experienced in Noatak and Selawik. In order for meaningful collaboration to continue to occur, it is necessary for other researchers to be open to the notion that their research focus may change, as ours did, based on the evolving interests and concerns of community residents. It also requires the commitment of researchers to be responsive to local needs that arise during research processes.

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Appendix

Semi-structured interview protocol

Background: Age, gender, any specific roles/employment in community, residency history, fishing involvement (past/current), modes of transportation used/owned/shared

Break Up/Open Water Season

Could you tell me about how break up happens here? Is it the same now as when you were young? How has it changed, and how it has impacted how people fish?

- Summer weather patterns and precipitation
- Water levels in rivers/lakes/wetlands
- Water temperature
- Water quality (color, silt load etc.)
- Fish habitats
- Fish health
- Fish movements, abundance, and distribution
- Fish species (declines in expected species, increases in uncommon species)
- Fishing methods or activities (access, timing, gear)
- Fish processing (methods, timing, concerns)
- Fish camp (timing, duration)
- Resource importance (cultural values, sharing)
- Other non-water/non-fish comments (forest fires, other flora and fauna changes)

Freeze Up/Ice Season

Can you tell me about the river freeze-up here? When does this usually happen? What changes have you noticed in the timing of freeze-up?

- Winter weather patterns and precipitation
- Ice thickness and snow depths
- Access and travel routes
- Winter fish movements and distribution
- Fish over-wintering habitats
- Health and quality of winter-caught fish

- Fish species (declines in expected species, increases in uncommon species)
- Winter fishing methods or activities (access, timing, gear)
- Other resources (fur bearers, bear denning, animal movements etc.)
- Fish processing and storage (methods, timing, concerns – any concerns about keeping fish frozen)

Table A.1 Noatak cultural consensus survey (C1-33 combined, N34-44 only presented to Noatak informants)

#	Observations	Agree	Disagree
C1	Spring floods are less common now than they were 20 to 30 years ago.	agree	disagree
C2	Break-up usually happens earlier now than it used to happen 20 to 30 years ago.	agree	disagree
C3	Big break-ups don't happen as much now; the ice just melts out.	agree	disagree
C4	The rivers are shallower now than they were about 20 to 30 years ago.	agree	disagree
C5	The number of sandbars in the river has not changed over the past 20 to 30 years ago.	agree	disagree
C6	There is more erosion of the river banks now than there was 20 to 30 years ago.	agree	disagree
C7	Changing water levels make it more difficult to access fishing spots.	agree	disagree
C8	There is the same number of beavers here now than there was 20 to 30 years ago.	agree	disagree
C9	Beaver dams interfere with fish movement more now than they used to.	agree	disagree
C10	The presence of beavers does not affect water quality.	agree	disagree
C11	Summers are cooler now than they were 20 to 30 years ago.	agree	disagree
C12	During the summer, it tends to rain more now than it did 20 to 30 years ago.	agree	disagree
C13	The permafrost is thawing more now than 20 to 30 years ago.	agree	disagree
C14	Thawing permafrost affects the land, river banks and lake edges.	agree	disagree
C15	Lakes and sloughs are drying.	agree	disagree
C16	The river and lake water is colder now than it was 20 to 30 years ago.	agree	disagree
C17	It usually rains more in the fall now than it did 20 to 30 years ago.	agree	disagree

Table A.1 continued

C18	Winters are usually warmer now than they were 20 to 30 years ago.	agree	disagree
C19	On average, there is less snowfall during the winter as there was 20 to 30 years ago.	agree	disagree
C20	I have not noticed any changes in ice thickness on the lakes and rivers over the last 20 to 30 years.	agree	disagree
C21	Overall, the ice is thinner on the lakes and rivers now than it was 20 to 30 years ago.	agree	disagree
C22	Fall freeze-up tends to happen later than it did 20-30 years ago.	agree	disagree
C23	It is harder to predict the weather now than it was 20-30 years ago.	agree	disagree
C24	We catch more fish now that are diseased or deformed than we did 20 to 30 years ago.	agree	disagree
C25	It is harder to know when fish will move now than it was 20 to 30 years ago.	agree	disagree
C26	I am able to harvest enough fish to meet my needs and the needs of others I share with.	agree	disagree
C27	The average size of fish I catch has not changed over the last 20 to 30 years.	agree	disagree
C28	There are as many fish in our waterways now as there were 20 to 30 years ago.	agree	disagree
C29	Climate change is affecting the way we live.	agree	disagree
C30	More access to store foods decreases how much native food people in Noatak eat.	agree	disagree
C31	I worry about the changes I am noticing in the environment.	agree	disagree
C32	I worry about the high costs of gas and equipment.	agree	disagree
C33	The high cost of food and fuel increases our need for subsistence foods.	agree	disagree
N34	The abundance of trout in the Noatak River has not changed much over the past 20 to 30 years.	agree	disagree
N35	There are fewer trout in the Noatak River now than there were 20 to 30 years ago.	agree	disagree
N36	Late fall freeze-up causes difficulty for aging fish outside.	agree	disagree
N37	Dirty water in the spring doesn't last as long as it did 20 to 30 years ago.	agree	disagree
N38	There are more whitefish (iqalupiaq) in the Noatak River now than there were 20 to 30 years ago.	agree	disagree
N39	The Kelly River is drier now than it was 20 to 30 years ago.	agree	disagree
N40	Beaver block the movement of trout to lakes and streams where they spawn.	agree	disagree

Table A.1 continued

N41	The amount of open water on the river in winter has not changed over the past 20 to 30 years.	agree	disagree
N42	More boats run aground on account of low water levels now than they did 20 to 30 years ago.	agree	disagree
N43	People now travel farther to find good fishing spots than they did 20 to 30 years ago.	agree	disagree
N44	There are now more thaw slumps on the banks of the Noatak River than there were 20 to 30 years ago.	agree	disagree

Table A.2 Selawik cultural consensus survey (C1-33 combined, S34-44 only presented to Selawik informants)

#	Observations	Agree	Disagree
C1	Spring floods are less common now than they were 20 to 30 years ago.	agree	disagree
C2	Break-up usually happens earlier now than it used to happen 20 to 30 years ago.	agree	disagree
C3	Big break-ups don't happen as much now; the ice just melts out.	agree	disagree
C4	The rivers are shallower now than they were about 20 to 30 years ago.	agree	disagree
C5	The number of sandbars in the river has not changed over the past 20 to 30 years ago.	agree	disagree
C6	There is more erosion of the river banks now than there was 20 to 30 years ago.	agree	disagree
C7	Changing water levels make it more difficult to access fishing spots.	agree	disagree
C8	There is the same number of beavers here now than there was 20 to 30 years ago.	agree	disagree
C9	Beaver dams interfere with fish movement more now than they used to.	agree	disagree
C10	The presence of beavers does not affect water quality.	agree	disagree
C11	Summers are cooler now than they were 20 to 30 years ago.	agree	disagree
C12	During the summer, it tends to rain more now than it did 20 to 30 years ago.	agree	disagree
C13	The permafrost is thawing more now than 20 to 30 years ago.	agree	disagree
C14	Thawing permafrost affects the land, river banks and lake edges.	agree	disagree
C15	Lakes and sloughs are drying.	agree	disagree
C16	The river and lake water is colder now than it was 20 to 30 years ago.	agree	disagree

Table A.2 continued

C17	It usually rains more in the fall now than it did 20 to 30 years ago.	agree	disagree
C18	Winters are usually warmer now than they were 20 to 30 years ago.	agree	disagree
C19	On average, there is less snowfall during the winter as there was 20 to 30 years ago.	agree	disagree
C20	I have not noticed any changes in ice thickness on the lakes and rivers over the last 20 to 30 years.	agree	disagree
C21	Overall, the ice is thinner on the lakes and rivers now than it was 20 to 30 years ago.	agree	disagree
C22	Fall freeze-up tends to happen later than it did 20-30 years ago.	agree	disagree
C23	It is harder to predict the weather now than it was 20-30 years ago.	agree	disagree
C24	We catch more fish now that are diseased or deformed than we did 20 to 30 years ago.	agree	disagree
C25	It is harder to know when fish will move now than it was 20 to 30 years ago.	agree	disagree
C26	I am able to harvest enough fish to meet my needs and the needs of others I share with.	agree	disagree
C27	The average size of fish I catch has not changed over the last 20 to 30 years.	agree	disagree
C28	There are as many fish in our waterways now as there were 20 to 30 years ago.	agree	disagree
C29	Climate change is affecting the way we live.	agree	disagree
C30	More access to store foods decreases how much native food people in Selawik eat.	agree	disagree
C31	I worry about the changes I am noticing in the environment.	agree	disagree
C32	I worry about the high costs of gas and equipment.	agree	disagree
C33	The high cost of food and fuel increases our need for subsistence foods.	agree	disagree
S34	The abundance of qalupiaq (whitefish) in the Selawik area has not changed dramatically over the past 20 to 30 years.	agree	disagree
S35	There are less qalupiaq (whitefish) than there were about 20 to 30 years ago.	agree	disagree
S36	Late fall freeze-up causes difficulty for aging fish outside.	agree	disagree
S37	In the spring, the water tends to gets too warm to keep fishing earlier now than it did 20 to 30 years ago.	agree	disagree
S38	The timing of qalupiaq (whitefish) movement has not changed over the past 20 to 30 years.	agree	disagree

Table A.2 continued

S39	It is getting harder to predict when the qalupiaq (whitefish) will show up.	agree	disagree
S40	Beaver block the movement of qalupiaq (whitefish) to lakes and streams.	agree	disagree
S41	The amount of open water on the river in winter has not changed over the past 20 to 30 years.	agree	disagree
S42	More boats run aground on account of low water levels now than they did 20 to 30 years ago.	agree	disagree
S43	Break-up is less predictable than it was 20-30 years ago.	agree	disagree
S44	I have not noticed any changes in the weather over the past 20 to 30 years.	agree	disagree

Table A.3 Demographic questions presented to each informant

What year were you born?				
What is your occupation?				
How long have you lived in this village?				
Are you currently an active fisherman?				
How many years have you been an active fisherman?				
How would you rate you fishing activity in the past?	very active	somewhat active	occasionally fish	rarely fish
How would you rate your current (over the past 1-5 years) fishing activity:	very active	somewhat active	occasionally fish	rarely fish
What kind of fish do you catch and/or process?	salmon	whitefish	other:	
What time of year do you go fishing or participate in fishing activities?	summer	fall	winter	spring