BUILDING RESILIENCE TO CLIMATE CHANGE IN RURAL ALASKA: UNDERSTANDING IMPACTS, ADAPTATION AND THE ROLE OF TEK

By

Erin Carey

A practicum submitted in partial fulfillment of the requirements for the degree of Master of Science (Natural Resources and Environment) at the University of Michigan
August, 2009

Faculty Advisors:

Professor Arun Agrawal
Dean Rosina Bierbaum

ABSTRACT

The arctic system is undergoing significant change, warming at twice the rate of the rest of the world due to anthropogenic climate change. Through interviews with Alaska Native communities along the Yukon River, this study documents traditional knowledge relating to the changes that are occurring in the weather and on the landscape, effects on subsistence livelihoods, and adaptation strategies. People observed significant changes, many of which are consistent with conventional scientific studies on ecosystem change in Alaska. They responded to environmental change by spreading risk across resources, space, time and households.

Since many current and historical adaptation practices are embedded in the subsistence lifestyle and fall under federal and state management, this study also explored the effects of management on resilience. Respondents viewed subsistence management regimes as detrimental to livelihoods when they did not prioritize subsistence uses over recreational and commercial uses of natural resources, provide for local involvement in regulatory and management decisions, and when they constrained subsistence harvesters' ability to pursue resources when they were available or most needed. People saw a benefit to agency management of subsistence when management actions supported local priorities, such as predator control. People viewed subsistence management even more favorably when local communities were able to voice concerns and have a role in shaping decisions.

Community resilience to climate change is in part determined by the ability to accumulate knowledge and act collectively, and is enhanced by the ability to participate in the decisions that affect the flow of resources. Therefore, management actions that inhibit the exchange of information and collective action, qualities inherent to many traditional knowledge systems, may undermine the resilience of Alaska Native communities to climate change. However, integrating traditional knowledge with natural resource management and allowing communities to participate in decisions through collaborative and co-management arrangements, if done in a way that allows traditional knowledge to actually shape management outcomes, may enhance resilience.

ACKNOWLEDGEMENTS

I thank Arun Agrawal, Rosina Bierbaum, Terry Chapin, Gary Kofinas, Catherine Benson and the tribal councils of Grayling, Anvik, Shageluk, Holy Cross and Beaver. I would especially like to thank Caroline Brown who enabled my visits to the villages and whose input proved invaluable to the research and writing of this report. Finally, I would like to thank the Doris Duke Charitable Foundation, the Ginsberg Center, the Edna Bailey Sussman Fund, the School of Natural Resources and Environment, and the University of Alaska Fairbanks for their support of this study.

TABLE OF CONTENTS

I. INTRODUCTION

Due primarily to anthropogenic climate change, global temperature is rising at an unprecedented rate. In particular, the arctic system is undergoing significant change, warming at twice the rate as the rest of the world (Global Climate Change Impacts in the United States 2009). Changes to Alaska's arctic and sub-arctic ecosystems and the services they provide are likely to significantly impact society. Indigenous peoples, many of whose livelihood depends on the environment, face potentially enormous challenges to their way of life. The ability to travel over the landscape and harvest a wide variety of wild foods- and the deep connection with the natural environment this entails- is central to Alaska indigenous culture and identity (MEA 2005, AHDR 2004). Although Alaska's indigenous peoples have adapted to variable environmental conditions for millennia (Sabo 1991; Ford et al 2006), location in rapidly changing ecologies, high dependence on wild foods, and various economic and social stressors may combine in ways that influence community resilience to climate change. Resilience, as applied to social ecological systems, refers to a system's ability to withstand shock, self organize and increase its capacity to adapt to future change (Olsson et al 2004). Historically, Alaska's indigenous peoples have been highly resilient to environmental change. Indeed, contemporary subsistence practices and culture are shaped by numerous adaptations to a constantly changing environment. Yet superimposed on a rapidly changing landscape is a relatively rigid subsistence management regime, comprised of a web of federal and state regulations and policies, that is just 50 years old. In light of the projected impacts from climate change in Alaska, subsistence management may play a significant role in influencing local responses to climate change by determining the timing, scope and methodology for many types of subsistence activities.

This paper seeks to identify the coping mechanisms embedded in subsistence practices and elucidate the role of subsistence management in either facilitating or constraining subsistence. The research for this paper focused on four areas: 1) Documenting changes in weather and environment experienced by rural communities; 2) Understanding how these changes have affected subsistence systems and ways of life; 3)

Learning about the strategies of individuals and communities to cope with these changes; and 4) Documenting local perceptions of subsistence management practices. As such, the research for this paper was primarily ethnographic and qualitative, drawing on the observations, experiences and perspectives of 40 individuals in four communities on the lower-middle Yukon River and in one community on the upper Yukon River (Appendix A: Questionnaire). All of the respondents were Alaska Natives, and nearly all were males over the age of 50 and have spent significant amounts of time engaged in subsistence activities (Appendix B: Respondents). Respondents were also asked to discuss personal values with respect to the landscape and the subsistence lifestyle, and their concerns for the future of their way of life. In addition, traditional mapping exercises were conducted with the respondents, to create a visual representation of land use and facilitate discussion of ecological change.

By learning about past and current adaptation practices of the people in these communities and the effects of subsistence management on their livelihood, this paper aims to identify policy and management strategies to enhance the resilience of Alaska's rural communities to climate change.

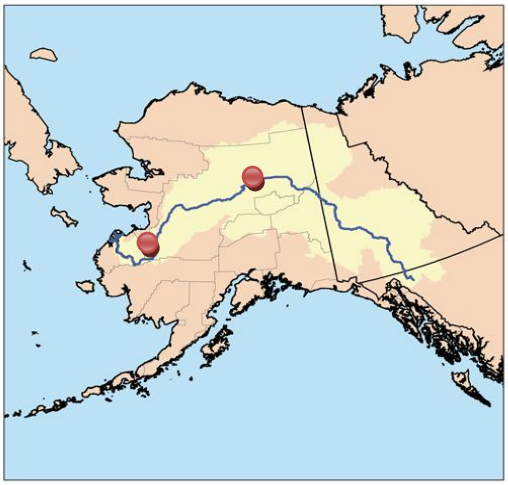
II. BACKGROUND AND STUDY AREA

In the last 50 years, annual average surface air temperature in Alaska has increased by 3.4 degrees Fahrenheit and average winter temperature has increased by 6.3 degrees Fahrenheit (Fitzpatrick et al 2008 in Global Climate Change Impacts in the United States 2009) (see also Appendix C: Climatic trends near study sites). Evidence of warming in Alaska has manifested in numerous ways. Delayed freeze-up of inland rivers and lakes (Global Climate Change Impacts in the United States 2009, ACIA 2005, Hinzman et al 2005), permafrost degradation (Global Climate Change Impacts in the United States 2009, ACIA 2005), land cover change (Sturm et al 2001, Lloyd and Fastie 2002), and changes in wildlife migration (ACIA 2005) have been documented and attributed to anthropogenic climate change. Average surface temperature in Alaska is expected to increase another 3 to 7 degrees Fahrenheit by the middle of the 21st century (Global Climate Change Impacts in the United States 2009) and earlier freeze-up of inland rivers and lakes, increased precipitation during the fall, treeline advance into tundra, continued permafrost degradation, and continued effects on wildlife are all expected to occur this century (ACIA 2005). However, projections for climate change and its effects in the arctic and sub-arctic regions are greatly complicated by uncertainty associated with positive feedbacks, such as ice melt that decreases surface albedo and cloud dynamics that may mitigate surface warming (Overpeck et al 2005). Moreover, anthropogenic climate change increases the probability of abrupt events such as a major slowdown of oceanic thermohaline circulation. Such an event would inevitably force the arctic system past a threshold to a dramatically different climatic and ecological state (Alley et al 2003). The Global Climate Change Impacts in the United States (2009) and the Arctic Climate Impact Assessment Report (ACIA 2005) provide syntheses of many of the changes and impacts for the region.

The research for this paper was conducted in four Alaska Native villages on the lower-middle Yukon and Innoko Rivers: Grayling, Anvik, Shageluk and Holy Cross (also referred to as GASH). In addition, several respondents were interviewed in the village of Beaver on the upper Yukon River in the Yukon Flats area (Map 1). All five villages are

situated in lowland Interior Alaska, a landscape characterized by numerous bogs, streams, lakes and sloughs, open spruce forests and shrubs. Both areas on the Yukon support a rich diversity of wildlife, including moose, many species of migratory waterfowl, beaver and other small game, bears and wolves. Travel over the landscape is greatly inhibited by the vast system of bogs during the spring, summer and fall; therefore travel to and from the villages is conducted primarily by boat and by airplane. During the winter, snowmachines are primarily used to travel over frozen surfaces and snow.

Figure 1. Map of Alaska depicting tudy sites. The GASH villages (left) are closely situated on the lower-middle Yukon River. Beaver (right) is located in the Yukon Flats on the upper Yukon River.



The residents of these villages harvest a wide variety of resources throughout the year. The seasonal availability of plants and animals (e.g., salmon and berries in the summer, moose in the fall, non-salmon fish and furbearers in the winter, and waterfowl in the spring), has shaped an annual subsistence cycle in these villages consisting of patterned movement over the landscape in pursuit of wild foods. Historically, the Athabascan people of the Alaskan interior were organized into semi-nomadic family groups that carried out seasonal patterns of transhumance, often alternating between summer and winter camps. Most villages in the region, including those visited in this study, were founded out of religious and economic pressures to settle near missions and trading posts (Brown et al 2005). Based in these permanent settlements, contemporary residents of the GASH and Yukon Flats villages typically travel to resource harvest

locations on short trips ranging from one to a few days; however, some households continue to maintain seasonal camps away from the village.

The communities in this study all support higher than normal subsistence activity, with each of the communities harvesting averages of 500 to 700 pounds of wild foods per person per year (according to the ADF&G Community Subsistence Information System, the average for rural Alaska is 354 pounds). Moose and salmon are key resources to all of these communities and serve as the main sources of protein for many families. Although moose are of highest importance to most of the informants in this study; salmon- especially chinook salmon- are also highly valued. Historically, moose were not common in western Interior Alaska until around the turn of the 20th century and have always been present in low numbers in the Yukon Flats area (Stephenson 2006). Salmon were the mainstay of many Interior Athabascan communities and were valued for their high protein yield as well as their relative predictability (VanStone 1974). Other wild foods, ranging from blueberries and non-salmon fish species to migratory waterfowl are dietary mainstays in the GASH and Yukon Flats communities. In addition, furbearers, such as marten, beaver, and lynx provide income to trappers and material for clothing and artwork in the villages.

According to the 2000 US census, the population in the five villages ranges from 84 in Beaver to 227 in Holy Cross. The population of the GASH villages is primarily Deg Hit'an Athabascan and Doy Hit'an Athabascan. Beaver's population is primarily Gwich'in Athabascan. The five villages share many common traits in terms of culture and livelihood. Also, the GASH villages are relatively closely situated on the lower-middle Yukon and Innoko Rivers and are highly interconnected through kinship, economic activity, and overlapping resource use areas (Brown et al 2005).

III. THE POLITICAL ECONOMY OF SUBSISTENCE IN ALASKA

It is impossible to understand subsistence in the Interior and throughout Alaska without situating these systems in the broader political context of the Alaska Native Claims Settlement Act (ANCSA) and the Alaska National Interest Lands Conservation Act (ANILCA). In 1971 US Congress, with a growing in interest in enhancing natural resource extraction in Alaska, passed ANCSA, extinguishing indigenous rights to the land and its resources. In exchange, Alaska Native communities were organized into 13 for-profit corporations, were given title to about 10% of these lands, and compensated $962.5 million dollars for the lands they relinquished. ANCSA legislation also included an ambiguous promise that subsistence rights would be protected under the US Department of Interior and the state of Alaska. This protection, however, was not formalized until 1980, when the passage of ANILCA prioritized subsistence use of wild resources over recreational hunting and commercial fishing during times of shortage. Although the law explicitly states the importance of natural resources to indigenous culture and livelihood, it does not distinguish between Native and non-Native uses of natural resources, instead awarding subsistence priority based on rural residency. This ambiguity has proved problematic as Alaska's non-Native population continues to increase rapidly with many non-Native residents choosing to live in rural areas, while more than half of Alaska Natives now reside in urban areas thus disqualifying them from the rural preference (Thornton, 2001). Subsistence priority awarded on the basis of location rather than ethnicity continues to be viewed by many Alaska Native communities as highly problematic, as demonstrated by the comments of the participants in this study. Wheeler and Thornton (2005), describe the disagreements of the state's subsistence policy as "perhaps the most contentious, intractable public policy dilemma Alaska has faced in its history as a state."

To further complicate the debate, in 1985 the Alaska Supreme Court ruled the rural priority unconstitutional and subsequently fell out of compliance with ANILCA. The rural priority, redefined, was reinstated briefly in 1986, but in 1989, the state adopted subsistence laws under which all Alaskans- regardless of ethnicity and location- were

eligible for subsistence priority in the Alaska state constitution. Finding the state laws inconsistent with ANILCA, in 1990 the federal government moved to extend federal jurisdiction over additional lands and freshwater bodies and assume subsistence management on all federal lands. Consequently, the federal government now owns and manages more than 60 percent of Alaska's lands and rivers. The state holds jurisdiction over state and private property, and most of Alaska's marine waters. With the GASH and Yukon Flats villages situated amidst a patchwork of state, federal and private lands, subsistence resource users must be aware of the complex web of rules and regulations that govern use on the lands surrounding the villages. Residents traveling over the landscape may cross multiple jurisdictional boundaries in the course of the day. This occasionally results in illegal harvests (planned or otherwise), as seen in the high-profile case of the non-Native Jeff King, a former Iditarod race champion, who possessed a permit for hunting on state land, but was charged with illegally taking a moose 600 feet inside the Denali National Park boundary in 2007.

Technically, residents of the GASH villages and Beaver are able to influence decisions made in both federal and state subsistence management boards. Decisions made by the Federal Subsistence Board and the State Boards of Fisheries and Game are then implemented by Office of Subsistence Management (OSM), and the Alaska Department of Fish and Game (ADF&G), respectively (Table 1). The Federal Subsistence Board receives recommendations from ten regional advisory councils (RACs) consisting of rural residents in different management regions. The State Boards of Fisheries and Game receive recommendations from 81 advisory committees (ACs). RAC recommendations to the Federal Subsistence Board are often accepted, since rejection requires substantial contrary evidence. This is less the case for AC recommendations to the State Boards. Occasionally, tensions bubble to the surface, particularly over the issue of State Boards membership and their low degree of receptiveness to subsistence oriented recommendations. This was evident in 2008 when, amid outcry, the Alaska Governor's recent appointment to the Board of Game, Teresa Sager-Albaugh, withdrew her name from consideration. Non-Native Sager-Albaugh's appointment was met with significant protest from the Alaska Native community since it would have marked the first time in

history the seven-member Board had no Native representation. Sager-Albaugh later received a seat on the Board, after the appointment of Stanley Hoffman who continues to serve as the Board's sole Native member.

Table 1. Comparison of federal and state subsistence management regimes

	FEDERAL		STATE
Subsistence Law	Title VIII ANILCA		Article VIII Alaska Constitution
Jurisdiction	All Federal lands; some marine resources		All State and private lands; most marine resources
Subsistence Priority	Only rural residents eligible to harvest subsistence resources on Federal lands; C&T designation for some communities	Some Federal/State coordination on research, management, C&T designation, and advisory body activities ⇐⇒	All Alaskans eligible for subsistence priority
Regulatory Board	Federal Subsistence Board		State Boards of Fisheries and Game
Implementing Agency	US Fish and Wildlife Service, Office of Subsistence Management		Alaska Department of Fish and Game
Advisory Bodies	10 Regional Advisory Councils comprised of rural residents		81 Advisory Committees, each with 15 locally elected members

Co-management arrangements between villages and natural resource management agencies are not common in the GASH villages or Beaver, but they do exist. The Yukon-Innoko Moose Management Working Group (YIWG) was created in 2005 to address concerns of a declining moose population in game management unit 21E (the GASH villages). YIWG consisted of both Native and non-Native members whose interests ranged from subsistence to recreational and commercial hunting and guiding. The YIWG met several times over the course of three years and developed a number of recommendations for addressing concerns regarding the stability of the moose population with specific management strategies. In 2006 YIWG's recommendations were accepted by the Board of Game which was regarded as a victory by the committee members and many GASH villagers. The Yukon Flats villages, including Beaver, tried a similar arrangement that was not as successful; however the Yukon Flats Moose Management Planning Committee was in the process of being resurrected during the summer of 2008. Though not technically co-management, the Anchorage based non-profit organization, Yukon River Drainage Association (YRDFA), has for several years provided a well received information sharing service on the Yukon River salmon fishery (commercial and non-commercial). Weekly teleconferences throughout the summer provide a forum for numerous stakeholders and managers to exchange scientific and experiential information, and to share concerns over the salmon stock and management practices.

IV. TRADITIONAL ECOLOGICAL KNOWLEDGE

Traditional Ecological Knowledge (TEK) emerged in the 1980s and received international attention when it was included in the 1992 Convention on Biological Diversity (Article 8j) (Box 1). TEK has since been integrated with environmental management in some areas; more recently, climate change has re-focused the lens on TEK as an important mechanism for filling key information gaps in climate science. For example, problems associated with downscaling Global Climate Models may be addressed through specialized and continuous observations of local dynamics and impacts on people. Riedlinger and Berkes (2001) and later Laidler (2006) explore this question with the Inuit of the Canadian Arctic and suggest knowledge of highly localized biophysical processes can help to determine the assumptions used in models of climate processes and feedbacks, as well as verify the findings of scientific climate research. The ACIA (2005) explains, "insufficient knowledge of many of the physical processes active in the arctic domain," is one of the major challenges to overcoming uncertainty in climate projections for the region. Although the authors also indicate a current lack of ability to make predictions for some of the processes of greatest concern to indigenous communities, the report stops short of recommending the involvement of indigenous people in climate modeling.

Advocates of the use of TEK in climate models build on an existing literature on articulations of TEK with policy-making tools such as environmental assessment and co-management (Usher 2000), and combinations of TEK with science that lead to improved understanding and outcomes for habitat and wildlife management (Moller et al 2004; Kellert et al 2000). Recent scholarship highlights the role of local involvement in ecosystem management that is both collaborative and adaptive. Adaptive management refers to a "learn-as-you-go" approach that tests hypotheses through management strategies and allows for learning and iterative adjustment in management planning (Holling 1978). Adaptive co-management takes this a step further by involving stakeholders at multiple scales to enhance monitoring and information exchange (Folke et al 2002) and is regarded as one promising mechanism for managing ecosystems under

significant uncertainty. Actions required for successful adaptive co-management include tailoring management to specific areas by monitoring environmental feedbacks, facilitating the flow of information across organizational scales and creating space for collaborative learning (Olsson et al 2004).

Box 1: Definitions of Traditional Ecological Knowledge

According to the Convention on Biological Diversity, Article 8(j), "Traditional knowledge refers to the knowledge, innovations and practices of indigenous and local communities around the world. Developed from experience gained over the centuries and adapted to the local culture and environment, traditional knowledge is transmitted orally from generation to generation. It tends to be collectively owned and takes the form of stories, songs, folklore, proverbs, cultural values, beliefs, rituals, community laws, local language, and agricultural practices, including the development of plant species and animal breeds. Traditional knowledge is mainly of a practical nature, particularly in such fields as agriculture, fisheries, health, horticulture, and forestry."

Usher (2000) classifies TEK in the following ways: 1) Factual knowledge about the environment, including weather, ice and travel conditions; 2) Factual knowledge about the use of environment that are based on experience, observation and oral history; 3) Cultural values that dictate human interaction with the environment; and 4) A knowledge system that is based on cultural cosmology and may fundamentally differ from Western science.

However, perceived rifts between western and traditional knowledge have been difficult to reconcile in both policy and legal arenas where indigenous knowledge is often either dismissed as anecdotal, requires conventional scientific evidence to support it when used in legal claims, and is simply added to natural resource management regimes without being allowed to reshape how the environment is viewed by the western scientists who design them (Nadasdy 1999, Huntington et al 2000, Berkes 1993). Yet TEK remains a subject of significant interest to scholars, particularly with regard to climate change. Subsistence resource harvesters, through the use of multiple resources, in most or all seasons of the year, and over large areas of the landscape, possess a rich understanding of their surroundings. Since knowledge in Alaska Native communities is transferred to subsequent generations primarily through oral history and teaching, TEK

may build on observations of environmental change that extends for decades, if not centuries. These attributes suggest TEK would be invaluable to establishing baselines from which to project future climate change.

The research for this paper attempted to access three categories of TEK, as defined by Usher (2000): factual knowledge about the environment, including observations of weather, ice, water conditions and animal behavior; factual knowledge about the use of the environment, including harvest data and land use patterns; and to a limited extent, culturally rooted values of the environment, including moral or spiritual significance and views on the human-environment relationship. Usher describes a fourth category, the formulation of the knowledge system, which is explored in this paper. In addition, the research for this study expanded on this model to include observations of the effects of environmental change on livelihoods and adaptation practices. According to the definition of TEK, an individual's knowledge stems from a communal pool of information and experience, thus observations of a few may be representative of the broader community. This study followed a more conventional model of attributing each observation to its informant; however, the discourse on TEK, described above, questions whether this is the best way to handle traditional knowledge.

V. LOCAL OBSERVATIONS OF ENVIRONMENTAL CHANGE

The respondents interviewed for this study possessed a high degree of experience on the land, demonstrated sophisticated understanding of ecological processes, and contributed valuable information as to how their surroundings have changed. Observations of changes in biophysical processes include animal abundance and behavior; vegetation distribution and growth; characteristics of freshwater bodies, snow and ice; and weather processes and seasonality. Nearly all of the respondents reported numerous changes in animal and insect populations, with most of these observations focused on salmon and moose. In addition to animals, there were more observations of changes in weather and seasonality and to freshwater bodies than observations of other categories of environmental change.

Respondents reported changes to the quality of chinook salmon, both in terms of greater presence of "slime" or disease, and greater proportion of "jacks," referring to smaller, younger chinook salmon. "The [chinook salmon] have sores all over them," one respondent said. Respondents said they fed the diseased salmon to their dogs instead of preserving them for human consumption. These observations are congruent with conventional scientific reports of both rising levels of Ichthyophonus hoferi, a fungal parasite, and reports of reductions in the proportion of large (five and six year old) chinook salmon returning to the Yukon to spawn. I. hoferi, which manifests as white lesions in internal organs of salmon, was virtually unknown to Yukon River salmon before 1985, but affected more than 40% of adult Yukon chinook salmon by 2003 (Kocan et al 2004). Eating salmon infected with I. hoferi is not harmful to humans, but the infection can damage the muscle tissue of the fish and degrade the quality of the meat. Although the prevalence of infection does not appear to be linked to ocean and river water temperature, the spread of the infection within the salmon host may be facilitated by warmer water conditions (Kocan et al 2003). Bering Sea water temperature increased significantly around the year 2000 (NOAA, Bering Climate: A current view of the Bering Sea ecosystem and climate). Kocan et al (2003) found the extent of the disease to be greatest from 1999 to 2001 when average water temperature was highest. Similarly,

respondents reported a slight decline in the number of salmon with I. hoferi from a spike two to three years ago. Observations of a higher proportion of small chinook salmon also support a recent study by Hyer and Schleusner (2005) which found a lower proportion of large chinook salmon in the Yukon River.

Several respondents noticed an increase in predator (wolf and bear) populations, and a decline in the moose population due to increased predation. The Alaska Department of Fish and Game asserts that large predators are responsible for 70 to 80 percent of moose and caribou deaths each year (ADF&G Technical Report: Predator Management in Alaska, 2007). Regelin et al (2005) found high densities of wolf and brown bear populations relative to historic levels, resulting in a "capping" of moose and caribou populations at low levels. Concern over predation on moose is widespread in the communities in this study and reflects in documents and proposals generated by the GASH and Yukon Flats ACs as well as moose co-management working groups for improved moose management efforts to protect declining moose populations. In the GASH area, observations of a significant decline in the moose population contrast slightly with ADF&G reports of a stable moose population. However, it is worth noting that about a quarter of the respondents in this study felt the ADF&G moose management was based on inaccurate population surveys. "We need a better count of moose," one man said, "Fish and Game overestimates [the moose population]."

Changes in bird populations were of concern to some of the respondents, especially those from the village of Beaver. Migratory birds (especially ducks and geese), are important food resources for the people of Beaver and other villages near the Yukon Flats National Wildlife Refuge, a major breeding area for more than 100 species of birds. Respondents noticed a decline in bird populations in the area. Several respondents from both the upper and lower-middle Yukon said they have not hunted birds since news surfaced a few years ago that avian flu is transported from Asia to Alaska by migratory bird species, compounding concerns that the AI strain H5N1 spreading in human populations throughout Asia and Europe at the time would soon find its way to North America. While other forms of AI are present in Alaska, as of 2006, H5N1 had not been

detected (USGS Alaska Science Center). Winker et al (2008) found the transfer of AI from Asia to Alaska to in fact be quite low.

A majority of respondents also observed an increase in temperature in the fall and winter. In the fall, respondents indicated both overall warmer weather as well and later freeze-up, with several respondents describing activities such as crossing frozen rivers to traplines being delayed by two weeks to one month. "It's not cold early enough," a respondent said. "It used to freeze by October, but now it's not until November." Similarly, respondents observed warmer temperatures during the winter, and there were several reports of extreme cold snaps lasting only a few days as opposed to a few weeks. According to the respondents, winter warming trends have been in process for the last several years. Data from the National Oceanic and Atmospheric Agency's National Climate Data Center (Appendix C) are congruent with respondents' observations.

A majority of respondents reporting drying lakes and sloughs as well as filling-in of lakes and sloughs with vegetation. In the scientific literature, these changes are thought to be attributed to permafrost degradation, which is widespread in Alaska (Serreze et al 2000). According to the ACIA (2005), permafrost thaw "will likely lead to catastrophic lake drainage" in some areas. Riordan et al (2006) found that surface area of closed-basin lakes in Interior Alaska has decreased due to permafrost degradation; in the Yukon Flats, the surface area of lakes decreased by 18 percent between 1950 and 2002. A few of the respondents specifically observed a reduction in permafrost, and several respondents reported an increase in erosion along the banks of rivers, although they did not attribute the erosion to permafrost degradation.

About half of respondents reported several changes to vegetation with most of the observations focusing on shrubs and trees. Respondents noticed significant drying or dying-out of trees, although they did not identify which types. Throughout Alaska, dying out of spruce forests due to reduced growth and increased insect infestation has been observed in correlation with recent warm temperatures (Soja et al 2007). Other studies have shown that permafrost degradation in the sub-arctic Interior lowlands has resulted in- and will continue to cause- widespread destruction of birch forests (Joregenson et al

2001). However, Lloyd and Fastie (2002), found a northward advance of the boreal treeline into the tundra ecosystem. Some of the respondents in this study observed an expansion of spruce forests, as one respondent described, "Black spruce are here now." The ACIA (2005) projects spruce forests will further advance into the tundra in northern Alaska. Respondents also observed increases in growth rate and overall abundance of willows. These observations support scientific studies showing increased shrubbiness in Interior Alaska (Sturm et al 2001).

In addition to various changes in the environment, respondents also observed changes in human behavior, including the number of non-local hunters visiting the area. Some respondents reported an increase in traffic and competition from non-local hunters, including hunters from urban areas as well as from villages in other game management units. This information is consistent with reports from ADF&G Wildlife Conservation Division's Harvest Lookup database, which shows an increase in the proportion of non-local hunters to local hunters in the last decade. However, it is difficult to verify this information as underreporting in subsistence communities has been documented (Andersen and Alexander 1992) and may also be common for other hunter groups. Questions on the topic of non-local hunters were often met with enthusiastic responses. "Sports hunting disgusts me," one respondent said, referring to mostly non-Native urban hunters and tourists who hunt recreationally rather than for subsistence. Comments such as this one are further evidence of strong disdain among some Alaska Native communities for the lack of a rural priority designation on state lands.

The observations of environmental change documented for this study, including changes to animals, vegetation, weather, water level, snow and ice conditions and human activity, are consistent with the scientific data for climate change and impacts in the Alaska and the broader arctic region (Table 2). The observations are also consistent with similar studies of the effects of climate change on indigenous livelihood and adaptation practices in Alaska and Canada (e.g., Krupnik and Jolly 2002, Berkes and Jolly 2002) and contribute to the discourse on the role of local knowledge in assessing the impacts of climate change.

Table 2. Comparison of local observations with scientific literature

Theme	***Changes Reported in Literature***	***Source***	***Changes Observed by Respondents***	***% Total***	***Variations and Nuances***
Winter temperature	Winters are warmer and shorter	Global Climate Change Impacts in the US 2009, UAF Arctic Climate Center	Winters are warmer, extreme cold periods are shorter	73	
Fall temperature	Increase in temperature in the fall	UAF Arctic Climate Center	Falls are warmer	43	
Freeze-up	Later freeze-up on rivers and lakes	ACIA 2005, Hinzman et al 2005	Freeze-up is later; unable to cross the river as early as before	73	
Breakup	Earlier breakup on rivers and lakes	ACIA 2005, Hinzman et al 2005	Break-up is earlier and/or it is occurring faster	28	10% reported later breakups
Permafrost	Increase thawing; permafrost line receding	ACIA 2005	Permafrost is thawing	15	
Ice over rivers and lakes	Thinner ice on rivers and incomplete freezing	ACIA 2005	Ice is thinner and has more holes	30	Reports from NOAA for middle and upper Yukon show variable ice thickness, with some above average measures in last 5 years
Precipitation	Increase precipitation in the fall	ACIA 2005	Increase in precipitation; most responses referring to precipitation in the fall	23	
Snow	Less snow in winter	Stone et al 2002 in: Hinzman et al 2005	Less snow in winter	10	5% reported more snow; data from GI McGrath and Bettles stations show slight increases in snowfall
Weather Variability	Greater variability	ACIA 2005, Hinzman et al 2005	Greater variability; alternating freezing and thawing; greater difficulty predicting weather	25	

Water level	Lakes and sloughs are drying and filling with weeds; increase base flow of rivers	Riordan et al 2006	Lakes and sloughs are drying and filling with vegetation	78	5% reported wider river channels; 35% said changing path
Flooding	Less flooding in the spring	ACIA 2005	Less flooding in the spring	23	
Erosion	Increase in erosion and landslides	ACIA 2005	More erosion of banks of rivers and sloughs	40	
Treeline advance	Treeline advancing into tundra	ACIA 2005; Hinzman et al 2005; Lloyd and Fastie 2002	Expansion of spruce forests to new areas	8	~25% reported trees drying/ dying out
Shrubbery	Increased shrubbery and advance into tundra	Sturm et al 2001	Increased shrubbery, especially willows	40	
Moose	Moose population in GMU 21E (GASH) reported as stable from 2000-2005; population is declining in 25D (Beaver) since 1990s	Stephenson 2006	Decline in moose abundance over the last 5-10 years; (GASH residents observed moose moving south/ downriver)	54	5% (all in 21E) reported increase in moose abundance
Salmon	Lower proportion of large Chinook salmon; 40% Yukon salmon have Ichthyophonus hoferi infection	Hyer and Schleusner 2005; Kocan et al 2004	Decline in quality of Chinook salmon, with most referencing increase in proportion of jacks (smaller/ younger salmon); more "slime," sores on salmon	48	
Birds	Change in migration	ACIA 2005	Reports of new birds including magpies and strange waterfowl/ decrease in abundance of game birds including geese and ducks	30/ 25	
Humans	Increase in number of non-local harvests reported	Alaska Department of Fish and Game Division of Wildlife Conservation, Harvest Lookup 1999-2008	Increase in traffic from non-local hunters	55	

VI. THE IMPACTS OF ENVIRONMENTAL CHANGES ON SUBSISTENCE

The impacts of environmental changes observed by respondents played out in their daily lives in multiple ways. Less than half of respondents identified ways in which environmental changes actually benefitted subsistence; however a majority of the responses in this section indicated respondents were adversely impacted by the environmental changes occurring. Respondents experienced benefits to their livelihood through a reduction in home heating costs due to warmer winter temperatures, and greater ease of travel in the winter due to less snow. Most respondents, however, reported hindered travel efforts, with the greatest effects felt in the fall and winter. In the fall, respondents reported difficulty with traveling across overgrown or degraded trails and in sloughs that were drying or filling in with weeds. In turn, this hindered hunters' access to moose. During the September season, hunters in these villages often travel in motorized boats along rivers as well as the myriad sloughs branching off the main stem of the Yukon and Innoko Rivers in search of moose browsing on shrubbery near the shoreline. Hunting along the banks of sloughs also reduces labor involved with pursuing moose inland and packing harvested meat back to the boats through boggy terrain. But "dry sloughs make it harder to find moose," a respondent said, and most other respondents interviewed indicated they have had difficulty accessing preferred hunting locations in recent years.

Most of the effects on travel were felt through delayed and incomplete freezing of the rivers, lakes and sloughs. "I can't maneuver my snowmachine," one man said, and other respondents expressed similar difficulty with traveling in softer packed snow and incomplete freezing over creeks and sloughs. Delayed freezing of the Yukon River also impacted peoples' ability to reach traplines when the trapping season opened. For some, a shortened trapping season resulted in an important loss of income from the sale of fur. Others reported impacts on ice fishing. "The ice isn't thick enough to fish for whitefish," a respondent said. In the winter, the frozen Yukon River, wide and relatively even, is a primary conduit for snowmachine travel. A few of the respondents were frustrated by not being able to travel to other villages for social purposes early in the season.

Respondents also reported negative impacts to the time and effort of resource harvest. Several of these impacts were closely related to worsened travel conditions. Respondents reported having to search for alternative pathways and to repair trails in order to access resources. Some respondents said they spent more time than usual cutting vegetation in order to transit trails and were working harder to identify adequate fishing sites. People also noted difficulty with finding the moose. According to respondents, cooler weather in the fall triggers moose movement toward breeding ranges and a dietary switch to woody browse, such as birch and willow. Moose typically move along the banks of sloughs and rivers for greater ease of movement and access to browse. But respondents reported that prolonged warm spells in the fall delayed this movement of moose, requiring hunters to dedicate additional time and effort to tracking and harvesting the animals. "It's more effort to get moose," a respondent said, "You have to go farther out."

Respondents reported negative effects on animal populations and vegetation. Consequently, people said they were experiencing less success with harvesting resources. Reports of reduced harvests focused mostly on moose, but also applied to a mix of resources, including salmon and non-salmon fish species, berries, and firewood. Respondents attributed the increased difficulty with harvesting sufficient resources to a variety of changes in the weather and landscape, to increased predation, and to increased competition from non-local hunters.

Although many of the changes observed in the interviews were not directly attributed to climate change, there is growing awareness in the villages that the changes they are observing and that are adversely affecting a range of subsistence activities may be a result of climate change. This was most clearly expressed in an emergency teleconference held by the State Board of Game in October of 2005. The teleconference was called to address a number of proposals and recommendations, including one submitted by the Tanana Chiefs Conference on behalf of hunters in game management unit 21E (the GASH villages). The petition called for an emergency extension of the hunting season "due to climate changes affecting moose migration patterns, increasing

pressure from outside hunters and local users who were not able to meet their subsistence needs." (Alaska Board of Game 2005). Although the Board rejected the proposal, it underscores the negative effects on livelihoods of many environmental and human changes observed in this study.

VII. COPING WITH CHANGE

Although some of the changes experienced in the study sites are recent, residents of the area are accustomed to environmental change. Developed over millennia and shared through oral history, adaptation to change is part of the fabric of contemporary Athabascan society. Methods for both the production and the distribution of resources capitalize on periods of abundance by storing foods in anticipation of shortage, and engaging in systems of reciprocity and exchange, allowing households to tap larger networks of resources and information. These adaptations have been woven through various aspects of Athabascan social, cultural and spiritual institutions and practices (Osgood 1958; VanStone 1974; Nelson 1983) and continue to shape how cash and non-food resources are incorporated into the subsistence cycle (Wheeler 1998).

In describing adaptation practices, this study draws on the framework developed by Halstead and O'Shea (1989) in which methods for coping and reducing risk to environmental change fall into the categories of diversification, mobility, storage, and exchange (Box 2). Agrawal (2008) adds to this framework a fifth category, communal pooling, comprised of local informal institutions for distributing risk across households through sharing assets, wealth and labor. Within these categories, respondents most often cited diversification and mobility as strategies for coping with the environmental changes they observed, although exchange and communal pooling also emerged as prominent coping mechanisms (Figure 1).

Diversification- Activities such as supplementing wild food harvests with wage employment or altering strategies for obtaining resources were employed by nearly all of the respondents. Respondents reported purchasing more foods from the store and seeking seasonal firefighting and commercial fishing jobs to supplement income. Respondents also described altering harvest methods in order to cope with shorter seasons and difficult travel conditions. Respondents also employed strategies such as building bridges over unfrozen sloughs, setting longer trap lines to harvest more animals in one trip, and camping out rather than making frequent day trips over the land to avoid travel over difficult terrain. For example, a respondent said, "I wait until the ice freezes and go out

with snowshoes and a chainsaw to build new trails." In addition, respondents coped with changes to distribution and abundance of moose and chinook salmon by harvesting greater quantities of other, more abundant types of salmon (e.g., summer and fall chum salmon). "When we don't get moose, we eat more salmon, geese and ducks," one man said.

Box 2: Categories of Adaptation

This paper places adaptation responses in five categories:

Diversification refers to spreading risk across livelihood activities. In the context of interior Alaska, diversification ranges from expanding the types of subsistence resources harvested to supplementing wild foods with store bought foods. Such activities reduce the risk of total loss when harvest of certain resources is unsuccessful.

Storage is a way to distribute risk temporally by setting aside surpluses when resources are abundant for use during times of shortage. Examples of storage include canning and drying fish during the summer for consumption later in the year.

Mobility distributes risk across space. In the context of subsistence, resource harvesters often travel further or to different locations when they experience a shortage of resources in the areas where they typically harvest the resource.

Exchange refers to a system of sharing and reciprocity and of distributing risk across households. Exchange is a form of storage that converts material assets into social capital allowing households experiencing shortage to rely on others in the community. In Native Alaska, systems of sharing have been well documented; members of society often share harvested resources with others, such as the elderly and less productive households.

Communal Pooling refers to collective assets and includes the sharing of wealth, labor and information (Agrawal 2008). Examples of communal pooling in Native Alaska include hunting collectively, sharing subsistence equipment, and transferring traditional knowledge of subsistence and the environment.

Source: Halstead and O'Shea 1989, Agrawal 2008

Storage- Respondents also described making changes to the storage of harvested resources. Storage allows households to plan for times of shortage by processing and storing wild foods when resources are abundant. Anticipating a shortage of moose meat,

several respondents described processing additional chum salmon by smoking and jarring the fish and using the stored foods to supplement meat throughout the year.

Mobility- Current patterns of transhumance are themselves an adaptation to variation in availability of resources and the ability to access them. Although the GASH and Yukon Flats communities are permanent settlements, movement over the landscape is timed to capitalize on seasonal availability of resources. Respondents described altering this pattern in minor ways to cope with both degraded travel conditions and changes to wildlife distribution. These actions include changing harvest location when the animals are no longer there, such as locating new areas for setting nets as river channels shift and eddies disappear. Respondents also reported traveling further in search of moose, and some people reported shortening travel distance to avoid dried-up sloughs or poor ice conditions. Some respondents reported traveling greater distances since certain resources are distributed more widely. For example, respondents said beaver are moving out of lakes to decentralized locations in streams, requiring hunters to spend more time finding and trapping the animals.

Exchange- Local practices associated with the production and distribution of wild food harvests in Alaska Native communities has been well documented (e.g., Magdanz et al 2002). Subsistence activities in the study sites and in many Alaska Native communities are typically conducted by a core of specialists, or "superhousehold," that hunts cooperatively; harvested resources are also processed cooperatively and distributed throughout the community along kinship lines (Wolfe and Walker 1987). Respondents in this study also described the sharing of moose meat across households as a strategy for coping with lack of success in moose hunting. "People here help each other out," a respondent said. Respondents reported receiving meat from others or sharing moose meat with families that were either not able to hunt or did not successfully harvest a moose. This practice applies not solely to moose but to all subsistence resources; the sharing of salmon was observed during visits to the villages during the summer of 2008. The respondents did not indicate that sharing of resources was becoming more common in

recent years, but nearly everyone identified sharing as important to their community and livelihood.

Respondents also discussed the importance of participation in the market economy. Due to the legal complications of selling subsistence resources, harvested resources do not directly translate to cash income in most rural Alaskan communities, with the exception of furbearing animals. Trappers interviewed for this paper reported that the sale of fur from animals like marten and beaver made important contributions to their livelihood. Respondents also discussed the importance of wage income through full, part-time or seasonal jobs as a source of cash to be used to purchase subsistence equipment and foods from the store. However for the purposes of this paper, descriptions of wage employment as a coping strategy were categorized as diversification rather than exchange.

Communal Pooling- Collective assets emerged in the interviews as highly important to the social fabric of the GASH communities and Beaver. However, not all of the communal pooling activities discussed during the interviews related directly to coping with environmental change. For example, gas prices were particularly high when the villages were visited. Respondents reported hunting more frequently with friends to share the cost of gas and food. Hunters frequently hunt moose in small groups to assist each other with dressing and packing out moose meat (a harvested bull moose can yield upwards of 700 pounds of meat). In addition to cash and labor, respondents described pooling knowledge by exchanging timely information about the location and movement of animals, and by passing traditional knowledge about subsistence and the environment to subsequent generations. "[We] will teach our kids everything we know," one respondent said. Because activities of sharing and exchange are rooted in cultural values of collective action, there is some overlap of the Exchange and Communal Pooling adaptation categories.

Adaptation practices falling within these five categories have been documented in other communities in the Arctic. For example, in Sachs Harbor, Canada, Berkes et al (2002) found both short term coping mechanisms (e.g., changes to timing and location of

harvest) as well as long term adaptation strategies (e.g., inherent flexibility in the seasonal subsistence round, detailed knowledge of the environment and networks of sharing and trade) were all in play as the community dealt with numerous changes to their environment.

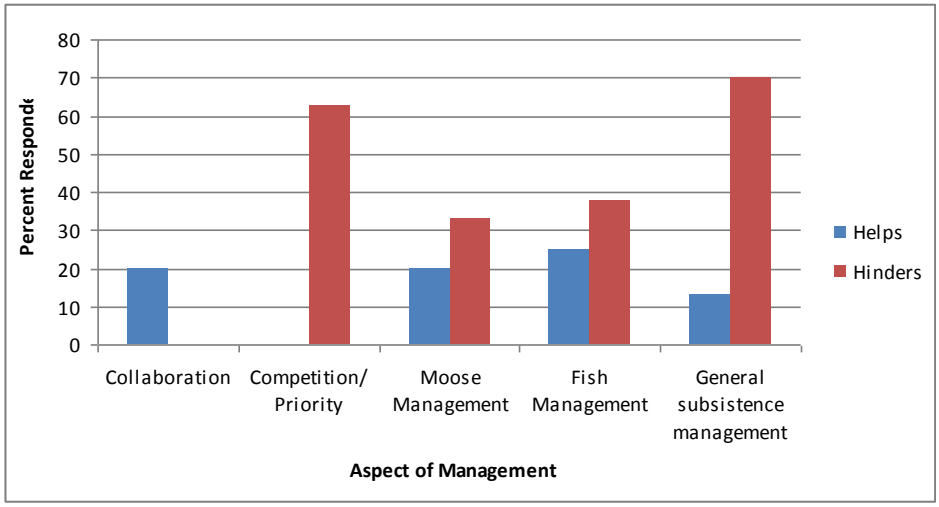
Table 2. Responses about adaptation practices employed in the communities

Category of Adaptation	***Examples of responses***	***Number of respondents (% total)***	***Number of responses***
Diversification	Going more often to store to buy meat Get odd jobs or sell wood for money When we don't get a moose, we eat more ducks and fish Thinking of gardening, raising potatoes and collards Build bridges across the sloughs [when not enough snow] Go out for longer- camp instead of making day trips	35 (88)	113
Storage	Processing fish more, more cases of jarred fish Jacks don't go as far, now we're saving every scrap	5 (13)	5
Mobility	Travel further to find moose Trapping closer to the village The best fishing spots are silted in- looking for new spots Hunt only off the main river	14 (43)	28
Exchange	Sharing more Get moose from my son, if I don't get one People here help each other out	15 (38)	17
Communal Pooling	Hunt with a group, share labor and moose We'll teach out kids everything we know We share information in the village	13 (33)	14

VIII. PERCEPTIONS OF RESOURCE MANAGEMENT AND REGULATION

Alaska Native cultural identity is in large part shaped by the "subsistence way of life," the ways wild foods are produced, distributed and consumed. But the subsistence way of life is surrounded by a complex scaffolding of institutional processes that regulate, restrict, and manage Alaska Natives' interactions with the environment. In this study, perhaps the most interesting information was the respondents' perceptions of the processes for regulating and managing natural resources and their use by society. Respondents were asked to identify management practices that facilitated and constrained subsistence. Although utilizing such a simple analytical framework may have resulted in a less nuanced understanding of the complex relationships between communities and managing agencies, it nonetheless helps to explain the influence of subsistence management over adaptation. The adaptation practices described are embedded in the subsistence way of life, of which nearly every aspect- the production, distribution and consumption of wild foods- falls under state and federal regulation and management. While the respondents felt strongly that certain aspects of subsistence management hindered their livelihood, many also identified positive aspects, demonstrating perceptions of the subsistence management regime that are as complex as the institutions themselves (Figure 2).

Figure 2. Perceptions of the effects of regulation and management on subsistence.



Most of respondents found the lack of formalized priority for subsistence and resulting competition with non-local hunters to be the greatest hindrance to subsistence. Respondents suggested the Board of Game limit permits to urban, guided and other non-local hunters (including subsistence hunters from other game management units). Some respondents also suggested the Board of Game establish a subsistence-only moose harvest period prior to the general hunting season starting in September. "Board of Game should prioritize subsistence and let subsistence go early," a hunter said. These respondents felt hunting near their villages should not necessarily be restricted for non-local hunters, but rather that local hunters should be allowed to access moose before the resource is depleted by other hunters. This sentiment was expressed by a respondent who said, "[ADF&G] should give locals a chance."

Respondents also identified many negative aspects of the subsistence management regime in general. Just thirteen percent identified positive aspects of the regime, including the agencies' efforts at predator control. One man was "glad [the agencies] are trying to control wolves." However, 70 percent of respondents felt the system either constrained subsistence or was otherwise harmful to their livelihoods in some way. In particular, respondents felt ADF&G or US Fish and Wildlife were not doing enough to control predator populations, regarded as one of the most serious threats to the moose population. These respondents felt there was insufficient effort to reduce predation on moose and wanted either improved efforts on the part of the agencies to conduct predator control (including aerial hunts), or for the agencies to exercise greater tolerance of individual and village efforts to reduce predator populations. Concern over predation on moose is evident in the transcripts of State Board of Game meetings for the last decade. AC proposals have often included recommendations for various improvements to programs or for relaxation of restrictions on predator control. The Board of Game has been more receptive to these proposals than has the Federal Subsistence Board due to stricter federal regulations under Endangered Species Act requirements. In addition to predator control, respondents also identified "nuisance" issues as a negative aspect of the regime, describing the quantity and complexity of regulations and harvest surveys, issues with enforcement officers entering hunting camps, and difficulties

associated with obtaining permits. “There are too many permits and regulations to keep straight,” one respondent said.

Responses to questions specifically pertaining to the management of moose and fish resources were more mixed. A fifth of respondents, all of them residing in the GASH villages, were generally satisfied with the management of moose, while a third were dissatisfied with the management. In several cases, both negative and positive responses came from the same individual. For example, one man said, “moose management is working,” but also listed several ways the system should change, including changing the dates of moose hunting season to enable travel in sloughs when the water is still high, conducting more aggressive predator control, reforming the methods for counting moose, and instituting a permit system to keep non-locals from hunting moose in the area.

A quarter of respondents felt the management of fish, mostly salmon, was satisfactory, while nearly half felt it should be changed. The window system typically does not apply to upriver communities, like Beaver. All of the respondents from Beaver expressed satisfaction with the window system downriver since it allows more fish to pass to upriver communities. Respondents from the GASH villages felt the scheduled windows system hindered their ability to “fish when the fish are there,” as one man said. These respondents felt that the timing of the windows should be adjusted to better match open fishing periods to salmon pulses passing by the village. They also suggested the windows either be discontinued or that people be allowed to fish up to a certain quota in one continuous fishing effort, rather than trying to meet this quota through several 48-hour long fishing efforts throughout the season. In addition to occasional timing mismatches, respondents said the windows are a nuisance and costly since villagers must reset and take in nets at the opening and closing of each fishing window, an activity that requires a significant amount of effort and gasoline for motorized boats. “I’m wasting time taking my net out of the water and then resetting it each time,” one man said.

The regulatory practices most often cited as helpful were collaborative agency-tribal processes, including the advisory committees and councils, the Yukon River Drainage Association teleconferences, the Yukon-Innoko Moose Management Working

Group and the Yukon Flats Moose Management Planning Committee. "The [YIWG] was good," a respondent said, "they should meet again." This sentiment was echoed by several other respondents. In fact, these types of collaborative efforts received only positive comments, with about a fifth of respondents specifically identifying collaborative processes as helpful to subsistence. However, as mentioned above, all of the respondents who described moose management as "good," or "working" – about a third of respondents – reside in the GASH villages, where current moose management schemes have been largely influenced by the YIWG.

Box 3: Summary of normative statements about state and federal subsistence management

"There needs to be less competition from non locals."

There should be better consideration of subsistence interests and better Native representation on the State Boards of Fisheries and Game. Agencies should consider the effects of commercial fishing on the Yukon River subsistence fishery and take efforts to minimize bycatch. Subsistence should be prioritized through regulations that limit the number of non-local hunters. This may be achieved through a revised permit system, stricter regulation of airplane access to hunting areas, or by creating a locals-only extended hunting season.

"There are too many regulations and permits to keep straight."

Agencies should consider ways to simplify the regulatory system and reduce nuisance issues associated with invasive and culturally insensitive monitoring practices, or rules that make it too difficult to do the right thing (i.e., proper reporting and disposal of bear carcasses).

"There needs to be more predator control."

Agencies should either conduct more aggressive predator control (i.e., aerial hunts) or allow communities greater freedom to reduce predator populations near their villages and hunting areas.

"They should tweak the windows so everyone gets a chance at the fish."

On the lower Yukon River, 48-hour fishing windows need to be better matched to pulses of fish as they pass the villages. The windows should also be modified, either by opening fishing more frequently on weekends to accommodate people with a conventional work schedule, or by replacing the windows with a quota system.

"The meetings are an opportunity to have a voice."

Collaborative processes, including the Regional Advisory Councils, Advisory Committees and the Yukon River Drainage Association teleconferences should be continued and strengthened. The ADF&G and the US Fish and Wildlife Service should explore with communities the possibility of additional opportunities for collaboration and co-management, such as the YIWG.

IX. DISCUSSION AND CONCLUSION

Important lessons emerged from respondents' discussion of the regulatory processes that affect livelihoods. By comparing perceptions of management activities, it is possible to distill some key features of activities that facilitate and constrain subsistence. Respondents perceived regulatory institutions as detrimental to subsistence when they did not prioritize subsistence uses over recreational and commercial uses of natural resources, provide for local involvement in regulatory and management decisions, or protect important resources from predation and over harvesting, and when they constrained subsistence harvesters' ability to pursue resources when they were available or most needed. Respondents described many negative aspects of subsistence management, but most people seemed unwilling to suggest that government management schemes be eliminated altogether.

The identification of some positive features of regulation and management, discussed earlier in the paper, implies that people see a benefit to agency involvement when the management of resources supports local priorities; respondents' discussion of collaborative processes suggests management is viewed even more favorably when local communities are able to voice concerns and have a role in shaping management decisions. For example, respondents often described the ACs and the YIWG, founded on principles of information sharing and collaboration, as good examples of management. Here, it is worth distinguishing between process and outcome. Since the YIWG led to a set of moose management recommendations that were subsequently adopted by the Board of Game, people in the GASH area felt strongly that both the process and the outcomes were helpful to subsistence. However, several people also felt positively about the AC in general, even though AC recommendations are frequently rejected by the Board of Game. Some of the respondents specifically described the actual process of the AC – sharing information, generating recommendations and presenting them to decision makers – as positive for subsistence, regardless of the outcome.

Information exchange and participation in decision making thus emerged as important determinants of respondents' perceptions of subsistence management. These

two issues may also be essential to community resilience. Institutional learning stems from iterative adjustments to change and the accumulation of collective knowledge, and builds the capacity of a system to buffer uncertainty (Folke 2002). It is a central component of resilience. Adger (2003) further articulates the positive links between a community's ability to act collectively and social resilience to climate change. The accumulation and sharing of knowledge- about the environment and human responses to change- is a defining characteristic of traditional knowledge systems. Case studies of indigenous communities and responses to perturbation demonstrate how information sharing and collective action reduce vulnerability and enhance resilience. For example, Newton (1995), describes how vulnerability of Canadian indigenous communities to natural hazards was mitigated through social networks that facilitated information flow about weather forecasts and collective responses to flooding. Berkes and Jolly (2002) in a case study of an indigenous community in the Western Arctic, explain how alterations in hunting practices in order to cope with ecosystem change are rooted in collective knowledge of the environment and previous responses to variability. In a study of subsistence systems in Alaska, Magdanz et al (2002) posit that the subsistence management regime, which preferences a system of individual permits and bag limits over policies that recognize collective hunting and sharing arrangements, undermines the resilience of Alaska Native communities to ecological and economic uncertainty by limiting information exchange and social networking.

Successful adaptation to climate change is also determined by access to resources (Brooks 2003). Having a say in the decisions that affect the flow of those resources, through participation in co-management or other collaborative processes, could prove to be viable mechanisms for strengthening the capacity of indigenous communities to plan for and adapt to climate change while increasing the legitimacy of government management strategies. The fact that several respondents described co-management and collaborative processes, such as moose management working groups, YRDFA teleconferences, and state and federal subsistence advisory processes as helpful to subsistence, supports this hypothesis. Respondents tended to indentify top-down

measures that provided little opportunity for influence from local communities as harmful to their livelihood.

In some cases, climate change may actually create political space for collaboration by promoting information exchange and cooperation. As resource managers contend with how to manage ecosystems under significant uncertainty, attention has again turned to the role of TEK in adaptive management. Chapin et al (2006) propose a set of policies to address changing dynamics in ecosystems due to climate change. Some of these policies necessitate indigenous involvement through adaptive co-management arrangements that facilitate close monitoring of local ecologies and information exchange. Folke et al (2002) recommend policies that recognize the interconnectedness of ecosystems and society and create new opportunities for collaboration. Similarly, Ullsten et al (2004) advance several policy strategies to enhance the resilience of northern countries to climate change, including developing institutional structures that facilitate long-term planning, collaboration, and information exchange across stakeholder groups.

However, the integration of TEK with policy through collaborative and co-management processes is fraught with complication. Scholarship on this issue suggests the problems stem from a lack of understanding on the part of policymakers of what TEK is and how it should be incorporated into management (e.g., Usher 2000, Nadasdy 1999). These scholars discuss fundamental differences between the reductionist western scientific paradigm and indigenous worldviews that tend be more holistic; although Agrawal (1995) advocates a more nuanced discussion of these differing forms of knowledge. In some cases, co-management has actually led to worse outcomes for both ecosystems and local people by allowing agencies to defray criticism for non-collaboration while not adequately incorporating traditional knowledge in natural resource management (Nadasdy 2003). Although several respondents perceived the YIWG process as positive, it is worth noting that many of the YIWG recommendations resemble the types of decisions made within a western science paradigm. For example, one of the first strategies listed in the final YIWG document aims to “establish a framework of state and federal moose hunting regulations designed to maximize hunting

opportunity when possible but which will also ensure that harvest remains within sustained yield" (Yukon-Innoko Moose Management Plan, 2006). Perhaps the use of this language and western scientific models of sustainable yield is due to a perception among local residents that they must insert their interests into a conventional framework rather trying to change the framework. However, as noted earlier, Nadasdy (1999, 2003) has raised important questions as to whether such integration of traditional and western knowledge actually leaves local communities better off.

The respondents' observations of environmental changes add to a growing body of research on the role of traditional knowledge in determining the potential impact of climate change on local ecologies. Descriptions of the effects of environmental change on livelihoods and adaptation practices help to predict how people may adapt to future climate change. Local perceptions of natural resource and subsistence management raise new and important questions about the role of regulatory institutions in either facilitating or constraining adaptation to future climate change. It is also important to understand community resilience in Alaska in the context of multiple stressors. The ways in which the impacts of environmental change compound with socio-economic patterns and stressors is beyond the scope of this study, but will likely affect communities profoundly. During the summer of 2008 when the interviews for this paper were conducted, the price of gasoline reached a record high, exceeding six dollars per gallon in all of the villages visited. Some respondents highlighted the high cost of fuel as the greatest threat to their livelihood. Households are adversely impacted by high fuels costs since the majority of subsistence activities requires motorized transport, such as boats and snowmachines. High fuel costs also lead to price increases in supplemental (store-bought) foods which are transported to villages by airplane or barge. Other trends, including outmigration from villages to cities and limited educational and wage employment opportunities in villages also pose challenges to community wellbeing.

In light of these outcomes, I advance three recommendations. 1) Measures should be undertaken to raise Alaska Natives' awareness of climate change. If they choose to do so, Alaska Native participants of the Advisory Committees and Regional Advisory

Councils could draw on collective knowledge (conventional and traditional) of climate change and its impacts on subsistence in order to engage in evidence-based advocacy for changes to management practices and regulations. Such evidence may lend additional strength to specific AC and RAC proposals submitted to the state and federal management boards. 2) Natural resource managers, faced with shifting ecosystem thresholds and unprecedented challenges, should recognize the potential of local communities to contribute to robust monitoring and management. Agencies like ADF&G, building on the lessons learned from processes like the YIWG, should explore the potential of adaptive co-management arrangements with indigenous communities throughout Alaska. In particular, indigenous partners can contribute specific observations of animal abundance and migration, water levels in rivers and lakes, and plant life, all resources that have undergone significant change- and are projected to undergo further change- due to climate-related impacts. 3) At the policy level, processes such as the development of Alaska's climate strategy, which will provide guidance to the Office of the Governor on climate change planning and implementation, should recognize indigenous peoples as a segment of Alaska's population that stands to be significantly impacted by climate change. Policy measures to support adaptation should focus on both urban and rural communities and look beyond infrastructure protection and relocation to activities that will enhance the underlying resilience of communities. Policymakers should advance a framework for adaptation planning, including capacity building through village-based workshops, to promote information exchange on climate change and begin collaborative planning for community responses to impacts.

The communities of Grayling, Anvik, Shageluk, Holy Cross and Beaver are part of a social ecological system that is rapidly changing. Yet Alaska's subsistence management regime is complicated and slow to change. By the time this regime was in place, indigenous peoples of the sub-arctic had already successfully adapted to a number of sudden and extreme climatic changes by pursuing alternate food sources, modifying technology, or migrating to different regions. It is precisely this flexibility and innovation- to "fish when the fish are there"- that have allowed indigenous peoples to survive in Alaska for millennia. Although climate change may cause unprecedented

changes to weather and the environment in Alaska, the ability to innovate, share information, learn, and influence decisions affecting the flow of resources, may prove vital to successful adaptation. Understanding the role of subsistence management in determining adaptation outcomes is essential to the development of thoughtful and effective strategies for enhancing resilience to climate change. Adaptive co-management and other processes that value flexibility, facilitate information exchange and provide opportunities for community participation in management decisions should be incorporated in statewide adaptation policy and planning. In doing so, however, it is important to be mindful of types of collaborative arrangements that fail to enable local stakeholders to truly shape the processes and outcomes of natural resource management.

X. APPENDICES

Appendix A: Questionnaire

Local Knowledge of Environmental Change

Interview ID #:	**Interviewee's name(s):**	. Individual Couple
Date of Interview		
Location of Interview		

Questions about you

I will start by asking a few quick questions about you.

What year were you born? _____
[If this is a couple, put the year of the older person]

Where were your parents living when you were born? _____

How long have you lived in this community? _____

Have you lived in other communities or cities?

no yes

How many years were you away?

How much time have you spent on the land <u>in the past 12 months</u>?

Did you …

only take day trips from town,
take day trips with occasional overnights,

□ were you out on the land for a week or more at atime, or
□ did you spend more than half of your time living out of town on the land?
[Check the one that fits the best, then write any notes or comments here]

Mark the map to show the areas and routes where you travel on the land and rivers for subsistence activities as well as places you used to travel to for subsistence but don't any longer.

Ecological Change:

Please tell me if you have noticed any changes in the last ten years in the land, rivers, lakes, plants, and animals on your village homelands.

□ no □ yes

↓

Please describe the important things that have changed

Weather

- *Summer; fall, winter, spring*
- *Temperature; wind; precipitation*
- *Timing of the seasons (seasonality)*
- *Freeze up; break up*
- *Permafrost*

Changes:

Effects:

How did you cope:

Rivers and Lakes

- *Water levels*
- *Hydrology*

Changes:

Effects:

How did you cope:

Vegetation

- *Herbs, mosses, lichens*
- *shrubs*
- *berries*
- *the forest*

Changes:

Effects:

How did you cope:

Animals and habitat *(quantity, distribution; movements; quality; diseases)*

- *Large mammals (moose, caribou)*
- *Predators (wolves, wolverines, lynx)*
- *Furbearers (martin, beaver, muskrat, weasels, wolverine)*
- *Small mammals (voles, moles)*
- *Insects*
- *Fish*
  - *(whitefish, salmon, pike)*
- *Birds (take bird book if you can)*
  - *Small birds (try to identify species)*
  - *Ravens*
  - *Waterfowl (ducks, geese)*
  - *Birds of prey (eagles, hawks, falcons)*
- *Appearance of new plants or animals in the area*

Changes:

Effects:

How did you cope

Changes in human activities

- *Local people's activities*
- *Non-local harvesters*

- *Other non-local activities (air traffic)*

Changes:

Effects:

How did you cope:

Other Changes:

Effects:

How did you cope:

Important things you get from homelands (land, rivers, lakes)

What are the five most important foods for you and your family that come from the land, rivers, and lakes in your homelands?

1.

2.

3.

4.

5.

Are there other foods that are important now that weren't listed?

What are the most important non-food items that you get from your homelands?

Are there things from the land that you used in your youth that you don't use anymore?

□ Yes □ No

↓ ↓

Please list *next*

Why not?

Are there things from the land that your parents and grandparents talked about as being important which you don't use any more?

□ Yes □ No

Please list *next*

Why not?

Non-local organizations/ regulations/ people

- How do non-local organizations or regulations help your subsistence lifestyle?
- How do non-local organizations or regulations hurt your subsistence lifestyle?
- What should they do differently?

Local organizations/ regulations/ people

- How do local organizations/ programs/ people help subsistence?
- How do local organizations/ programs/ people hurt subsistence?
- What should be done differently at the local level?

Historical coping mechanisms

- Were there any years when you did not get enough of a subsistence resource?
- What did you do for food instead?
- Would a change in how that resource is regulated or managed have had any effect on your ability to meet your subsistence needs that year?

Managing future change

- If the changes you mentioned continue or get worse, what kinds of policy/regulatory changes should occur to ensure people can still get what they need from the land?

- What do you think should be done locally to manage future changes in the environment?

Greatest Concerns about change

Are these changes a concern to you?

□ Yes □ No

Why not?

Which of the changes in the land that are occurring now are of greatest concern to you and your family?

Future Studies.

Researchers at the University of Alaska are doing a study to estimate what changes may occur in climate, land and animals, and if recent patterns of change will continue. Would it be interesting or useful to your family or your community to know what changes might occur near your community in the future?

□ no □ yes

What about change and possible future changes would you most like to know about?

Is there anything else about changes that you want to talk about?

Evaluation of interview

Please evaluate this interview

[Select one of these]

☐ It was worthwhile

☐ The idea is good, but it needs some major changes. *[If they select this, please ask what changes]*

☐ It was okay, but is not really that necessary.

☐ Don't repeat this interview; the study should be ended. *[If they select this, please get their reasons]*

Thank you! We will be sending you a copy of the draft report for your comment.

Appendix B: Respondents

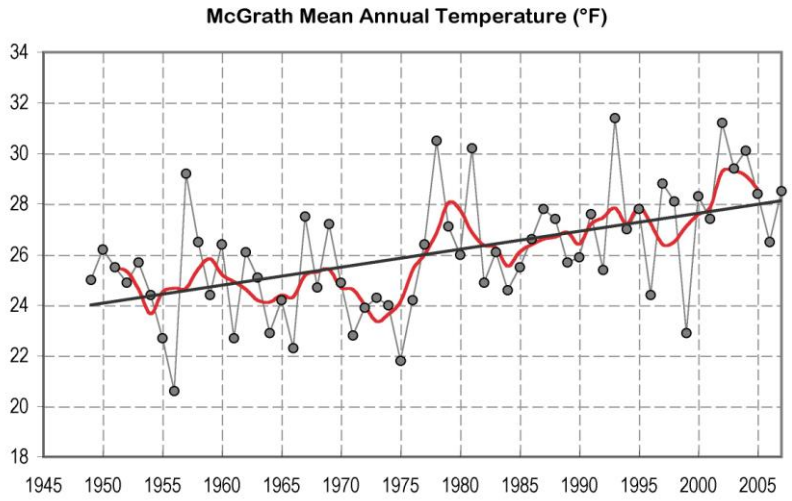
Respondent ID	***Community***	***Year born***	***Gender***	***Date interviewed***	***Score of time on the land***[1]
1	Grayling	1946	Male	6/7/08	2
2	Grayling	1940	Male	6/7/08	1
3	Grayling	1941	Male	6/8/08	NA
4	Grayling	1948/1957	Couple	6/8/08	2
5	Grayling	1952	Male	6/8/08	2
6	Grayling	1954	Male	6/9/08	2
7	Grayling	1954	Male	6/9/04	2
8	Grayling	1958	Male	6/9/08	2
9	Grayling	1965	Male	6/9/08	2
10	Grayling	1952	Male	6/10/08	2
11	Grayling	1946	Female	8/10/08	3
12	Anvik	1949	Male	8/7/08	1
13	Anvik	1934	Male	8/7/08	2
14	Anvik	1966	Female	8/7/08	2
15	Anvik	1959	Male	8/7/08	2
16	Anvik	1959	Male	8/8/08	2
17	Anvik	1944	Male	8/8/08	2
18	Anvik	1928	Male	8/8/08	1
19	Anvik	1951	Male	8/8/08	2
20	Anvik	1965	Male	8/8/08	1
21	Anvik	NA	Male	8/8/08	NA
22	Anvik	1982	Male	8/9/08	2
23	Anvik	1948	Male	8/9/08	2
24	Shageluk	1949	Male	6/1/08	2
25	Shageluk	1953	Male	6/1/08	1
26	Shageluk	1965	Male	6/1/08	3
27	Holy Cross	1953	Male	6/3/08	2
28	Holy Cross	1940	Male	6/4/08	2
29	Holy Cross	1969/1965	Couple	6/4/08	1
30	Holy Cross	1950	Male	6/5/08	1
31	Holy Cross	1957	Male	6/5/08	2
32	Holy Cross	1955	Male	6/6/08	3
34	Koyukuk[2]	1931	Male	6/6/08	2
35	Beaver	1932	Female	8/1/08	1
36	Beaver	1930	Female	8/2/08	3
37	Beaver	1945	Male	8/2/08	2
38	Beaver	1936	Male	8/2/08	2
39	Beaver	1970	Male	8/3/08	2
40	Beaver	1962	Female	8/3/08	3

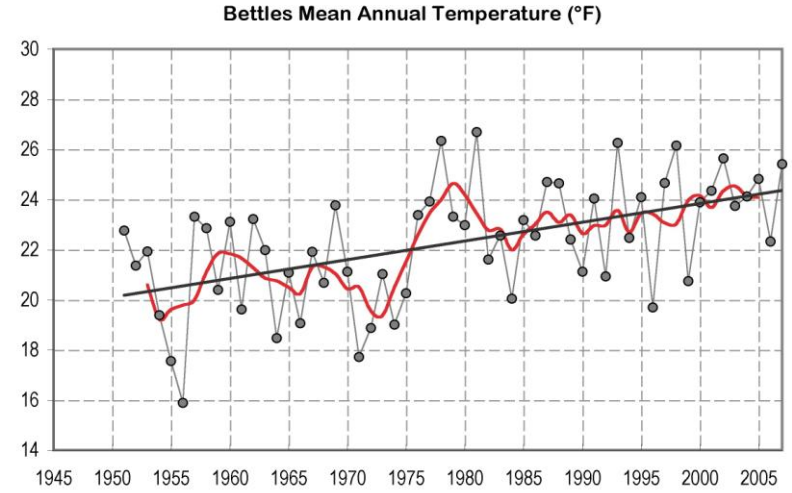
[1] In the last year, respondents either 1) took only day trips from town; 2) took day trips with occasional overnights; 3) were out on the land for a week or more at a time; 4) spent more than half of time living out of town on the land

[2] This man was present at an elder's conference in Holy Cross. Since he is from a nearby village and his observations were similar to the other respondents' observations, I chose to include this data in my analysis.

Appendix C: Climatic trends near study sites

Mean average temperature 1949-2008 for McGrath[3] and Bettles.[4] Source: Alaska Climate Research Center, University of Alaska Fairbanks Geophysical Institute





Location	Winter	Spring	Summer	Fall	Annual
McGrath	6.6	5.0	2.3	0.1	3.6
Bettles	8.5	4.6	1.8	1.1	3.9
Statewide average	6.0	3.5	2.1	0.9	3.1

[3] Based on data from NOAA National Climate Data Center observing station in McGrath, AK (nearest station to GASH villages)
[4] Based on data from NOAA National Climate Data Center observing station in Bettles, AK (nearest station to Beaver)

XI. LITERATURE CITED

ACIA. 2005. Arctic Climate Impact Assessment. Cambridge University Press, Cambridge.

Adger, WN. 2003. Social capital, collective action and adaptation to climate change. Economic Geography 79(4):387-404.

Agrawal, A. 1995. Indigenous and scientific knowledge: Some critical comments. Indigenous Knowledge and Development Monitor 3(3), 1-10.

Agrawal, A. 2009. The role of local institutions in adaptation to climate change. Washington, DC: World Bank.

ADF&G Wildlife Conservation Division's Harvest Lookup. <http://www.wildlife.alaska.gov/index.cfm?fuseaction=harvest.lookup> Accessed on March 1, 2009.

ADF&G Community Subsistence Information System. <http://www.subsistence.adfg.state.ak.us/CSIS/> Accessed on March 1, 2009.

ADF&G Technical Report: Predator Management in Alaska. 2007. Alaska Department of Fish and Game Division of Wildlife Conservation, Juneau, Alaska.

AHDR. 2004. Arctic Human Development Report. Stefansson Arctic Institute, Akureyri, Iceland.

Alaska Board of Game. 2005. Emergency Teleconference Summary of Actions. <http://www.boards.adfg.state.ak.us/gameinfo/meetsum/2005_2006/summ100405.pdf> Accessed on June 1, 2009

Alaska Climate Research Center, Geophysical Institute, University of Alaska Fairbanks < http://climate.gi.alaska.edu/> Accessed on June 1, 2009

Alaska Department of Fish and Game, Division of Wildlife Conservation. Harvest Lookup 1999-2008. <http://www.wildlife.alaska.gov/index.cfm?fuseaction=harvest.lookup> Accessed on June 1, 2009.

Alley RB, J. Marotzke, W.D. Nordhaus, J.T. Overpeck, D.M. Peteet, et al. 2003. Abrupt climate change. Science 299:2005–10

Andersen, D.B. and C.L. Alexander. 1992. Subsistence Hunting Patterns and Compliance with Moose Harvest Reporting Requirements in Rural Interior Alaska. Technical Paper No. 215. Alaska Department of Fish and Game, Division of Subsistence. Juneau, Alaska.

Berkes, F., and D. Jolly. 2002. Adapting to climate change: social-ecological resilience in a Canadian Western Arctic community. Conservation Ecology 5(2):18

Berkes, F. 1993. Traditional ecological knowledge in perspective. In: J. T. Inglis (Ed.), Traditional ecological knowledge: Concepts and cases (pp. 1–9). Ottawa, Ontario: International Development Research Centre.

Brooks, N. 2003. Vulnerability, risk and adaptation: a conceptual framework. Tyndall Centre Working Paper 38. Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK.

Brown, C.L., J. Burr, K. Elkin, and R.J. Walker. 2005. Contemporary Subsistence Uses and Population Distribution of Non-Salmon Fish in Grayling, Anvik, Shageluk, and Holy Cross. Technical Paper No. 289. ADF&G Division of Subsistence. <http://www.subsistence.adfg.state.ak.us/TechPap/tp289.pdf> Accessed on March 1, 2008

Chapin, F.S., III, Peterson, G., Berkes, F., Callaghan, T.V., Angelstam, P., Apps, M., Beler, C., Bergson, A.S., Crepin, K., Danell, T., Elmquist, T., Folke, C., Forbes, D.L., Fresco, N., Juday, G., Niemela, J., Ssuidenko, A., and Whiteman, G. 2004. Resilience and vulnerability of northern regions to social and environmental change. Ambio 33(6):344–349.

Chapin, F.S., III, Hoel, M., Carpenter, S.R., Lubchenco, J., Walker, B., Callaghan, T.V., Folke, C., Levin, S.A., Maler, K.G., Nilsson, C., Barrett, S., Berkes, F., Crepin, A.-S., Danell, K., Rosswall, T., Starrett, D., Xepapadeas, A., and Zimov, S.A. 2006. Building resilience and adaptation to manage Arctic change. Ambio 35(4):198–202.

Dietz, T., E. Ostrom, and P. C. Stern. 2003. The struggle to govern the commons. Science 302:1907-1912.

Folke, C., S. Carpenter, T. Elmqvist, L. Gunderson, C. Holling, B. Walker, J. Bengtsson, F. Berkes, J. Colding, K. Danell, M. Falkenmark, L. Gordon, R. Kasperson, N. Kautsky, A. Kinzig, S. Levin, K.-G. Mäler, F. Moberg, L. Olsson, P. Olsson, E. Ostrom, W. Reid, J. Rockström, H. Savenij, and U. Svedin. 2002. Resilience and sustainable development: building adaptive capacity in a world of transformations. Report 2002:1. Swedish Environmental Advisory Council, Stockholm, Sweden.

Folke, C. 2004. Traditional knowledge in social–ecological systems. Ecology and Society 9(3).

Folke, C., L. Pritchard, Jr, F. Berkes, J. Colding, U. Svedin. 2007. The problem of fit between ecosystems and institutions: Ten years later. In: Ecology and Society 12(1).

Global Climate Change Impacts in the United States. 2009. Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). Cambridge University Press.

Ford, J., B. Smit, and J. Wandel. 2006. Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Canada. Global Environmental Change 16(2):145 –160.

Halstead, P. and J. O'Shea. 1989. Introduction: cultural responses to risk and uncertainty. In P. Halstead and J. O'Shea (Eds.). Bad Year Economics: Cultural Responses to Risk and Uncertainty. Cambridge, Cambridge University Press: 1-7.

Harvell C.D., K. Kim, J.M. Bukholder, R.R. Colwell, P.R. Epstein, D.J. Grimes, et al. 1999. Emerging marine diseases- climate links and anthropogenic factors. Science 285:1505-10.

Hinzman, L.D., N.D. Bettez, W.R. Bolton, F.S. Chapin, III, M.B. Dyurgerov, C.L. Fastie, B. Griffith, R.D. Hollister, A. Hope, H.P. Huntington, A.M. Jensen, G.J. Jia, T. Jorgenson, D.L. Kane, D.R. Klein, G. Kofinas, A.H. Lynch, A.H. Lloyd, A.D. McGuire, F.E. Nelson, M. Nolan, W.C. Oechel, T.E. Osterkamp, C.H. Racine, V.E. Romanovsky, R.S. Stone, D.A. Stow, M. Sturm, C.E. Tweedie, G.L. Vourlitis, M.D. Walker, D.A. Walker, P.J. Webber, J.M. Welker, K.S. Winker, and K. Yoshikawa. 2005. Evidence and implications of recent climate change in northern Alaska and other arctic regions. Climatic Change 72:251-298.

Holling C.S. 1978. Adaptive Environmental Assessment and Management. John Wiley & Sons, New York.

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

Hyer, K.E., and C.J. Schleusner. 2005. Chinook salmon age, sex, and length analysis from selected escapement projects on the Yukon River. U.S. Fish and Wildlife Service, Office of Subsistence Management, Alaska Fisheries Technical Report Number 87.

Jorgenson, M.T., Racine, C.H., Walters, J.C., Osterkamp, T.E., 2001. Permafrost degradation and ecological changes associated with a warming climate in central Alaska. Climatic Change 48 (4), 29.

Kellert, S.R.; J.N. Mehta; S.A. Ebbin and L.L. Lichtenfeed. 2000. Community Natural Resource Management: Promise, Rhetoric, and Reality. Society and Natural Resources, vol. 13, pp. 705-15.

Kocan R., P. Hershberger, and J. Winton. 2004. Ichthyophoniasis: an emerging disease of Chinook salmon in the Yukon River. J Aquat Anim Health 16:58–72

Kocan R., P. Hershberger, and J.Winton. 2003. Effects of Ichthyophonus on Survival and Reproductive Success of Yukon River Chinook Salmon. Federal Subsistence Fishery Monitoring Program, Final Project Report No. FIS 01-200. U.S. Fish and Wildlife Service, Office of Subsistence Management, Fishery Information Services Division, Anchorage, Alaska.

Krupnik, I. and D. Jolly (eds.). 2002. The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change. Arctic Research Consortium of the United States, Fairbanks, Alaska.

Laidler, G. 2006. Inuit and scientific perspectives on the relationship between sea ice and climatic change: The ideal complement? Climatic Change 78(2–4):407–444.

Lloyd, A.H., Fastie, C.L. 2002. Spatial and temporal variability in the growth and climate response of treeline trees in Alaska. Climatic Change 52 (4), 29.

Magdanz, J., C.J. Utermohle, and R.J. Wolfe. 2002. The production and distribution of wild food in Wales and Deering, Alaska. Juneau: Alaska Department of Fisheries and Game, Division of Subsistence.

MEA. 2005. Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Current Status and Trends. Cambridge University Press, Cambridge.

Moller, H. F., F. Berkes, L. O'Brian, and M. Kislalioglu. 2004. Combining science and traditional ecological knowledge: monitoring populations for co-management. Ecology and Society 9(3).

Nadasdy, P. 1999. The politics of TEK: Power and the "integration" of knowledge. Arctic Anthropology 36(1–2): 1–18.

Nadasdy, P. 2003. Hunters and bureaucrats: Power, knowledge, and aboriginal-state relations in the southwest Yukon. Vancouver: UBC Press.

Nelson, R.K. 1983. Make prayers to the raven: A Koyukon view of the northern forest. Chicago: University of Chicago Press.

NEWTON, J. 1995. An assessment of coping with environmental hazards in northern aboriginal communities. The Canadian Geographer 39(2):112–120.

NOAA, Bering Climate: A current view of the Bering Sea ecosystem and climate. <http://www.beringclimate.noaa.gov/index.html> Accessed on August 1, 2009.

Olsson, P., and C. Folke. 2001. Local ecological knowledge and institutional dynamics for ecosystem management: a study of Lake Racken Watershed, Sweden. Ecosystems 4(2):85-104.

Olsson, P., C. Folke, and F. Berkes. 2004. Adaptive co-management for building resilience in social–ecological systems. Environmental Management 34:75–90.

Osgood, Cornelius. 1958. Ingalik Social Culture. New Haven: Yale University.

Overpeck, J.T., Sturm, M., Francis, J.A., Perovich, D.K., Serreze, M.C., Benner, R., Carmack, E.C., Chapin III, F.S., Gerlach, S.C., Hamilton, L.C., Hinzman, L.D., Holland, M., Huntington, H.P., Key, J.R., Lloyd, A.H., MacDonald, G.M., McFadden, J., Noone, D., Prowse, T.D., Schlosser, P., and Vosmarty, C. 2005. Arctic system on trajectory to new, seasonally ice-free state, EOS, Trans. Amer. Geophys. Union, 86, 309–312.

Pierce, J.M. 2006. Units 21A and 21E moose. Pages 427-441. In: P. Harper (ed.). Moose management report of survey and inventory activities 1 July 2003- 30 June 2005. Alaska Department of Fish and Game Project 1.0. Juneau, Alaska, USA.

Regelin, W.L., P. Valkenburg, and R.D. Boertje. 2005. Management of large predators in Alaska. Wildlife Biology in Practice 1(1): 77-85.

Riedlinger, D., and F. Berkes. 2001. Contributions of traditional knowledge to understanding climate change in the Canadian Arctic. Polar Record 37: 315-328.

Riordan, B., D. Verbyla, and A.D. McGuire. 2006 Shrinking ponds in subarctic Alaska base on 1950–2002 remotely sensed images, Journal of Geophysical Research, 111, G04002, doi:10.1029/2005JG000150.

Sabo, G., 1991. Long-term Adaptations among Arctic Hunter-Gatherers. Garland Publishing, London, UK.

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

Soja, A. J., N.M. Tchebakova, N.H.F. French, M.D. Flannigan, H.H. Shugart, B.J. Stocks, A.I. Sukhinin, E.I. Parfenova, F.S. Chapin III, P.W. Stackhouse Jr. 2007. Climate-induced boreal forest change: Predictions versus current observations, Global and Planet. Change, 56, 274– 296.

Stephenson, R.O. 2006. Unit 25 moose. Pages 599-630 *in* P. Harper, editor. Moose management report of survey and inventory activities 1 July 2003- 30 June 2005. Alaska Department of Fish and Game Project 1.0. Juneau, Alaska, USA.

Stone R.S., E.G. Dutton, M. Harris, and D. Longenecker. 2002. Earlier spring snowmelt in northern Alaska as an indicator of climate change. Journal of Geophysical Research, 107, 4089.

Sturm, M., C. Racine, and K. Tape. 2001. Increasing shrub abundance in the Arctic. Nature 411:546-547.

Thornton, T. 2001. Subsistence in northern communities: Lessons from Alaska. The Northern Review 23 (Summer):82-102.

Tompkins, E., W.N. Adger. 2004. Does adaptive management of natural resources enhance resilience to climate change? Ecology and Society 9(2): 10.

UAF Geophysical Institute. University of Alaska Fairbanks. Climate observation stations in McGrath and Bettles. <http://climate.gi.alaska.edu/Climate/index.html> Accessed on March 15, 2009.

USGS Alaska Science Center. Avian Influence: Information and Ongoing Research at the USGS Alaska Science Center. <http://alaska.usgs.gov/science/biology/avian_influenza/index.html> Accessed on August 1, 2009.

Ullsten, O., J.G. Speth, and F.S. Chapin, III. 2004. Options for enhancing the resilience of northern countries to rapid social and environmental change: A message to policy makers. Ambio 33:343.

Usher, P.J. 2000. Traditional ecological knowledge in environmental assessment and management. Arctic 53(2):183–193.

Yukon-Innoko Moose Management Plan for Game Management Subunits 21A and 21E. 2006. Alaska Department of Fish and Game, Division of Wildlife Conservation, in cooperation with the

Yukon-Innoko Moose Management Working Group.
<http://www.wc.adfg.state.ak.us/management/planning/planning_pdfs/yukon_innoko_plan.pdf>
Accessed on March 15, 2009.

VanStone, J. 1974. Athapaskan Adaptations: Hunters and Fishermen of the Subarctic Forests. Illinois: Harlan Davidson, Inc.

Wolfe, R.J., and R.J. Walker. 1987. Subsistence economies in Alaska: Productivity, geography, and developmental impacts. Arctic Anthropology 24(2):56–81.

Wheeler, P.C. 1998. The Role of Cash in Northern Economies: A Case Study of Four Athabascan Villages. Ph.D. Dissertation, Department of Anthropology, University of Alberta, Edmonton, Alberta.

Wheeler, P.C. and Thornton, T. 2005. Subsistence Research in Alaska: A Thirty Year Retrospective. Alaska Journal of Anthropology 3(1).

Winker K., K.G. McCracken, D.D. Gibson, C.L. Pruett, R. Meier, F. Huettmann, M. Wege, I.V. Kulikova, Y.N. Zhuravlev, M.L. Perdue, E. Spackman, D.L. Suarez, and D.E. Swayne. 2007. Movements of birds and avian influenza from Asia into Alaska. Emerging Infectious Diseases, 13, 547–552.